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26th ESA Symposium on European ROCKET & BALLOON programmes and related research

19-23 May 2024 · Luzern · Switzerland

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26TH ESA SYMPOSIUM ON EUROPEAN ROCKET AND BALLOON PROGRAMMES AND RELATED RESEARCH

19-23 May 2024

Luzern - Switzerland

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Editor's Note

The complete Proceedings will be published in a digital form only, shortly after the symposium. Papers not handed in at the symposium should be sent in pdf to:

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Submission deadline: 30 August 2024

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MONDAY 20 MAY 2024, MORNING SESSION

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CHAIR: M. EGLI

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FRENCH BALLOON ACTIVITIES 2022-2024: NATIONAL REPORT

The French Centre National d'Etudes Spatiales (CNES) goes on supporting a significant balloon program and infrastructure, for scientific and technological purposes. The CNES balloon systems and operation means are mobile; they can be deployed and operated worldwide, at several latitudes, in compliance with safety and environmental rules. The extended range of vehicles and payload gondola support provided by CNES allow addressing several kinds of missions such as atmospheric physics and chemistry, stratospheric and tropospheric meteorology, and astronomy. In particular, CNES provides a very high performance pointing gondola service.
The new command and control systems have been operational for ten years now for large zero pressure balloons (ZPB) and for long duration super pressure balloons (SPB). Thus, since 2022, 2 successful scientific campaigns of heavy ZPBs have been carried out by CNES from Timmins (in partnership with the Canadian Space Agency. The Timmins 2022 campaign gave the opportunity for two flights under the umbrella of the HEMERA European infrastructure for balloons.
In the field of long duration balloons, CNES is conducting the STRATEOLE 2 project, for the study of the low stratosphere (UTLS) in equatorial regions. The observing system is based on the use of fleets of small super pressure balloons (SPB) flying up to 4 months each, carrying payloads of 25 kg at 18 to 20 km in altitude.
The first scientific campaign, involving 17 flights was conducted from October 2021 to January 2022. Good scientific results have been collected during these flights.
Regarding the huge French-US Fireball UV telescope, a new AIT and flight campaign was carried out in Pasadena and Fort Sumner.
Last but not the least, CNES and HEMERIA began the development of an innovative steerable balloon, based on the use of a pumpkin shaped external envelope.
This paper gives a synthesis of the launch campaigns of the past two years and their preliminary results. Then the perspectives are considered, in terms of content of the next campaigns of 2024, in particular the Kiruna-Canada ZPB "transatlantic" campaign with SSC, but also the new services and performances available, and the new developments.

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SOUNDING ROCKET AND BALLOON RESEARCH ACTIVITIES WITHIN THE GERMAN SPACE PROGRAMME 2022 - 2024

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Sounding (suborbital) rockets and stratospheric balloons currently play a major role in the following research disciplines of the German space programme: Atmospheric Research, Space Science, Life and Physical Sciences under Microgravity, Space Technology development, and Education. In its role as space agency, DLR manages these activities and promotes the related experiments by grants and contracts. Involved research entities are mainly German universities, the Max-Planck Society, the Helmholtz Association, the Fraunhofer Association, and the Leibniz Community.

In its role as a research establishment the German Aerospace Center (DLR) also executes flight projects. The DLR Mobile Rocket Base (MORABA) provides launch services for sounding rockets, executes scientific sounding missions and supports the STERN programme. The DLR Institute of Materials Physics in Space, together with several DLR research institutes, develops and conducts own microgravity experiments in the frame of the MAPHEUS research rocket missions.

The National Report highlights the German research activities in the timeframe 2022 – 2024: In the Space Science discipline the research focus was the middle atmosphere of the Earth using stratospheric balloons, lidars, and DLR FALCON flights. Further, in-situ measurements of atmospheric parameters up to 140 km were conducted by sounding rocket campaigns of the project PMWE (Polar Mesospheric Winter Echoes) from the Andøya launch site in Norway. PMWE is now succeeded by DEFINE (Density Field in the MLT: Neutrals, Electrons, and trace gases. Radiative and dynamical balance) with a launch campaign in 2025. It is planned to launch one rocket from Andøya (DEFINE with the CONE4 instrument, FIPEX sensors, and others) and one (the Swedish ORIGIN project) from ESRANGE in parallel. The scientific coordination of DEFINE is performed by the Leibniz-Institute of Atmospheric Physics at the University of Rostock (IAP) in Kuehlungsborn. 3-dimensional measurements are targeted for the future by releasing three daughter payloads from a single rocket. Biological, physical, and chemical phenomena under microgravity conditions were studied by German scientists using the national TEXUS and MAPHEUS missions as well as the Swedish Suborbital Express programme.

Within the German-Swedish REXUS/BEXUS student programme more sounding rocket and balloon missions have been performed systematically. A wide range of scientific and technological experiments such as additive manufacturing and test of space equipment was addressed by the selected student teams.

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NORWEGIAN NATIONAL REPORT – ARCTIC SPACE RESEARCH

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The main scientific activities are within Solar-terrestrial physics, cosmology, planetology, and space exploration.

Important ground infrastructure in Northern Norway and on Svalbard is essential in studying the middle and upper atmosphere and the interaction with the Sun. This includes the utilization of sounding rockets, ground-based installations like radars, lidars and other optical instrumentation.

The University of Oslo (UiO) and The Arctic University of Norway in Tromsø (UiT) both have ongoing sounding rocket programs. The MXD-2 campaign with a scheduled launch in summer 2025 aims to measure the mesospheric dust and ambient medium and to recover collected dust samples. The sounding rocket mission led by UiO focuses on investigation of the role of precipitation in plasma structuring and ionospheric turbulence with a suite of instruments in collaboration with several partners.

Both UiT MXD2 and UiO ICI-5b are parts of the ongoing Grand Challenge M/LT, and the payloads are being built by Andøya Space Sub-Orbital. Furthermore, Andøya Spaceport was inaugurated 2nd November 2023, and is a new facility for launching satellites into space.

The new EISCAT_3D facility in Norway now in place and will be operational in 2024. The SuperDarn radar at Svalbard that, was destroyed during a severe snowstorm in 2018, has been rebuilt and operating again. This will provide a significant improvement of polar and ionospheric research infrastructure in Northern Norway and Svalbard.

The solar physics and heliophysics community is also heavily involved in the solar missions Solar Orbiter (ESA), HINODE (JAXA) and IRIS (NASA). Norway is supporting downlink of data via the Svalbard Station for the latter two missions.

The Norwegian Mapping Authority (NMA) operates a real time space weather monitoring service, prototype 1hr forecast, and a new geodetic observatory in Ny Ålesund at Svalbard.

Norway is also participating in the ESA Space Safety Programme with a strong focus on the space weather elements. In particular to utilize, and further develop the arctic space infrastructure. A national space weather center has been established in Tromsø to serve the user needs in Norway. A new 24/7 national warning center is also planned in the near future.

Norway operates 11 small national satellites focusing on ship detection but also includes science instruments observing space weather and the energy output from the Sun.

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SWEDISH SPACE ACTIVITIES – GENERAL OVERVIEW WITH A FOCUS ON BALLOONS AND ROCKETS

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Swedish space research involves many fields of space science, such as astronomy, space physics, astrobiology, atmospheric research, life and physical sciences in microgravity and Earth observation. A major part of Swedish space research activities is supported by the Swedish National Space Agency (SNSA), within its national programmes for space research and Earth observation. Most projects utilise flights offered by ESA programmes and/or data provided by ESA satellites and other space missions. Several national projects deal with the utilisation of balloons and rockets, launched from the Esrange Space Center in Northern Sweden. Since 2022 Sweden has a new astronaut, Marcus Wandt, who went to ISS as an ESA Project astronaut, to carry out 20 European experiments within his Muninn mission, including two experiments from Swedish universities.

Esrange Space Center and its utilisation is emphasised in the strategy of SNSA as one of the focus areas. Esrange provides unique opportunities for scientists and engineers from universities and private entities to to undertake basic and applied science and to carry out technology tests for e.g. future space exploration missions and. Is also allows combining basic science with instrument and platform development and close cooperation between universities and industrial partners. To meet the needs of the Swedish space community and to promote scientific utilisation of Esrange, SNSA is carrying out a dedicated national programme for balloon and rocket projects with regular calls for proposals.

During recent years, several successful balloon and rocket launches have been performed within the national balloon and rocket programme. The most recent one was the launch of the BROR rocket that took place in 2023. BROR studied small-scale processes and structures in the auroral ionosphere by means of an active modification of the ionosphere using multiple releases of barium. Currently two new rocket projects are ongoing, SYSTER and ORIGIN, and will study processes in the ionosphere and middle atmosphere.

Sweden is one of the partners in the student rocket and balloon programme REXUS/BEXUS. The programme is a joint undertaking of the German Aerospace Center DLR and SNSA, in cooperation with ESA, and a call for proposals is being issued every year, offering an opportunity to carry out student experiments on real rockets and balloons. Two REXUS rockets and two BEXUS balloons are being launched from Esrange every year and more than 2000 European students have participated in the programme since its start in 2008.

Besides national activities, Sweden contributes to many ESA programmes. The E3P programme involves considerable Swedish participation, and Swedish activities are mainly focused on MASER/Suborbital Express sounding rockets for microgravity research. One of the recent experiments on MASER/Suborbital Express dealt with stem cells and was the basis for the Swedish ISS experiment MemoBC that was carried out during the Muninn mission of Swedish ESA astronaut Marcus Wandt.

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SOUNDING ROCKET AND BALLOON ACTIVITIES AND RELATED RESEARCH IN SWITZERLAND 2022–2024

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Preferred session: National report

Swiss-based institutions and industries play a significant role in endeavors of the upper atmosphere. From 2022 to 2024, numerous studies, missions, and campaigns involving Swiss participation were conducted. These initiatives utilized various research platforms, including sounding rockets, balloons, and the high-altitude research stations Jungfraujoch and Gornergrat, situated in the Swiss Alps.

The primary focus of these endeavors encompassed inquiries into atmospheric physics, astrophysics, astronomy, and space medicine. Life sciences experiments, such as those investigating the impact of physical forces like gravity on cellular processes, were commonly conducted aboard sounding rockets. For instance, the T-REX experiment led by a Swiss research team concentrated on mechanosensitive genomic activities, while the NeuroBeta experiment explored the potential benefits of cultivating pancreatic tissue for future diabetes treatment.

Swiss student groups actively participate in advancing sounding rocket technology. Notable examples include the ETH-based ARIS group and the EPFL Rocket Team, which launched multiple sounding rockets and competed internationally against other student rocket teams. Additionally, Swiss research groups explored the capabilities of stratospheric balloons, with one student team testing the potential of polarized light for detecting life during a balloon flight.

While the national report highlights select Swiss ventures utilizing sounding rockets or balloon research platforms and activities at the high-altitude research stations, a comprehensive overview of all relevant activities conducted between 2022 and 2024 exceeds the report's scope.

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ITALIAN SPACE AGENCY BALLOON BORNE RESEARCH ACTIVITIES AND PROGRAMMES

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This contribution will present the activities that the Italian Space Agency (ASI) is carrying out in the field of stratospheric balloons. ASI promotes activities from the design and manufacturing of scientific experiments to the development of technologies for the balloon chain. For the Hemera project, ended in October 2022, ASI developed an innovative telecommunication system for balloons capable to enable new payload classes and to allow the real-time download of scientific data during the flight. In addition, the Agency supported the development of various scientific payloads in different research fields.

ASI also participates in NASA projects such as EUSO-SPB2, a technological demonstrator for measurements of ultra-high energy cosmic rays and neutrinos using fluorescence and Cherenkov emission in atmosphere that has flown from Wānaka (NZ) in May 2023, and GAPS, an instrument conceived to pioneer a novel detection technique for the measurement of the antimatter component of cosmic rays on a future flight from Antartica.

Furthermore, ASI supports the realization of national scientific payloads. In 2018 ASI flown from the Svalbard Islands the OLIMPO experiment, dedicated to measurements of the Cosmic Microwave Background (CMB) spectral distortion in the direction of rich clusters of galaxies; the result of its technological flight represents an important step in the TRL advancement of KID (Kinematic Inductance Detectors) technology. For this mission, it is under investigation the possibility of a second flight operated by NASA from Antarctica. Another mission namely LSPE/SWIPE, focused on the measurements of the CMB polarization, is currently under development. The challenge of this mission regards the flight profile: SWIPE, in fact, needs to fly in dark conditions.

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USA NATIONAL REPORT - NASA SOUNDING ROCKETS AND BALLOONS

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An overview of the NASA Sounding Rockets and Balloon Programs will be presented. Highlights will include recent and upcoming launch campaigns in support of world class science investigations. Also, a summary of significant capability enhancements, recent and currently in development, will be discussed.

Sounding Rockets:
In calendar years 2022 and 2023, 31 sounding rockets were launched from six different launch sites. Geospace Science, Solar Physics, Astrophysics, and Student Outreach were supported with launches from Wallops Island (WI), Virginia, White Sands Missile Range (WSMR), New Mexico, Poker Flat Research Range (PFRR), Alaska, Andøya Space (AS) and Svalbard, Norway, as well as the newly established launch range Equatorial Launch Australia (ELA) at the Arnhem Space Center, Northern Territory, Australia.

Eight missions supporting Astrophysics were launched from WSMR, ELA, and WI, and carried telescopes and spectrometers to study targets in the ultraviolet, infrared and X-ray portions of the spectrum. After many years of planning three Astrophysics missions were launched from ELA's Arnhem Space Centre in Australia. All launches were successfully executed, and the payloads were recovered. This new launch site enables scientists to study Astrophysics targets in the southern hemisphere sky. Recovery and reuse of these payloads is paramount, and the land impact area at ELA enabled retrieval of the payloads.

Two Solar Physics missions gathered data on the Sun, including the Solar Dynamics Observatory - Extreme Ultraviolet Experiment (SDO-EVE). The SDO-EVE calibrates the same instrument on board the orbiting observatory.

Fourteen Geospace Science missions were flown. Launch ranges included AS, Svalbard, PFRR, WSMR, and WI. Of note are the three Atmospheric Perturbations around Eclipse Path (APEP) payloads launched from WSMR to study the ionosphere during the Annular Eclipse visible in the western parts of the US. The Black Brant IX vehicles were launched 35-minutes apart, before, during and after the peak eclipse.

To support future scientist and engineers, four student missions were flown in 2022/2023. These missions cover three skill levels, beginning, intermediate and advanced. Approximately 100 students participated in each launch opportunity.

2023/2024 has been designated the "Helio Big Year" and NASA Sounding Rockets are planning to launch six missions to study the Sun, and an additional three for the Total Solar Eclipse transiting the eastern and central US on April 8, 2024.

Solar Physics mission, traditionally flown from WSRM in New Mexico, will be offered a new campaign style opportunity with flights planned from PFRR, Alaska, in 2024. Two separate launch windows are scheduled for the campaign; the first, a ten-day window, for Solar eruptioN Integral Field Spectrograph (SNIFS) opens mid-March, and the second, a 14-day window for Focusing Optics X-ray Solar Imager (FOXSI) 4 and High-

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JAPANESE SOUNDING ROCKET ACTIVITY IN 2020-2023

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Japan Aerospace Exploration Agency (JAXA) is operating three kinds of sounding rockets, S-310, S-520, and SS-520 and is providing an opportunity for advanced experiments in space science and engineering. In Japan, this suborbital platform has been used to achieve various objectives such as a study of the thermospheric, ionospheric physics, microgravity experiment, demonstration of unverified instrument and technique, and advanced engineering experiments. In this talk, we will present recent activities of Japanese sounding rocket programs.

S-310-45 sounding rocket with a length of 8 m and a diameter of 310 mm was launched in January 2020 from Uchinoura Space Center (USC) in Japan. The main purpose was to experimentally demonstrate 1) advanced technology to control payload attitude with a high precision using an inertia platform and 2) in-situ measurement technology in a space away from the rocket.

S-520-31 rocket was launched in July 2021 from USC with the main purpose of demonstrating a basic performance of a very new engine system for future use of deep space exploration. In this experiment, Nagoya University played a central role in developing the new detonation engine system, which was tested as a new technology using shock waves produced by burning a mixture of methane and oxygen gases. A capsule containing data about the engine was retrieved in nearby sea.

In November 2021, SS-520-3 sounding rocket was launched from the SvalRak facility at Ny-Ålesund in Svalbard, Norway. The main purpose was to elucidate the plasma acceleration/heating mechanism responsible for the ion upflow in the ionospheric cusp region using a combination of the high time resolution in-situ rocket measurements and the ground-based optical and radar observations.

S-520-32 rocket was launched in August 2022 from USC with the main purpose of observing vertical and horizontai plasma density structure of Medium Scale Travelling Ionospheric Disturbance (MS-TID) during the geomagnetically active period. The wave from Global Navigation Satellite System (GNSS) was received on the rocket to estimate total electron content along the propagation path in addition to in-situ observation by probe.

In December 2023, S-520-33 rocket was launched from USC to demonstrate advanced space engineering techniquie. This experiment consists of 1) Demonstration of large inflatable aeroshell technology, 2) Experiment of extensible inflatable platform, 3) Instrument data collection system, and 4) New advanced navigation sensor.

We will continue the current activity level of the sounding rocket experiment, i.e., one or two sounding rocket experiments every year.

Ranges Facilities 1

Monday 20 May 2024, Afternoon session – part 1

Room 1

Chair: K. Blix

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THE ARCTIC LIDAR OBSERVATORY FOR MIDDLE ATMOSPHERIC RESEARCH – ALOMAR – THROUGH 30 YEARS

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The investigation of physical processes in the middle and upper atmosphere depends mostly on remote and in-situ measurements performed from ground-based lidars and radars, research satellites, sounding rockets and stratospheric research balloons. Platforms used for in-situ measurements such as balloons and sounding rockets as well as research satellites, which utilize remote sensing, have the disadvantage that they move with relatively high speed above the ground. Consequently, these platforms are only able to collect data during a short period of time before leaving the region of scientific interest. In contrast, remote sensing by means of lidars and radars provide highly needed continuous data sets that can be used for long-term studies of physical processes in the atmosphere, e.g., tropospheric and stratospheric clouds, sudden stratospheric warming, the annual change of winds in the polar vortex, noctilucent clouds and polar mesospheric summer echoes.

In 1994, the Arctic Lidar Observatory for Middle Atmospheric Research (ALOMAR) was opened on top of the 378m high Ramnan mountain at Andøya. ALOMAR is an advanced laboratory, specialized in passive and active remote sensing of all layers in the Arctic atmosphere. ALOMAR hosts two Rayleigh/Mie/Raman Doppler lidar systems, one ozone lidar system and several other instruments owned by institutions from different countries. On the flat lands, in direct vicinity of the observatory, several unique radar instruments were installed. If combined, the scientific measurements performed at ALOMAR cover the entire atmosphere up to the edge of space at 80 – 100 km altitude. This way, ALOMAR has supplemented research campaigns which involved in-situ measurements from sounding rockets and stratospheric balloons launched from the launch facilities at Andøya Space or its sister launch facility in Ny-Ålesund on Svalbard.

Data collected at ALOMAR are used to understand the formation and properties of noctilucent clouds, to investigate polar mesospheric summer echoes and to monitor the annual variability of the winds in the middle atmosphere, sudden stratospheric warming, ozone concentration in the stratosphere as well as properties of clouds and aerosol in the troposphere. After almost 30 years, the data collected at ALOMAR has been subject to more than 500 scientific publications, which present results of great importance.

This presentation provides an overview of ALOMAR's history and the observatories' applicability for lower, middle and upper atmospheric research. It will demonstrate how the unique measurement systems available at ALOMAR are used in comprehensive field campaigns to gather unprecedented data sets.

Topic: Range facilities
Preference: Oral presentation (Keynote)

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SOUNDING ROCKET PRODUCTION AND QUALIFICATION FACILITIES AT ANDØYA SPACE

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We have been launching sounding rockets from Andøya for half a century. The last decades we have also built and qualified payloads under the Hotel Payload concept. The customer; the science team, can check in their instrument into the hotel, and we take care of all the necessities to assure a pleasant flight and that the instrument gets delivered into the right spot to do it's science.

A rocket launch puts the payload under a huge amount of stress. To make sure that the payload can withstand such loads, each payload has to be put through a number of qualification tests, often referred to as environmental tests. The environmental tests shall simulate the expected loads during a flight. The test used to qualify a payload is carefully considered on a case-to-case basis, but often consists off; Static and dynamic balancing, vibration (sine and random), bending, mass properties measurement and deployment testing.

Over the years we have gradually expanded or in-house capabilities both in production and qualification equipment. In-house production and qualification are a major advantage. It gives us shorter lead-time, more flexibility, lowers costs and reduces risk associated with shipping and delays.

This oral presentation provides an overview of the payload qualification facilities and production capabilities currently available at Andøya.

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ESRANGE SPACE CENTER – LATEST HIGHLIGHTS AND FUTURE PLANS

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The last ESA-PAC meeting in Biarritz 2022 heralded a return to more normality in the world as the pandemic that had ravaged the world started to subside, but also new challenges with the newly started war in Ukraine.

In the summer of 2022, a NASA balloon campaign with two large payloads were conducted with one flight crossing the Atlantic for a landing in Canada, while the other flight was ended over Sweden after problems with the payload were found after launch.

The HEMERA EU project was concluded with three balloon launches in late summer and early autumn, two smaller sounding balloons and one larger zero pressure. This concluded SSCs flights for HEMERA with a total of three large and four smaller balloons launched over 5 years.

In September the TEXUS 57 rocket campaign was started, with a launch in the first days of October. The campaign was originally intended to be conducted in February/March but had to be postponed due to the war in Ukraine.

MAPHEUS-12 and the delayed launches of the student programme REXUS 27/28 followed in October and November, and Suborbital Express 3 wrapped up 2022 with a launch in late November. In total 4 large rocket campaigns in 2 months, which was a quite hectic period for Esrange.

2023 started with the Swedish national BROR rocket campaign in March, with REXUS 29/30 following same month.

A double TEXUS campaign started in April, partly with STERN HyEND campaign in parallel. The launch of TEXUS 58 did not go as planned, as the rocket landed in Norway and a decision to postpone the launch of TEXUS 59 was taken until the cause of the erranous flight was found. HyEnd successfully launched one rocket, while the second encountered an anomaly.

MAPHEUS-13 and SERA-4 concluded launches before summer.

The year ended with BEXUS flights in September, followed by the HIFLIER 1 mission in October, and the MAIUS 2 campaign in November/December.

For the first half of 2024 the plan for Esrange is to launch three German rockets, two Swedish/German student rockets, as well as the fourth Suborbital Express. Some small Swedish balloons are also planned. NASA will come back in the spring to fly three large balloons to North America, and CNES will arrive in June for their first trans-Atlantic balloon flight.

Apart from the launch campaigns performed there has also been other tests performed in the period. Parachute tests from aircraft as well as static tests of solid motors. The development of orbital capacity has progressed and Spaceport Esrange was inaugurated in January 2023. Tests of liquid rocket engines and stage tests have also been performed for orbital rocket manufacturers.

A new facility for payload preparation – the Multi Purpose Facility (MPF) – have been erected in close vicinity

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ON THE FEASIBILITY OF THE BALTIC SEA AS A DROP ZONE FOR SUBORBITAL ROCKET FLIGHTS

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This paper presents and justifies a concept of organizing suborbital rocket flights above the Kárman line with the Baltic sea used as a drop zone. Currently, several civil entities conduct low-altitude test flights of new rocket vehicles and land these rockets on the Baltic Sea. High altitude flights are under consideration. Introduction of new actors in the suborbital and orbital sector has significantly increased the demand for ranges that can allow efficient and safe rocket operations across Europe. This motivates a thorough analysis of the Baltic area in the context of suborbital rocket flights. In this paper, currently observed and projected demand for rocket launches across Europe is analysed and it is related to existing and planned test ranges and their capabilities. Baltic Sea is discussed in terms of flight safety and impact hazard areas, with an emphasis on the western Baltic, where calculations based on RCC 321-20 are made, with usage of real marine traffic data provided by the European Maritime Safety Agency. Safety analysis of the critical infrastructure on the Baltic sea includes plans detailed in Baltic's maritime spatial planning. The study shows that flights above the Kárman line with the Baltic sea used as a drop zone are feasible and provides recommendations for a further work on this subject.

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PLANNING AND DEVELOPMENT OF THE ROCKET LABORATORY AT THE MEXICAN SPACE AGENCY.

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The planning and development of the Rocket Laboratory at the Mexican Space Agency (AEM) have been a 7-year effort stemming from the initial dialogues between federal and local authorities. The history of experimental rocketry in Mexico dates back to 1957 but has not been a consistent path. Since the creation of the AEM in July 2010, the initial strategic lines were outlined, followed by the development of the Regional Centers for Space Development (CREDES). The Rocket Laboratory is located at the CREDES in the State of Mexico and aims, among its objectives, for the development of a new generation of sounding rockets. This paper describes the work carried out in recent years with the intention of creating infrastructure that allows for sustained long-term efforts.

This work discusses the history and regulatory framework that has enabled the creation of the building that will serve as the headquarters for the equipment and machinery intended to be acquired in the next 10 years. Currently, a portion of the laboratory's work is focused on developing indigenous software that allows us to analyze trajectories of sounding rockets and commercial rockets that traverse the national territory. Our laboratory's vision is to create a launch base that enables collaboration with other international institutions.

Part of the AEM's work involves seeking adherence to international frameworks, such as the missile technology control regime, in order to provide certainty and cooperation in scientific research and space exploration for peaceful purposes.

[A-183]

Esrange Space Center Phoenix project - The return with improved capability

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The fire at Esrange Space Center that occurred on the 26th of August in 202 reduced the capability of the range significantly as several key facilities were completely or partially destroyed in the fire.

Recovery from this state commenced immediately to have the first sounding rocket launch conducted only 3 months after the fire. First efforts to enable the Mapheus launch was a result from close the collaboration between SSC and DLR Moraba.

In parallel with the recovery work a failure investigation was also conducted also done in close collaboration between experts at SSC and at DLR Moraba resulting in root cause identification and in several recommendations for improvements.

The upgrades of the Skylark launcher and the controls has brought the launcher to a start of a new era, with modernized technology and improved operability through several improvements.

In Q1 of 2024 the final improvement has been implemented by means of taking the MPF building next to the Esrange Space Center in use, with significant modernization of payload preparation facility combining Bio-Labs, clean room, mechanical workshop, electronics workshop, payload assembly hall with spin and balance and a flexible operational area configurable to various needs of different range users. It also incorporates meeting and kitchen area during operations and significant safety improvement by means of separating payload activities from rocket motor preparation, The MPF is directly accessible from the Esrange Space Center hotel without the need of going outside and the location next to Main building also makes breakfast, lunch and dinner available for the range users without the need of using car for transport, which reduces emissions and traffic significantly at the base area.

The close interaction with range users in the design process has resulted in a facility that meets and exceeds most of the customer expectations and brings new capabilities to the base.

Balloons & Rockets in Space Education 1

Monday 20 May, Afternoon session – part 1

Room 2

Chair: E. Menting

[A-7]

AN OVERVIEW OF THE NASA SUBORBITAL RESEARCH PROGRAM ACTIVITES

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These are incredible times of space and Earth science discovery related to the Earth system, our Sun, the planets, and the universe. The National Aeronautics and Space Administration (NASA) Suborbital Research Program (SRP) provides suborbital platforms as a component part of the NASA's science and technology programs. The Suborbital Research Program, managed by NASA Goddard Space Flight Center (GSFC)/Wallops Flight Facility (WFF), and administered by NASA's Science Mission Directorate (SMD), is actively advancing the vision for suborbital platforms as cost effective and capable tools for research. GSFC/WFF manages SMD's suborbital carriers, including piloted aircraft and unmanned aircraft systems (UAS), sounding rockets, scientific balloons, along with CubeSats and small International Space Station (ISS) payloads, to provide frequent flight opportunities for NASA science, technology, and education investigations. Over the past two years, despite the COVID-19 pandemic, GSFC/WFF has launched over 21Sounding Rocket and 17 Balloon missions and flew over 500 airborne science hours in support of science and technology investigations, while at the same time providing over 800 undergraduate and graduate students hands-on flight project experiences in scientific research. Current activities include developing new and improved suborbital and special orbital capabilities to advance science, exploration, and innovation. WFF continues to integrate WFF launch range and airfields to increase access to space for the "new space" suborbital and orbital launch model through the Mid-Atlantic Regional Spaceport to enable NASA missions. Further, suborbital continues to serve as a training ground for young scientists and engineers, where students can make authentic contributions to all phases of balloon science missions Recently published astrophysics decadal survey shows that suborbital platforms are vital assets working to address essential science goals and will open opportunities for researchers in developing and validating cutting-edge space technologies. The use of these agile, cost effective and capable research platforms are part of a growing trend in pursuing space and Earth science. The paper will present the status of current Wallops-led SRP activities that SMD is sponsoring and expects to fly in the near future, as well as results studies of suborbital platforms for obtaining high priority science data, and platform capabilities that will have a high impact on science and technology return.

[A-78]

THE CLEMSON UNIVERSITY STUDENT SPACE PROGRAM

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The Clemson University Student Space Program (CUSSP) aims to educate undergraduate students about sounding rocket missions and create involvement in atmospheric research. Taught and run by other undergraduates, students participate in a semester-long model rocket mission adhering to NASA sounding rocket guidelines. Students go through design review presentations along with the development of hard skills before creating their atmospheric research-based payloads for their rockets. Along with the hard skills of soldering, 3D printing, and electronics, students become accustomed to the soft skills of collaboration, communication, and problem-solving. After the construction of rockets and payloads, our launch ensues concluding the semester. After a semester of becoming accustomed to sounding rocket missions, students are given the opportunity to help with different atmospheric research projects in Dr. Stephen Kaeppler's laboratory. These are broadly categorized into data analysis and instrumentation projects.

CUSSP is currently participating in the NASA RockSat-X 2024 mission, where groups of students from universities around the United States are creating payloads for a NASA sounding rocket launching out of NASA's Wallops Flight Facility (WFF). CUSSP's team currently consists of six undergraduate students creating a Langmuir probe and mechanical boom system. The payload's purpose is to quantify electron density and temperature throughout the E-region of the ionosphere. It functions by biasing voltages through electrodes within the plasma of the ionosphere and reading induced currents. The boom system is designed to extend the Langmuir probes away from the spacecraft's potential for accurate measurements. This payload is also intended to fly on the NASA GHOST RockSat 2025 mission out of Andøya Space.

Another project that is currently in the developmental stages is a low-power, inexpensive, high-frequency (HF) ionospheric chirp sounder. This project's purpose is to measure the layers of the ionosphere by sweeping a portion of the HF radio frequency band from an AD9959 Arduino shield and collecting reflected signals with an Ettus USRP N2XX. These instruments are set up at the Clemson Atmospheric Research Laboratory (CARL) utilizing antennas to transmit and receive signals. Preliminary results have been obtained; however, there is more work to be done with the tuning of the chirp sounder.

[A-141]

UPDATES ON THE GERMAN NATIONAL STUDENT SPACEFLIGHT SOCIETY, ITS EDUCATIONAL ACHIEVEMENTS, AND THE POLITICAL INFLUENCE IN THE GERMAN POLICY

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The BVSR e.V. (German National Student Spaceflight Society) is an umbrella association, that was founded and registered by eight university and college student groups from Germany, who have decided to network, to actively facilitate, and to promote the exchange of knowledge across universities. The BVSR organizes workshops on different topics, like rocketry, ballooning, REXUS/BEXUS how-to application and more. First positive results are already visible in knowledge transfer or extremely high acceptance rates for the German BVSR teams within the fifteenth REXUS cycle. Also, the first joint projects of multiple student groups across the country are taking place, including a study of how to use the new ESA-DLR LUNA facility which may result in a scientific experiment or project.

Additionally, a highlight is the BVSR student conferences taking place once a year. In May 2023 in Stuttgart, in May 2024 in Friedrichshafen, where student groups, universities, industry and politics from the German-speaking countries are invited for talks, workshops and networking. The conference in Stuttgart was supported by the DLR, industry partners and the German government that also sent the Coordinator for Aerospace Policy for the opening of the conference.

Over the past two years, the topics in the BVSR have expanded. From the beginning with the aim of exchanging knowledge, it has now reached the stage of being heard and recognized in the German politics of the government concerning space related topics. For the DLR “Kleinsatellitenkonferenz” (Small Satellite Conference) in 2022 and 2023 in Berlin the BVSR got a chair in panel discussions, giving the student groups a voice in the German political landscape.

This paper gives an update and an overview of the activities of the BVSR over the last two years, showing the structure, the methods of the association and the plans for the upcoming years.

[A-148]

PLANETE SCIENCES ACTIVITIES IN SPACE EDUCATION.

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Planete Sciences is a French non-profit organization of popular education. Its pedagogic project is the development of scientific and technical culture among young people, mainly in 10 to 25 age group. It offers scientific and technical leisure to youth teams. It also works in schools by offering topics to teachers and providing them, technical support. Its main fields are: astronomy, robotics, environment and space.

On the occasion of the 26th ESA Symposium on European Rocket and Balloon, we will present activities in the space field for youth teams such as:

- Rocket : conception, realization and launching of rockets with powder motors that can reach an altitude from 50 meters for the little ones to 4000 meters for those which ship experimental setups.

- Balloon : conception, realization and launching of a gondola which shuttle meteorological, technical and scientific experiences thanks to an helium balloon that reaches a 30 km altitude.

Indeed, Planete Sciences with the CNES assistance, offer technical support for the conception and the realization of the project and organize and fund the launching of the rockets and balloons.

Furthemore, Planete Sciences and CNES celebrate, this year, 60 years of activity and technical support at the service of young rocket manufacturers and 30 years of activity dedicated to young balloon manufacturers.

[A-77]

MECHANICAL DESIGN OF ECRIDA EXPERIMENT FOR DYNAMICAL LOADS ON BOARD THE REXUS29 SOUNDING ROCKET

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The paper aims to present the mechanical design of the ECRIDA experiment for the vibration environment during the REXUS rocket flight. ECRIDA is an additive manufacturing (AM) apparatus utilizing the Digital Light Processing (DLP) technology for microgravity research onboard the REXUS 29 rocket.

The purpose of developing the ECRIDA experiment was to create an alternative to the repair and logistic issues that arose on the International Space Station (ISS) in the last decade. More and more resupply flights report broken or missing parts when sent to ISS. At current launch charges of 5000$/kg or more, the ECRIDA experiment can provide substantial cost savings by requiring a liquid feedstock that can be transported very efficiently.

The developed apparatus is capable to cure 20 ISO 527 type 5B standard tensile samples in 2s, having a 200ms exposure time and 395nm wavelength under a LED power of 40W. The samples were sliced in 10 layers of 0,1mm. In order to achieve such a high printing resolution the experiment had to resist the vibration environment of the rocket. A numerical analysis and 5 practical tests are detailed in the paper and results are compared. The analysis and test were performed according to the requirements from the rocket manual at qualification level.

The vibration performance of the design and the postflight analysis after the launch campaign of ECRIDA experiment are discussed. The experiment showed a good performance in flight, being able to achieve the printing performace. No parts were damaged during launch and the experiment was recovered successfully.

Technology & Infrastructures for Sounding rockets 1

Monday 20 May, Afternoon session – part 1

Room 3

Chair: J. Grösse

[A-29]

RAPID PROTOTYPING AND COMPONENTS OF THE SHELF FOR SOUNDING ROCKET EXPERIMENTS

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The development and construction of hardware for space experiments is increasingly utilizing new technologies, such as 3D printing. Compartments of the shelf (COTS), e.g. microcontrollers, sensors and actuators, which are easy to obtain from public retailers, are also playing an important role in the construction and realization of experiments. As part of the DLR MAPHEUS rocket program, COTS products and rapid prototyping in form of 3D prints have already been used to successfully conduct life science experiments in microgravity. Development of printable materials and the availability of electronic components is opening a new world of experiment development for sounding rockets and other platforms. This trend in the growing new space sector also enables the application-based training of young scientists. The presentation will provide an overview of the life science experiments that have already been carried out and the prospect of future ones.

[A-11]

PLD SPACE: MAKING SPACE ACCESSIBLE TO ALL WITH THE MIURA FAMILY

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PLD Space is a pioneering Spanish aerospace company and a benchmark reference in Europe for developing reusable rockets. With a solid reputation and steadfast commitment, the company has produced notable orbital launchers: the suborbital MIURA 1 and the orbital MIURA 5. These innovations position Spain among the select few nations capable of successfully deploying small satellites into space.

PLD Space was founded in 2011 by Raúl Torres and Raúl Verdú with the aim of facilitating access to space. The company, based in Elche (Alicante) and with technical facilities in Teruel, Huelva, and French Guiana, has already raised more than 65 million euros of investment to boost its space sector project and has a team of more than 150 professionals.

The analysis of the data collected by the Spanish company PLD Space after the launch of their MIURA 1 rocket shows that the mission has been a complete success. 100% of the main objectives have been achieved and all the technologies developed by the company have been validated in flight. This is a milestone that positions PLD Space as the only European private company with launch capability in Europe today.

The success rate of a first launch in the space industry is only 45%. To reduce these high levels of uncertainty and risk, the Spanish company has always been committed to testing each subsystem, as well as all the systems as a whole. "Space works on the basis of learning, and PLD Space got everything right the first time because, from the beginning, PLD Space adopted a strategy based on 'trial and error'.

PLD Space have experienced a series of many 'first accomplishments'. The first private company in Europe to launch a rocket, the first Spanish company to achieve a goal that positions the country with a new capability, the first in Europe to develop and launch a liquid fuel engine powered by kerosene and liquid oxygen (KeroLOX), the first space launch from continental Europe and the first space launch of European space technology startups.

MIURA 1 test flight meets all objectives:

PLD Space has collected data and performed a first analysis of the launch of MIURA 1. The mission, which took place in the early morning of October 7th, went according to all the planned parameters, both in the behavior of all the subsystems and the execution of the operations.

The flight had a total duration of 306 seconds, reaching an altitude of 46 kilometers. MIURA 1 reached apogee with the correct attitude of the vehicle. The rocket managed to enter microgravity conditions and eject the individual photos of the team and their families. It was also possible to collect data from the onboard experiment of the German Center for Applied Space Technology and Microgravity (ZARM) and, following the tradition of first launches, PLD Space integrated a cheese in the payload bay of the rocket.

As for the re-entry, the supersonic phase was successful and the aerodynamic control and stability results were better than expected, highlighting the behavior of the aerobrakes used to brake and stabilize the vehicle. The subsonic phase of the flight was also stable. The ejection of the braking parachute was performed correctly and opened as planned….

[A-66]

ADVANCED ADDITIVE MANUFACTURED INJECTION HEAD DESIGN FOR A LOX/CH4 SOUNDING LIQUID ROCKET ENGINE APPLICATION

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PoliTo Rocket Team is a rocketry team from Politecnico di Torino, that builds and tests sounding rockets. This research is part of the EFESTO Project, aiming at designing and manufacturing the first Italian student-made Liquid Rocket Engine. The engine is based on a pressure-fed system using LOX/bio-CH4, features a regenerative cooled Combustion Chamber and is designed for reusability. Thanks to the sole use of Additive Manufacturing technologies, the production of the Thrust Chamber Assembly can be accomplished dividing the design in two main components, the Injection Head and the Main Combustion Chamber, reducing the setbacks of common multiple components assemblies. Both the Injection Head and the Main Combustion Chamber will be manufactured in Inconel 718.

The primary emphasis in the design of the Injection Head lies on ensuring printability, and this will be the central focus of the paper. This component needs to face harsh environments characterized by high pressures and wide temperature variation ranging from cryogenic fluids to hot reacting gases, which lead to significant mechanical and thermal stresses. Additive Manufacturing allows to explore non-conventional design solutions, particularly optimizing injector plate, injectors, and propellant domes. The Additive Manufacturing physical constraints have been strategically used to design the complex injector feeding lines, turning printing limits into advantageous features. On the same line, the injector plate design has been optimized through a complex injectors' geometry, overcoming traditional manufacturing limits. Laser Powder Bed Fusion (LPBF) is the state of the art for this kind of Liquid Rocket Engine components manufacturing process.

Upon the completion of the preliminary design, the component undergoes a detailed structural and fluid-dynamic analysis, that leads to improvements and optimizations to validate the behaviour of the Injection Head, through accurate FEM/CFD computations and comparison with analytical models. The next step involves producing sample parts to verify real performance. The entire Injection Head is then manufactured to proceed with cold flow tests, further validations, and experiments, culminating in the pursuit of full engine integration and ignition.

[A-193]

UPDATED ETHERNET TELEMETRY SYSTEM FOR TEXUS PROJECT

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Since December 1977, 58 TEXUS and 10 MAXUS rockets have been launched from ESRANGE Space Center in Sweden. The main objectives of these scientific rocket missions is fundamental, physical, material and biological research under microgravity conditions. For the communication between ground and onboard systems, a command uplink with a proprietary data transmission standard is used and an IRIG based standard from board to ground, providing i.a. for low rate serial communication. The objective of the Ethernet for TEXUS Project (E4T) is to provide with an Ethernet based communication standard interfaces for current and future experiments. The envisaged hardware, based on commercial, of the shelf products, provides for trans-parent Ethernet connection on both sides. This allows the much easier integration of user provided experiments with use of TCP/IP services for bi-directional, flexible communication from the experiment control workstation to the experiment on board. E4T first application in a test configuration was on TEXUS 56 and updated flown with the experience learned on TEXUS 57/58 missions.

[A-165]

PAYLOAD RECOVERY ON SOUNDING ROCKETS – PARACHUTE OPERATION AND DEVELOPMENT AT MORABA

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As part of German Aerospace Center's Space Operations, the Mobile Rocket Base (MORABA) plans and conducts sounding rocket campaigns for scientific missions and experiments. Providing the appropriate flight hardware to support a successful conduction of the individual experiments is one of its core competences. Beeing an essential aspect of that, parachute recovery systems guarantee the safe retrieval of the scientific payload. This not only allows the post-flight inspection of probes and the capture of high-resolution on-board data which could not have been included in telemetry, but also enables the reusability of payload subsystems. A constant development in this field and experience from almost a hundred successful flights over the last decades result in a large variety of customized recovery systems and parachutes for a broad spectrum of boundary conditions. They enable both land and sea recovery for payload masses between 70 and 800kg and activation velocities up to 150m/s.

The difficulties of a successful operation of those recovery systems not only lie in the design of the parachutes themselves and the ability to correctly predict the occurring forces, but even more in the details of the sourrounding mechanical, electrical and pyrotechnical systems responsible for a safe and reliable deployment and a nominal sequence of the parachutes. Furthermore, an elaborate packing and integration procedure ensure a defined opening and filling of the parachute canopy. These aspects are subject to continous assessment and improvement to increase effectiveness and reliability.

This also applies to the parachutes themselves. The evaluation of flight data – inclucing on-board IMU measurements and video footage – feeds the constant analysis of the parachute behaviour and their effective parameters under real flight conditions. These learnings improve the layout process and yield a better understanding of the margins and flight envelopes of the systems in use. Ultimatively, this leads to an improved prediction of the parachute's characteristics under extended boundary conditions – like higher deployment velocities – and thus to an increased range of applications for payload recovery.

Atmospheric Physics & chemistry 1

Monday 20 May, Afternoon session – part 2

Room 1

Chair: N. Ivchenko

[A-24]

CLIMATOLOGICAL COMPARISON OF POLAR MESOSPHERE SUMMER ECHOES OVER THE ARCTIC AND ANTARCTICA AT 69° LATITUDE

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Polar Mesosphere Summer Echoes (PMSE) have been observed for more than 30 years with 50-MHz VHF radars at various locations in the Northern Hemisphere. Continuous observations of PMSE are conducted on the northern Norwegian island of Andøya (69.3°N) using the ALWIN radar (1999-2008) and MAARSY (since 2010). The same kind of PMSE measurements began in 2004 in the southern hemisphere with the Australian Antarctic Division's VHF radar at Davis Station in Antarctica (68.6°S), which is at an opposite latitude to Andøya. As the radars at both sites are calibrated, the received echo strength of PMSE from more than one decade of mesospheric observations on both hemispheres could be converted to absolute signal power, allowing a direct comparison of the measurements. The analysis of PMSE observations from the two radar sites over 23 boreal summers and 15 Austral summers indicates comparable PMSE signal strengths. However, there is a noticeable difference, with significantly fewer PMSE occurrences in the southern hemisphere compared to the northern hemisphere. Compared to Andøya, the PMSE season over Davis starts about 7 days later on average and ends 9 days earlier, resulting in a duration that is 16 days shorter. PMSE over Davis occur less frequently but with greater variability in seasonal, diurnal, and altitudinal occurrence. Specifically, PMSE over Davis reach maximum altitudes approximately 1.5 km higher than those observed over Andøya.

[A-55]

MESOSCALE DYNAMICS AND TURBULENCE IN THE MLT DURING THE VORTEX-1 SOUNDING ROCKET EXPERIMENT

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The Vorticity Experiment (VortEx) is a NASA sounding rocket experiment comprising four missions launched in two identical salvoes from Andøya Space Center, Norway (69°N, 16°E). The main science objectives are mesoscale dynamics associated with gravity wave breaking in the upper mesosphere and lower thermosphere and quantifying the vertical component of vorticity. The sounding rocket techniques provide high-resolution, in-situ wind and temperature profiles in the lower thermosphere (up to ~150 km) that cannot be achieved with any other observational method. The first salvo was launched on March 23, 2023, at 21:00 UT and included the release of sixteen sub-payloads for spatially distributed wind tracer observations. The second salvo is planned to be launched in October 2024.

Ground-based observations provided temperature profiles, OH temperature mapping, and spatially resolved meteor radar winds. The wind and temperature profiles from the rocket experiments and the ground-based measurements, together with global modeling, form the basis for further high-resolution modeling with the Model for Acoustic and Gravity wave Interactions and Coupling (MAGIC). Simulations of large model domains using adaptive mesh refinement (AMR) can incorporate the full VortEx experiment and simulate the tracer evolutions at high resolution, while closely tracking the dynamics of the flow field. This will allow the quantification of mesoscale and instability dynamics down to the turbulence development visible in the tracer releases.

The EISCAT UHF radar at Tromsø supported the rocket campaign every night of the launch window to provide additional neutral wind estimates. The launches took place during a geomagnetic storm (Kp~7, AE 8-10). This was also evident in the rocket observations; from neutral wind forcing, Joule heating in the temperature, to instabilities in the in-situ plasma density profiles. Sporadic E layers present at different altitudes in horizontally separated rocket and EISCAT observations further highlight the variability of the wind field.

[A-181]

STATUS AND FURTURE PLANS FOR THE GRAND CHALLENGE INITIATIVE – CUSP AND M/LT PROJECTS

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GCI M/LT

The current GCI project – M/LT (mesosphere / lower thermosphere) has been in active since August 2021. It includes US, Norway, Germany, Sweden, UK, Canada, Japan and Poland, but other nations are more than welcome to join. Due to working with lower altitude science than its CUSP cousin, GCI M/LT has a potential for even more activities. Rockets, measurements using aircrafts, satellites, balloon borne and ground-based instruments. Launching out of even more sites is also a possibility to be discussed, all based on the science topics raised during the planning phase. The first project to launch in M/LT was the XENON French balloon (European balloon infrastructure project HEMERA and CNES balloon campaign KLIMAT 2021) with their flight to 32.6 km altitude on the night 16-17 August 2021 from ESRANGE. The second project was the Sounding rocket project "PMWE" for investigation of polar mesosphere winter echoes by IAP in Germany. Two instrumented sounding rockets were launched on 13th and 18th of April under PMWE and non-PMWE conditions, respectively. The latest activity was the sounding rocket project NASA Lehmacher VortEx with 2 out of its 4 planned rockets from Andøya Space in March 2023.

Student Rockets

The people working with the GCI projects are highly devoted to including students, and also for the M/LT project a student sounding rocket mission will be provided by NASA and Andøya Space. The GHOST – "Grand cHallenge mesOsphere Student rockeT" is set for launch from Andøya in November 2024 as a part of the rocket missions – NASA RENU3, UiO ICI-5b and NASA VortEx. It is important for us that the students get to experience the feeling of being part of a real GCI M/LT (or similar) rocket operation, and this can also mean that the launch time must be changed to adapt to this. The flight opportunity was announced internationally in April 2023 through ESA-PAC delegates, universities and interested researchers.

GCI 3.0 CUSP Solar Max – new initiative (2026)

During CEDAR Workshop 2023, a successful workshop on the proposed GCI CUSP follow-up project "GCI 3.0 CUSP Solar Max" was conducted, and the conclusion was that a solar max version of the highly successful CUSP (solar min) project is both timely and scientifically justified with regards to new and remaining questions, ensure access to scientific infrastructure that could otherwise be made unavailable if there are no future projects that can make use of it, and lastly, new and upcoming ground-based/space based infrastructure will be available compared to the original CUSP project operational phase ended 2021. In addition, Andøya Space is building a new major sounding rocket launcher at its Andøya site, and at the Ny-Ålesund (Svalbard) site, NASA and Andøya Space has agreed to continue the temporary second launcher built for the first GCI CUSP project. This to keep the possibility for dual launches also in the proposed Solar Max project. Several groups, both in USA and Japan already has plans to propose missions to be part of the new initiative.

An AGU Fall Meeting 2023 talk, and additional side event paved the road for continued development of this important future CUSP research project through NASA support statements.

The proposed timeline is first launch around 2026, but this is off course dependent on missions being funded in the time to come.

Technology & Infrastructures for Balloons 1

Monday 20 May, Afternoon session – part 2

Room 2

Chair: M. Abrahamsson

[A-91]

NAVIGATING MARS WITH AN AIRSHIP - A NOVEL WAY TO EXPLORE THE RED PLANET

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Increasing interest in Mars would benefit from a new approach that bridges the gap between local rover measurements and global orbit observations. This study proposes an airship to serve as a platform for hosting scientific instruments, thus adding the advantage of capturing vertical features of Martian terrain and benefiting science. The most critical challenge for an airship design is the thin atmosphere, which results in a large balloon size. This paper, building on previous studies conducted at EPFL, addresses this issue and presents a refined design of a Martian airship mission. The focus is placed on the operations and design of the airship as well as a comparison of entry, deployment, and landing methods.

For the selection of the operational zone, the impact crater Hellas Planitia and Valles Marineris are analyzed using the Mars Climate Database. A thorough comparison leads to Hellas Planitia being selected, due to its favorable atmospheric conditions in terms of density and solar radiative flux. Within Hellas Planitia, a Design Reference Mission is defined and a trajectory control algorithm is developed to follow it, taking into account the winds on Mars.

The paper continues with a comprehensive study on the design of the airship including the envelope and the gondola. The envelope, with a radius of 19m, enables the airship to lift a 500 kg mass up to 3000 m from the ground. An inner balloon filled with ambient CO2 air, located inside the envelope, controls the airship's altitude by pressurizing the hydrogen lifting gas. The gondola hosts all the mission-critical subsystems as well as a scientific payload that analyzes the geological composition of the crater walls. To design the envelope and gondola, a systems engineering approach is followed, involving the definition of requirements, system architecture, and subsystem trade-offs. Based on this, a preliminary design with mass, power, and data budgets is established. Special attention is given to the design of the solar panel structure, crucial for harnessing energy in the challenging Martian environment.

Furthermore, this paper explores two solutions for Entry, Deployment, and Landing applicable to a Martian airship: space-based-deployment and ground-based-deployment. To perform a trade-off, comparison criteria are defined. They are subsequently evaluated, by undertaking preliminary sizing for both solutions. Ground deployment emerged to be the most suitable solution, of which a first design concept is presented in this paper.

[A-111]

A WIND FISHER SYSTEM FOR IMPROVING STEER BALLOON MISSIONS

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Since 2021, CNES and HEMERIA Airship have been working on the development of a new balloon named BALMAN (a steerable balloon). BALMAN is able to float/fly at different altitudes thanks to an air ballast system containing a compressor and a valve. By this air ballast system, BALMAN will mainly address two types of mission: “Station keeping” and “Routing”.

The mission achievement and its optimization depends on the reliability of the wind forecast. As it is known, weather models at high altitudes (in the stratosphere) are not very accurate and their consistency decrease rapidly over the time.

Regarding the BALMAN balloon, going down is much more power consuming than going up because of the compressor activation. In a window of 24h, the number of compressor activations is limited by batteries and its recharge cycle. Therefore, it is important for the mission control team to be sure that the “going down” maneuver will reach the expected wind direction.

A simple way to improve wind forecasts and models is by collecting in-situ real data. To collect this data, the wind fisher system is composed of a gondola and a sonde. The gondola is mechanically linked to the balloon flight train and contains a winch system to pull up and down the sonde. Both parts, gondola and sonde, communicate by LoRA.

The sonde is equipped with several COTS sensors like GPS, IMU, pressure and temperature. In addition, the external shape has been chosen to offer a well-known aerodynamic effort in order to deduce as easier as possible the wind speed.

On the other hand, the gondola is equipped with a GPS, a motor driver, an encoder and finally with an IRIDIUM modem to send data to ground.

Heating circuits are present either on the gondola either on the sonde. These circuits are passive and piloted by a simple thermo-switch.

Real data is collected up to 1000m under the balloon and the sounding is done by steps of 50m, so we sample 20 levels. Each step takes about 5 minutes for spooling 50m of cable, for stablishing communication, for making several measurements and for sending data to ground…

The wind fisher system is under development. It shall be tested and validated on flight during the next CNES campaign at ESRANGE by mid-2024.

[A-190]

DISRUPTING THE SMALLSAT LAUNCH MARKET: B2SPACE'S ROCKOON TECHNOLOGY

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B2Space is an aerospace company that aims to disrupt the market of smallsats launches through its rockoon technology. B2Space's purpose is to democratise access to orbit and facilitate the development of new technologies and uses of space, by providing a reliable, flexible, and low-cost access to Low Earth Orbit (LEO) for small and micro satellites and become Europe's first dedicated, customised satellite launch system. B2Space has dedicated the last 7 years in the development of the multiple technical challenges that the Colibri Launcher requires. Another strategy that B2Space has followed from the beginning is to stablish strong alliances with top industry leaders to make use of their capabilities and matured technologies, which give us a huge advantage in lead times and funding required. The reason is because the development of a launcher is a task of a magnitude that B2Space understands it cannot be done alone. The rockoon launcher technology has its unique technical challenges link to the launch from the stratosphere but also has multiple advantages compared with vertical launch.

Key differentiator characteristics:

1. Adaptable and fully flexible launches. Launches can be planned in different geographies, environments (i.e. land, sea,) and with quick and agile response times, as well as reach targeted orbits which is very demanded by current clients.

2. Unparalleled cost efficiency. The rockoon launch technology developed by B2Space is currently among the cheapest options to send small satellites to space.

3. Superior safety. Safer environment thanks to remote ignition from a self-operative platform, leading to lower insurance premiums and speedier approvals and licenses lead times.

4. No design constraints. Greater design freedom for clients due to reduced vibro-acoustic loads and no aerodynamic constraints caused by sharing space with main satellite operators.

5. Environmentally friendly. Launching at 35km altitude means no aerodynamic constraints, which reduces carbon emissions and propellant consumption by 70%

To date, B2Space has already developed and successfully tested at PoC level all key stages of its rockoon technology including all system developments and tests, thus solving all technical challenges and risks of the rockoon system.

On our way to the commercial launcher solution, we wanted to take advantage of the knowledge acquired with the operation of stratospheric balloons to launch other lines of business that allow us internally to have our own funds and that not only help in the development of the launcher but also become active lines of business and research. These lines are:

- NST (Near Space Testing)
- HAPS (High Altitude Pseudo Satellites)
- Consulting Services (Safety, Management)

LIFE SCIENCES 1

MONDAY 20 MAY, AFTERNOON SESSION – PART 2

ROOM 3

CHAIR: A. PETERS

[A-112]

BONE VOYAGE – OSTEOBLASTS' JOURNEY TO THE STRATOSPHERE

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Ionizing radiation is one of the most prominent dangers of the space environment and poses a serious threat to the human body. In order to look for countermeasures that could potentially keep the astronauts safe, such as radioprotective agents, there is a need for thorough research on the effects of space radiation on humans, which is not an easy endeavour. Space research is not available enough and space radiation is very hard to mimic on Earth. One way to achieve a near-space environment is by utilizing stratospheric balloons. Although they don't leave Earth's atmosphere, they reach altitudes where cosmic radiation is a lot higher than on the ground.

This study aims to assess the influence of cosmic radiation on two human osteoblast cell lines, NHOst (normal) and MG63 (cancerous), through a series of lightweight stratospheric balloon experiments. The research focuses on evaluating cell viability, cytotoxicity, and DNA damage to understand the potential effects of cosmic on bone cells during high-altitude exposure.

Two cell lines, enclosed in a well plate with a self-developed hermetic lid and kept at the proper temperature by a specifically designed PCB board, were subjected to cosmic radiation during three stratospheric balloon flights. In addition to the standard Earth-based control group maintained in the incubator, a supplemental control group, placed in an exact copy of the balloon gondola, was incorporated. This one stayed in the outside conditions, following the research group in the pursuit and recovery of the balloon. Samples were transported to the laboratory for testing straight after the recovery. Presto Blue was employed for cell viability testing, ToxiLight for cytotoxicity assessments, and ELISA GADD45 for measuring DNA damage.

The results show that cosmic radiation during stratospheric balloon experiments can adversely affect the viability, cytotoxicity, and DNA integrity of both osteoblast cell lines, with slight differences between them. These findings contribute to our understanding of the potential risks of cosmic radiation during high-altitude exposure and are essential for developing strategies to safeguard bone health in astronauts during extended space missions.

[A-164]

WITH SHRIMPS TO OTHER PLANETS – THE FINAL STORY OF THE SHREAMP PROJECT

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This paper presents the history, as well as scientific and engineering value of the SHREAMP 2.0 (Space Habitat Research – Effectiveness of Anesthetics Monitoring Payload) – a project aiming at finding a safe way to transport *Neocaridina davidi* shrimps in a sounding rocket. Shrimps, as aquatic animals, might one day become a part of extraterrestrial aquaponics systems and help provide food for the future Moon and Mars settlers.

The project started as SHREAMP and was developed by members of the AGH Space Systems Student's Association to compete in the 2021 virtual edition of the SDL Payload Challenge taking place during the Spaceport America Cup. The first version of the project took 2nd place at the 2021 challenge and the first flight test was conducted shortly after. During this test, a few issues arose, so the project was redesigned into SHREAMP 2.0 and the progress was presented during the 25th ESA Symposium on European Rocket & Balloon programmes and related research. Since then, after undergoing an electronic redesign, the project flew on a second attempt at Spaceport America Cup 2023. Although it did not come back in one piece, the results achieved during its development are worth mentioning, particularly the electronic design and the research done on shrimp sedation.

The electronics have been completely redesigned. Three new electronic systems have been developed: Krewetka CM4, Peltier Control System, and Electrical Power System. The main PCB, responsible for monitoring the living conditions of shrimps, Krewetka CM4, has a Raspberry PI CM4 as a central processing unit due to its large capabilities and small size. The PCB allowes the connection of two cameras to observe the movement of shrimps in the aquariums, measures vibrations using a high-frequency IMU and could also utilize CO2 and O2 sensors for air quality control. The Peltier Control System is responsible for controlling the temperature in aquariums, using a Peltier module and the Electrical Power System is tasked to power the other two systems using three 18650 lithium-ion batteries.

At the beginning of the project, no data was available on sedating the chosen species of shrimp, therefore the team had to establish the proper anaesthetics and dosing by themselves. Basing on general guidelines for aquatic animals, many tests were performed and eugenol was chosen as the safest sedative. There were four series of tests conducted: one without anaesthetic, one to establish a safe dose for the one-phase sedation, one to establish the maintaining dose for the two-phase sedation and one to combine proper initial and maintaining dose for two-phase sedation. An additional series of tests was conducted to gain repeatability of the sedation process. The best outcomes are achieved when the procedure is divided into two phases: initial and maintaining.

Astrophysics & Astronomy 1

Tuesday 21 May, Morning session – part 1

Room 1

Chair: I Mann

Plenary Invited Lecture

[A-185]

NUCLEATION PROCESSES OF CARBONACEOUS DUST IN MICROGRAVITY EXPERIMENTS USING SOUNDING ROCKETS

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Since dust plays a crucial role in both physical and chemical processes in the universe, understanding the characteristics of dust in various astronomical environments is one of the fundamental and essential challenges in astronomy. However, due to the peculiarities of space, basic experimental data are lacking, and the interpretation of dust formation in space involves many assumptions. For example, the amount of dust formed around a star is close to the upper limit of model calculations, so even assuming a sticking probability of 100% when atoms/molecules collide, some of the dust will be destroyed by space weathering and must be re-grown somewhere. However, since neither the sticking probability nor the destruction efficiency is known, an appropriate dust formation model has not been constructed. Here, we focus on astrochemistry around carbon-rich stars, and introduce the reproduction experiments of carbonaceous dust analogues conducted under microgravity conditions obtained using sounding rockets, and the nucleation processes that have become known as a result of these experiments.

The abundance of carbon in interstellar space is more than an order of magnitude larger than that of silicon and magnesium, which are constituent elements of the abundant dust, silicates. It has also been suggested that the abundance of carbonaceous dust is several times to nearly an order of magnitude larger than that of silicates. Large amounts of carbonaceous dust have been found in meteorites in many forms, including nanodiamonds, nanotubes, graphitic carbon, fullerenes, and hollow carbonaceous particles (globules). Many of them also contain pre-solar particles. Thus, carbonaceous matter is one of the major components of the interstellar medium. To understand the formation process, high-temperature carboneseous vapor is generated in a microgravity environment obtained by sounding rockets, and its cooling and condensation processes are measured in situ with a double-wavelength laser interferometer. Using the latest nucleation theory, the analysis can determine the sticking probability and surface free energy of dust analogues during nucleation.

In an experiment conducted in 2019 using a sounding rocket of Swedish Space Corporation (SSC), MASER14, the goal of the experiment was to clarify the formation process of carbonaceous dust with a titanium carbide core. The results showed that the homogeneous dust formation required extremely high supersaturation, which is far from thermal equilibrium. It was also found that the dust was formed via a non-classical nucleation process. Theoretical predictions of dust formation were found to be possible by considering physical quantities (sticking probability and surface free energy) obtained in the actual size and temperature range of dust, as well as characteristic phenomena appearing in nano-acale such as melting point depression and fusion growth. To elucidate the formation process of carbon dust, we are planning to conduct another microgravity experiment using SSC's sounding rocket in spring 2024. The preliminary results of this experiment will also be reported.

Ackknowledgements: Microgravity experiments were conducted with the technical support of the SSC with financial support from the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK), and the Institute of Space and Astronautical Science (ISAS), the Japan Aerospace Exploration Agency (JAXA). Development of the experimental system was supported by the Technical Division of the Institute of Low Temperature Science, Hokkaido University, and the Advanced Machining Technology Group of JAXA. This work was supported by FY2016 ISAS Small-Scale Science Projects of JAXA, Grant 50WM1846 of DLR, and Grant in-Aids for Scientific Research (S) from KAKENHI 15H05731 and 20H05657.

[A-26]

TEXUS-56 ICAPS - BROWNIAN DUST AGGLOMERATION IN A MICROGRAVITY EXPERIMENT

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Theory predicts that the initial stage of planet formation is determined by the agglomeration of roughly micrometer-sized dust particles through low-speed collisions inside protoplanetary disks. Computer models have further shown that in the beginning of the agglomeration phase, so-called *hit and stick* collisions dominate the growth behavior, in which the colliding grains stick upon first contact due to the van der Waals force. To study the efficiency of this initial agglomeration, the ICAPS (Interactions in Cosmic and Atmospheric Particle Systems) experiment reproduces the conditions inside protoplanetary disks, but with much shorter growth timescale. ICAPS flew on board the TEXUS-56 sounding rocket in 2019 and employed a novel, specially designed four-Peltier-ring system to compensate drifts caused by external temperature gradients.

With this setup, we were able to observe the growth processes for ~6 min of microgravity using two overview cameras and a high-speed long-distance microscope. In 2021 in Biarritz, we presented results from the analysis of the Brownian motion of the particles as well as preliminary data on the growth processes. In this talk, we will build upon those findings and present the final results of the growth analysis of ICAPS, which we put into context using both an analytical and a numerical model. As we are now also able to apply refined methods to data from the second flight of ICAPS in April of 2023 on board TEXUS-58, we will also be showing those results.

[A-98]

BISOU: A STRATOSPHERIC BALLOON FOR CMB SPECTRAL DISTORTIONS MEASUREMENTS

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Following the success of the ESA Planck mission, outstanding questions about the concordance cosmological model are still unanswered, in particular the simplest inflationary model proposed as the origin of the initial matter perturbations. In addition to projects attempting to observe observed through the Cosmic Microwave Background polarization: namely B-modes, the CMB frequency spectrum is another key observable to probe the cosmological model. Departures of the CMB blackbody spectrum called spectral distortions, encode information about the full thermal history of the Universe from the early stages until today. Following several space mission proposals and white papers, several agencies have identified this research theme as one of the highest priorities.

In order to prepare for a future dedicated space mission, a pathfinder is needed to consolidate the instrument concept, develop key sub-systems, while performing a first measurement. The BISOU (Balloon Interferometer for Spectral Observations of the Universe) balloon-borne project, based on a Fourier Transform Spectrometer (FTS) operating between 90 GHz and 1.5 THz, has passed successfully a CNES phase 0 study and is entering a Phase A. We present here the latest results on the design of the instrument, of the mission parameters together with the expected sensitivity to CMB Compton y-distortion and the Cosmic Infrared Background measurements. In parallel to the Phase A, a cryogenic breadboard of the instrument is being developed. Its concept and purpose will also be presented.

[A-191]

ADVANCEMENTS IN BALLOON-BORNE HARD X-RAY SPECTRO-POLARIMETRY: SCIENCE TOPICS AND ENABLING TECHNOLOGIES

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A balloon-borne hard X-ray spectro-polarimeter experiment (50 - 250 keV) is presented. The instrument is based on two enabling technologies: a 10 m focal length Laue lens and a Cadmium Zinc Telluride focal plane detector. The former is a ~2 m diameter diffractive concentrator made of perfect germanium and silicon bent crystals. Each ring of crystals, responsible to diffract into the lens focus a given energy passband, has different thickness in order to optimize the diffraction efficiency and thus the effective area of the lens. The Laue concentrator is made of sectors which are co-aligned towards the common lens focus. The latter is a matrix of CZT detection modules based on the Caliste-HD concept, developed by CEA. Each Caliste-HD module is an edgeless, pixels spectro-imager CZT detector with sub-mm spatial resolution in the three dimensions. The high sensitivity enabled by the focusing capability of a diffractive optics, and the 3d spatial resolution of the Caliste detector represent a unique combination of technologies which would enable hard X-ray spectro-polarimetry. The proposed hard X-ray spectro-polarimeter will complement and extend to the higher energies the outstanding results achieved in soft X-ray polarimetry, both from the space-borne IXPE (2-10 keV) and from the balloon experiment XL-Calibur (15-80 keV).

[A-149]

CZT SPECTROMETERS WITH 3D SPATIAL RESOLUTION FOR HARD X AND SOFT Γ-RAY ASTRONOMY: DEVELOPMENT STATUS AND PRELIMINARY RESULTS FROM A STRATOSPHERIC BALLOON FLIGHT.

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New instruments for high energy astronomy require detectors exploiting high dynamics to cover a large energy band and very high performance in terms of efficiency, spectroscopy, imaging, and, in particular after the launch of IXPE satellite, high polarimetric capabilities. Our collaboration for several years has been dedicated to the development of an innovative CZT drift strip sensor unit (3D-CZT). This device, operating at room temperature, coupled with a dedicated signals digital readout allows to obtain unprecedented performance with three-dimensional spatial resolution (<0.5 mm), fine spectroscopy (1% FWHM at 511 keV), and high response uniformity (few %) through use of a limited number of electronics channels.

In the framework of the European HEMERA program for stratospheric balloon flights we successfully launched in September 2022, from the ESRANGE base the BADG3R (BAlloon Detector for Gamma ray with three-dimensional Resolution) payload consisting of a detection system based on one 3D-CZT sensor unit. Herein, we present the state of the 3D-CZT sensors development, we describe the BADG3R payload and the preliminary results obtained from the performed flight. Finally, we briefly outline the prospects for their use in future balloon or satellite missions for high energy astrophysics.

[A-153]

PR^4: MAGNETIC FIELD RECONSTRUCTION USING COSMIC-RAY ARRIVAL DIRECTION MEASUREMENTS ON A ROCKET

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Motivated by finding a pathway for research on the effects of cosmic-rays on cloud formation, the student team Payload for Radio interferometry and Radiation measurement in Rockets Revisited (PR^4 Space) aims to develop a two-part payload on the REXUS 31 rocket (Rocket EXperiments for University Students), which is to be launched in March 2024. PR^4 Space is a collaboration of students from both the Eindhoven University of Technology (TU/e) and the Radboud Radio Lab (RRL) in the Radboud University of Nijmegen. Apart from those universities, the team consists of students from many other universities as well. The team has been focused on multi-disciplinary collaboration between students, with levels varying from high school projects to master theses, with the overall aim to develop two experiments.

The first experiment uses radio-interferometry for live location and orientation tracking of the sounding rocket during flight. The second experiment performs astrophysical measurements by characterizing the flux and arrival direction of cosmic-rays using a multi-layer scintillator detector built with 2U CubeSat dimensions. The arrival direction of the cosmic-ray particles is characterized by studying the triggered detector layers. Furthermore, the efficiency of the detector is calculated as well by comparing the obtained data to simulations. This experiment provides a unique opportunity to study cosmic-rays in the domain between ground-based detector and space-based detectors.

The detector consists of eight layers of polystyrene, which emits light when a cosmic-ray particle interacts with it. This light is then guided towards a Multi Pixel Photon Counter (MPPC), triggering an electronic circuit to convert voltage pulses from the MPPC's into counts. The full data stream is stored in on-board storage for later recovery.

The REXUS flight will occur during a solar maximum, providing a large flux of low-energy cosmic radiation in addition to the background of cosmic-rays of galactic origin. A simulation study is presented of the expected cosmic-ray signal above the atmosphere consisting of a uniform galactic cosmic-ray background and a dipole contribution of the lower-energy solar particles aligned with the Earth's magnetic field. This study will act as a model to interpret the measurements of the REXUS flight. In addition, during the ascent phase of the flight, the particle flux will be measured as a function of altitude, which provides additional information on the proportion of low- and high-energy cosmic-rays.

[A-180]

CORMAG – CORONAL MAGNETOGRAPH FOR OBSERVATIONS OF THE SOLAR CORONA FROM THE STRATOSPHERE

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The Coronal Magnetograph - CorMag - experiment aims at studying the magnetic field topology of the solar corona. The direction of the coronal magnetic field vector would be derived from observations in the narrow-wavelength bandpass of the linearly polarized FeXIV line-emission (530.3 nm), interpreted through the "saturated" Hanle effect.

CorMag is a medium-duration, high-altitude balloon payload consisting of a coronagraph with a large field-of-view (±0.84°). This allows the discrimination of the magnetic signatures of different coronal structures (e.g., streamers), and at the spatial (< 10 arcsec) and temporal (< 10 s) resolutions required to address outstanding problems in coronal physics, such as the correlations between the topology of the coronal magnetic field and the solar wind origins.

CorMag is an internally-occulted coronagraph whose design was derived from the externally-occulted, formation-flying ASPIICS coronagraph of the PROBA-3 ESA solar mission. The focal plane instrumentation of CorMag comprises a mechanically-tunable (i.e., by tilting) narrow-bandpass (FWHM=0.5 nm) filter, centered alternatively on the green line and the continuum K-corona spectrum. The telescope's detector is a CMOS sensor overlaid with a micro-polarizer array to analyze pixel by pixel the image linear polarization (PolarCam®).

On August 2023, CorMag was launcged from Timmins, Canada, up to 32 km of altitude, onboard a CNES stratospheric zero-pressure balloon. The gondola platform "Carmencita" of CNES accommodated the CorMag system comprising telescope and mount. The mount includes a sun-sensor, closed-loop pointing and tracking system developed to acquire the Sun and to maintain the sun-center pointing within 10 arcsec over the typical dwell acquisition time of 1 minute.

This presentation will illustrate the CorMag instrument and its performamces during the August 2023 flight. Post-flight calibrations were carried out. This presentation will report the results of those tests.

Technology & Infrastructures for Balloons 2

Tuesday 21 May, Morning session – part 1

Room 2

Chair: S. Venel

[A-1]

STRATOSPHERIC BALLOON FLIGHTS AS A PATH TO A SATELLITE MISSION FOR THE AEROSOL LIMB IMAGER (ALI)

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The Aerosol Limb Imager (ALI) is a novel multi-spectral polarimetric imager designed to measure aerosol properties above clouds in the upper troposphere and stratosphere. The instrument design uses a large aperture acouto-topic tunable filter paired with a liquid crystal polarization rotator to rapidly select spectral bands and polarization states with no moving parts. ALI was recently selected by the Canadian Space Agency as a Canadian contribution to the upcoming NASA Atmosphere Observing System (AOS) satellite mission. ALI was originally developed for stratospheric balloon and this presentation will discuss the development of several successively advanced prototypes of the ALI instrument that have flown on stabilized gondolas. Optical, thermal, and electronic design approaches will be covered as well as scientific results. These balloon flights were a critical element in the development of the technical and scientific readiness of the instrument for a major satellite mission, and provided valuable engagement opportunities for students.

[A-57]

MUTATION AND ADAPTATION: NAVIGATING THE COMPLEXITIES OF STRATOSPHERIC BALLOON PROJECTS

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Stratospheric balloons offer cost-effective access to space and grant the opportunity for fast scientific innovation cycles and higher-risk explorations. In addition to science pathfinders, they serve as platforms for the advancement of technology readiness level, and offer a unique opportunity to train future instrument scientists and PIs. However, the increase in complexity of such projects (sub-arcsecond pointing, numerous degrees of freedom, advanced cooling systems, real-time communication and data transfer, low readiness level technologies) simultaneously elevates the scale of challenges.
This talk discusses the issues brought by the increase of payloads complexity in the constrained area of ballooning projects, focusing specifically on the FIREBall project. We discuss the intrinsic technical, operational, and logistical hurdles faced during the course of the project and expose crucial lessons for future missions.
We will then propose strategies for future balloon projects and necessary adaptations by funding agencies to accommodate these emerging complexities.
The objective being to foster a nuanced understanding of the balloon-borne project landscape, and to generate more robust strategies for handling high-complexity undertakings.

[A-87]

STRATOSPHERIC BALLOON MISSIONS AS A PRECURSER FOR SATELLITE MISSIONS

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This abstract explores the innovative use of small weather balloon missions as precursors for scientific satellite experiments. We emphasize the opportunity to train teams with limited space mission experience to space-specific expertise.

The Institute of Photovoltaics (*ipv*) at the University of Stuttgart is currently developing the PÆROSPACE experiment to test perovskite solar cells in orbit. The experiment will fly as a payload on the satellite ROMEO (Research and Observation in Medium Earth Orbit), developed by the Institute of Space Systems at the University of Stuttgart [1]. The launch is foreseen for the year 2026. Perovskite solar cell technology holds the potential to achieve significantly higher efficiency in converting solar energy into electrical power than conventional solar cell technologies. In August 2023, a laboratory-scale efficiency of 26.1 % was attained [2]. The semiconductor property in perovskites is achieved by building up crystal structures from readily available elements. This process requires relatively low process temperatures; enabling more energy- and cost-efficient manufacturing of solar cells. Therefore, perovskite technology holds the potential for a substantial increase in environmentally friendly power generation on Earth. Furthermore, lightweight and deployable solar panels could also enable new mission concepts in the space sector.

A smaller-scale experiment was previously flown on a weather balloon like mission. Future tests of the PÆROSPACE experiment using the BUBBLE balloon system [3] are in the planning stage. Since *ipv* has very limited experience with space missions, stratospheric balloon missions are an excellent opportunity for hands-on training the team and establishing adequate procedures. The accessibility and affordability of these missions provide an ideal platform to establish essential skills, understanding space-specific challenges, and familiarizing the team with satellite technology requirements and procedures. We discuss the versatile opportunities, but also the challenges, associated with employing balloon missions as a prelude for space missions.

[1] Löffler, Thorben et al. (2022). Preliminary Design of the Radiation Protection of the ROMEO Satellite in the lower Medium Earth Orbit.

[2] HTTPS://WWW.NREL.GOV/PV/CELL-EFFICIENCY.HTML

[3] "Business Case BUBBLE", Max Schneider, this symposium

[A-131]

EVOLUTION OF A LIGHT, MODULAR SOUNDING BALLOON SYSTEM

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The Small Satellite Student Society of the University of Stuttgart (KSat e.V.) has been launching their sounding balloon system “BUoyancy Balloon Bus Lifted Experiments” (BUBBLE) since 2019, amounting to a total of 8 flights. BUBBLE has been under continuous incremental development; however, the team has recently begun a complete redevelopment of the system, which will represent the next step in the evolution of the project. This paper aims to give an overview of the planned new system, focusing on the following technologies.

BUBBLE will be equipped with a fueling adapter, enabling easier and more consistent filling of the balloon, thus allowing for more precise flight profiles to meet specific payload demands. The adapter will also house a flight termination system (FTS), allowing for more flexible mission planning and guaranteed safe destruction of the balloon. All on-board electronics are being condensed into a custom PCB with duplex hot-redundant system paths for the activation of the FTS. The structure of the gondola will be redesigned to reduce structural weight and making it possible to split the payload between a 1kg main gondola and a 3kg payload gondola, suspended from the main gondola, to maximize payload capacity while meeting legal requirements. Furthermore, the possibility of using hydrogen instead of helium as a lifting gas for the balloon is being investigated. A major point of focus of the new developments is an improved recovery system. BUBBLE has utilized a classical round-cap parachute, necessitating chase vehicles to recover the gondola wherever it may land. In order to cut cost of the recovery and reduce the risk of landing in a non-recoverable area, a steerable alternative, taken from a rc paraglider, will be implemented. The gondola will thereby gain a return-to-home function or, if wind conditions do not allow the necessary range for a full return, land in designated safe zones with good access for the recovery team.

These modifications will likely decrease operational costs per launch, increase payload capacity and enable higher launch cadence, a more reliable recovery, and a reduced risk of landing in undesired areas. The necessity of these improvements and their technical implementation are discussed in this paper.

[A-156]

DEVELOPMENT AND TESTING OF A HIGHLY RELIABLE AND USER-FRIENDLY TELEMETRY AND TRACKING SYSTEM FOR HIGH-ALTITUDE BALLOON FLIGHTS

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The Small Satellite Student Society of the University of Stuttgart (KSat e.V.) has been launching their sounding balloon system "BUoyancy Balloon Bus Lifted Experiments" (BUBBLE) since 2019, providing access to the stratosphere for external research institution as well as testing and refining the BUBBLE flight hard- and software. As of December 2023, 8 such flights have been conducted. While the system has been under continuous incremental development; the team has recently begun a complete redesign, focusing on improving launch cadence through lowered cost, a more flexible system and easier integration of external payloads. This paper focuses on how the newly developed telemetry system, as well as on-the-ground tracking equipment, is part of this effort.

Arguably most critical to the success of any high-altitude balloon mission, the telemetry system cannot fail during the flight as it ensures the recoverability of the vehicle. The new system will also need to allow transmission of experiment data from the stratosphere to the ground, as well as provide an uplink for controlling various systems throughout the flight. Commercially available radiosondes previously launched by the German Meteorological Service were repurposed to provide tracking capability on all eight flights up to this date. By being physically separated from the main payload they were unlikely to be affected by failures on other systems and thus very reliable; however, sending custom and mission-specific data was not possible. To remedy this, the hardware of the new telemetry system is integrated on the main PCB and connected to the Payload Onboard Computer. Two transceivers working in parallel are used to provide redundancy. To retain robustness against failures on other subsystems, each transceiver is controlled by a dedicated microcontroller with each running independently developed software as well as being not reliant on power or data from the main system.

The new system is based on the LoRa spread spectrum modulation as well as newly developed software, to allow full customization of the data being sent. In addition, FSK-modulated packets are transmitted to provide backwards compatibility with the radiosonde-based system.

For recovery operations and external teams flying their experiments on BUBBLE, ground stations are being developed which require minimal knowledge of the system to operate, and display received telemetry data in the web browser of connected devices.

[A-13]

ESCARGO - NEW ESRANGE GONDOLA FOR STRATOSPHERIC FLIGHTS

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SSC (Swedish Space Corporation) has been launching more than 675 stratospheric balloons since 1974! The most common way of launching an experiment on a balloon is to mount it on a structure called “gondola”. If some of the missions are coming to Esrange Space Centre with their own gondola, other missions are a rideshare. This is why SSC can provide a gondola where all experiments are accommodated; this is the traditional way for missions like BEXUS (Balloon EXperiment for University Students). Therefore, a family of gondola, called EGON (Esrange GONdola), has been developed by SSC. EGON is available in three versions: Small, Medium and Large. The medium size, dedicated to BEXUS, has therefore been reused for more than 10 years. Consequently, the structure requested higher and higher maintenance costs. Moreover, the needs of the scientists evolved in the last years and SSC has foreseen the interest in developing a more flexible gondola.

Thus, in 2022, SNSA supported the SSC project called “ESCARGO”, the Esrange Space Center Adaptable Rectangular Gondola, dedicated to educational activities within the REXUS/BEXUS programme. The starting point was the collection of feedback from more than 15 teams from BEXUS and SSC users (Launch Team, Instrumentation Team and Business Development). Therefore, ESCARGO can carry scientific research payloads of all kinds, thanks to its modularity provided by standard BOSCH profiles. Interfaces for the experiments and SSC equipment are now standard and they can be accommodated anywhere on the gondola frame while being easily accessible. The rectangular shape also enables easier storage and transport but also easy experiments access during integration. In addition, ESCARGO has a modular floor available in different materials and that can be partially removed for experiments requesting a downward access (camera, system deployment…). ESCARGO has also smaller curtains set that can be accommodated according to the experiments’ requirements and more crash pads than EGON to increase the chances of smooth landing. Finally, to expand the variety of stratospheric missions, it is easy to reduce the size of ESCARGO by simply shortening the longitudinal profiles or to increase the size by combining two ESCARGOs; payload capacity would then increase from 100kg (maximum BEXUS performance) to 200kg. Several configurations can be imagined making the gondola taller, wider or larger according to experiments’ needs.

Maiden flight of ESCARGO is planned for October 2024 during the BEXUS 34/35 campaign from Esrange Space Centre.

Technology & Infrastructures for Sounding Rockets 2

Tuesday 21 May, Morning session – part 1

Room 3

Chair: G. Rosanova

[A-35]

MAIDEN FLIGHT OF HYIMPULSE SR75 HYBRID SOUNDING ROCKET

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HyImpulse aims at revolutionising the new space industry by providing dedicated and reliable launches for small satellites. The identified satellite market for the HyImpulse Small Launcher (SL1) covers both the private and public sectors. The current space landscape in Europe offers scarce access to launch vehicles, being the market limited to few actors. HyImpulse will be capable of offering affordable launch services thanks to their proprietary technology based on green propulsion. Through the low-cost hybrid rocket propulsion technology HyImpulse can offer high launch frequency and a tailored capability to customers' requirements.

A key asset to enable the development of the main company product is the successful testing of the technology demonstrator SR75, a single stage sounding rocket for microgravity experiments. This paper provides an insight on the development activities related to the SR75's maiden launch that is planned to take place from Australia in early Q2/2024, and potentially discusses the outcomes and lessons learned from the first launch campaign. The maiden launch is a critical milestone for HyImpulse and provides a platform to validate both motor and vehicle. The workflow and preparations leading up to the launch are also discussed in this work.

SR75 serves are demonstrator for the in-house developed hybrid rocket motor, the HyPLOX75. An overview of the successful testing and qualification of HyPLOX75, as well as the vehicle's design and key components is presented in the technical section. HyImpulse exploits low-cost Commercial-Off-The-Shelf (COTS) components, embraces innovative technology from non-traditional aerospace industries and applies additive layer manufacturing techniques such as 3D printing.

The mission profile of SR75 from Koonibba Test Range, Australia, is also discussed, with connection to the current regulatory frameworks that contextualise space activities and their importance for safety of operations. Since HyImpulse recently obtained a flight permit to allow a suborbital launch from the UK, a comparison with European regulations is made, in the specific for what concerns the licensing process for launch operators. Another key point of this work is to underline the complexity of regulations and authorities involved in the European context as well as the number of stakeholders, with reference to space, maritime and airspace domains.

Future activities for suborbital and orbital flights of the company products are also presented. The culmination of these efforts aims to propel HyImpulse at the forefront of commercial New Space endeavours, offering a glimpse into the future of hybrid propulsion and small satellite launch capabilities.

[A-54]

FLIGHT QUALIFICATION OF THE RED KITE SOLID ROCKET MOTOR

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The Red Kite© is a commercially available, serially produced and ITAR-free solid propellant sounding rocket motor in the class of one ton of net explosive mass. It was first launched on November 13th 2023 at the Andøya Space launch site in Norway after five years of development. The flight was named SOAR (*Single Stage Operational Assessment of Red Kite*) and was administered by DLR-RB-MRB.

Main objective of SOAR was to collect a body of data sufficient to determine flight worthiness. Red Kite had already been tested successfully in two static firings in August 2023 at ESRANGE, Sweden. The role of flight testing was to confirm that it would work under the additional inertia and aerodynamic loads. Further, compatibility with existing infrastructure (radar, telemetry, launcher, data acquisition systems) was tested. Secondary objective was to establish suitable flow conditions for APEX-TD (*Air Breathing Propulsion Experiment - Technology Demonstrator*) by DLR-AS-HYP with contributions by DLR-BT-RSI and DLR-AS-HGK. This required to fly fast in the low atmosphere and to actively open the inlet of the scamjet type duct shortly after motor burn-out. Both objectives required live streaming of data to ground because the vehicle was not equipped with a parachute recovery system.

Motor data and experiment data were sent and received continuously from lift-off until shortly before impact. On-board GNSS and passive radar track agree well showing that the vehicle reached an apogee of 71 km (prediction: 75 km) and impacted the Norwegian Sea 59 km from the launch site (prediction: 63 km); the maximum speed was Mach 4.8. Key trajectory parameters are all within one standard deviation of predictions. This is considered a small deviation completely satisfactory for the sounding rocket application. The deviation could, to date, not be attributed to any single source. Post-flight simulation suggests that motor pressure and ambient air density as measured by balloon sounding had only negligible influence on flight trajectory. The best match of simulated and observed trajectory is achieved when assuming 5% higher than modelled drag coefficient of the vehicle.

Red Kite is now fully qualified with its first flight in a multistage configuration scheduled for early 2024. SOAR demonstrated the capability of Red Kite and DLR-RB-MRB supplementary systems to provide the scientific community with an easy, reliable and highly customizable sounding rocket flight. The paper describes the SOAR objectives, design, execution and results as well as noteworthy observations from vehicle and ground based instruments.

[A-64]

ILR-33 AMBER 2K SYSTEM – GOING FURTHER

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Since the recent overview of the activity in mid-2022, a maiden flight of AMBER 2K version (capable of reaching over 100 km altitude) was executed in late 2022, as announced. That launch aimed to verify in flight the reliability of the technical improvements not only to the vehicle itself but also to the ground support equipment, especially rocket launcher WR-2.

This paper presents final steps of the maturation process of the selected elements from the ILR-33 AMBER launch system architecture, being developed by Łukasiewicz Research Network – Institute of Aviation (Poland). Several results from the aforementioned launch, having led to the subsequent improvements implemented in the period of 2022-2023, allowed to prepare the system for 100 km launch. Furthermore, in-house developed software for mission safety analysis filled with results from four launches of AMBER rockets achieved satisfactory level of confidence allowing to serve for other suborbital rockets' analyses.

The low-altitude flight of AMBER 2K rocket, with 8 km of ceiling, in combination with on-ground flight-like tests for the whole system executed in 2023 prove that the architecture of the system is reasonable to conduct a high altitude flight test, to which the Łukasiewicz Research Network – Institute of Aviation team is currently preparing.

[A-69]

PROGRESS OF FLIGHT DEMONSTRATION BY REUSABLE VEHICLE EXPERIMENT RV-X

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In order to make the access to space for scientific research much easier and make the opportunities of the rocket launches much frequent, a fully reusable sounding rocket is proposed in ISAS/JAXA. The mission definition of the proposed reusable sounding rocket are 1) To achieve 100km in altitude and returns to the launch site, 2) The 100kg payload to be carried, 3) Flight frequency is higher than 10 times per a year, 4) The minimum flight interval is one day, and 5) Operational flight cost should be an order of magnitude less than the existing ISAS sounding rocket. Reusable system is different from the present expendable rockets. Some key technologies related to characteristics of reusable system have been successfully verified to design an operative reusable sounding rocket from 2010 to 2016.

After these technical demonstrations, we are proceeding with a study for system level velifications by a flight demonstrator from 2016 as the next step for the development of the reusable vehicle system. In this plan, a small test vehicle RV-X (Reusable Vehicle eXperiment) is establish for repeated flight demonstrations. Objectives of the demonstration are 1) system architecture study for repeated flight operation such as quick turnaround operation and fault tolerant design method, 2) life controlled and frequently repeated use of cryogenic propulsion system and its flight demonstrations, 3) study for the advanced returning flight method of vertical landers and its flight demonstrations, and 4) demonstration of advanced technology for future RLVs.

In the flight tests, we will demonstrate pump fed and deep throttling engine, gimbaling attitude control for vertical landing by lift-off and landing with powered flight, a quick turnaround operation, returning flight and landing by engine cut-off and re-ignition, and so on. For the flight demonstration, two series of the ground firing test have been conducted from 2019 to 2021 in order to obtain the characteristics of engine/propulsion systems, structures, ground operations, and so on. And landing gear tests and motion table tests for onboard-avionics have been also successfully conducted.

In this paper, the progress of research and development for flight demonstrations by RV-X and the future plan for reusable systems are summarised and reported.

[A-74]

PERUN ROCKET – SUMMARRY OF TEST FLIGHTS AND PLANS FOR FUTURE SUBORBITAL FLIGHTS

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This article presents a comprehensive overview of the inaugural test flights of the PERUN Suborbital Rocket, offering insights into its performance and capabilities. The assessment covered all critical subsystems, affirming the rocket's robust design and functionality. Furthermore, the recovered rocket components from both flights have yielded invaluable data, contributing to the refinement of future operations. Looking ahead, the paper outlines the ambitious plans for upcoming launches and the start of commercial operations in 2024 and 2025, marking a great milestone in PERUN's journey towards establishing itself as a key player in suborbital space travel.

PERUN is a reusable suborbital rocket designed to deliver 50 kg of scientific and commercial payloads to altitudes of up to 150 km. During its nominal flight PERUN will be able to provide up to 5 minutes of high-quality microgravity and access to high-speed testing environment. It is developed by a Polish company SpaceForest which aims to reduce the cost of suborbital flights by making PERUN entirely reusable. The development of the PERUN rocket has started in mid-2018 and is almost finished.

In 2023, a significant milestone was achieved with the completion of two pivotal test flights for the PERUN Suborbital Rocket. The first took place in June, propelling the rocket to an altitude of 22.3 km with a velocity exceeding Mach 2. The second test flight, conducted in October, reached an altitude of 13 km, showcasing velocity exceeding Mach 2.3. These achievements mark crucial advancements in the validation of PERUN's capabilities and set the stage for its promising trajectory in space exploration. During both test flights conducted comprehensive tests of all subsystems of the PERUN suborbital rocket, including ground segments, launch procedures, thrust vector control, separation systems, onboard computers and recovery systems. Successful recovery of the rocket after each flight not only confirmed the feasibility of reuse, but also provided invaluable insights for further improvements. Both missions took place from the military training ground in Ustka in Poland, which will also serve as a testing ground for future ascents to higher altitudes, paving the way for the rocket's expanded operational capabilities.

[A-127]

ATMOSPHERIC PROBING MISSION WITH THE DART ROCKET SYSTEM FROM ESRANGE

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In the second week of February 2024, a launch campaign using the T-Minus DART sounding rocket system was carried out from Esrange by a cooperation of T-Minus Engineering and KTH. T-Minus Engineering provided two DART rockets with ground infrastructure including a mobile launcher as well as the launch operations for this campaign, while KTH provided the scientific payloads. The goal of the mission was to measure the electron density of the atmosphere. This was done by a novel method using miniaturized active free-flying payloads in combination with the T-Minus DART rocket system and a mobile launch system. This makes it a very versatile and cost-effective method for determining time series and vertical traces of atmospheric properties, such as electron density.

The launches were performed at Launch Complex 3 (LC3) at SSC Esrange, being the first rocket launches from this orbital launching pad. The rockets, marked DART MOD III, were a first use of this system and contained payloads from KTH as well as a flight reconstruction payload of T-Minus. This paper presents the results of the campaign, as well as an in-depth analysis of the rocket performance.

LIFE SCIENCES 2

TUESDAY 21 MAY, MORNING SESSION – PART 2

ROOM 1

CHAIR: K. DANNENBERG

[A-41]

DIRECT AND DELAYED EFFECTS OF MICROGRAVITY ON NEURAL CREST STEM CELLS

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Boundary cap neural crest stem cells (BCs) generate neurons and glial cells during neural development and have been shown to support motor neurons and beta cells *in vitro* and *in vivo* after transplantation in animal models. BC themselves are resistant to oxidative stress, and their extreme stress-resistant capacities were proven in sounding rocket experiments aboard the MASER 14 and MASER 15. Now, BCs are in preparation for a two-week space experiment on the International Space Station. After long-term microgravity exposure, the cells will be subjected to genetic, metabolomic, physiological, and morphological analysis and their potential to generate new types of cells in cultures and 3D-printed scaffolds. These properties will be compared with the ground controls, including simulated microgravity experiments and the conventional cultures. The cells will be collected for analysis either directly after they return to the laboratory or processed for further analysis for several weeks after the trip to detect if some positive or negative consequences of microgravity were not seen directly but can appear several days or weeks later. A better understanding of the effects of microgravity on stem cells will contribute significantly to improving precautions for people exposed to microgravity. Furthermore, the potential use of microgravity and stem cells in regenerative medicine will be highlighted. The preliminary results are presented at this conference.

[A-88]

SIMULATED SPACE GRAVITY RECAPITULATES PARKINSON'S DISEASE PATHOLOGY IN NEURAL CELL MODEL

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This investigation centers on the potential influence of microgravity on α-synuclein aggregation, a hallmark feature of Parkinson's disease (PD) characterized by the formation of insoluble Lewy bodies. Despite the persistent mystery surrounding the mechanism triggering synuclein aggregation and the challenges posed by delayed PD diagnoses and protracted in vitro experiments, our study takes a pioneering approach by meticulously examining the impact of microgravity at the cellular level. Employing the SH-SY5Y cell line and a mutant 3K-SNCA clone that overexpresses an aggregation-prone α-synuclein variant to emulate PD conditions, microgravity conditions were induced using a clinostat at diverse temporal intervals. Notably, our quantitative analysis of synuclein and its insoluble conformations reveals a marked temporal augmentation in aggregate numbers, reaching a significant peak at 48 hours. This empirical evidence underscores the time-dependent relationship between microgravity and synuclein aggregation within cellular models. Beyond providing insights into PD etiology, our findings underscore microgravity as a pivotal determinant, offering an accelerated platform for the generation of intricate cellular models pertinent to PD and aging research. The study beckons further exploration into the elucidation of mechanistic pathways associated with microgravity-induced synuclein aggregation.

[A-123]

EXPLORING BLOOD BEHAVIOR IN HYPER AND MICROGRAVITY: AN ELECTROMAGNETIC PERSPECTIVE – STUDENT’S SPACE MEDICINE EXPERIMENT

daniel cieślak , magdalena prud

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In collaboration with the Gdańsk Medical University, Gdańsk University of Technology presents an innovative experiment designed to investigate the behavior of blood components under the influence of electromagnetism in both hypergravity and microgravity environments. This groundbreaking study aims to deepen our understanding of the physiological effects of extreme gravitational conditions on human blood, a crucial aspect for the future of space travel and astronaut health.

The experiment involves the application of electromagnetic fields to blood samples while simulating hypergravity using advanced centrifugation methods, and hyper and microgravity through LDC. The primary focus lies on observing the reactions of different blood components, such as red blood cells, white blood cells, and platelets, to these unique environmental stresses.

While the full analysis of the results is still underway, our preliminary findings have begun to shed light on the complex dynamics of blood in varying gravitational fields. These initial observations suggest potential changes in cellular behavior, which could have significant implications for long-duration space missions and the overall health of astronauts in space.

The importance of this research extends beyond space medicine. It also holds potential for enhancing medical treatments on Earth, particularly in understanding how electromagnetism can be used therapeutically in different gravitational contexts.

As an applicant of ESA Academy's 'Spin My Thesis' program, this experiment represents a vital step in addressing the challenges of human space exploration. The ongoing analysis and interpretation of our results will provide invaluable insights into the intersection of gravity, electromagnetism, and human biology.

Medical University of Gdańsk, Faculty of Medicine

[A-45]

SOFT AND ACTIVE MATTER ON THE MAPHEUS SOUNDING ROCKET

Thomas Voigtmann[1], Philip Born[2], Bart-Jan Niebuur[3], Laura Alvarez[4], Olfa D'Angelo[5]

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Soft matter acquires its name from its sensitivity to even moderate external forces. Thus, soft-matter systems are sensitive to gravitational forces. Experiments in microgravity help to reduce or eliminate unwanted effects, notably drifts from sedimentation. The situation is even more dramatic for active materials such as microswimmer suspensions, where buoyancy matching is often not possible due to restrictions on specific solvents and solute materials. On the sounding rocket MAPHEUS and at the drop tower of ZARM, we have recently performed several soft- and active-matter experiments, which will be reviewed in this talk.

Agglomeration of gold nanoparticles has been studied in the sounding rocket experiment ARNIM-II, incorporated in a modular soft-matter light scattering and microscopy module SOMEX. Theories compete whether gravity supports reaction-limited growth of nanoparticle aggregates by enhanced mass transport, or impedes it by lowering aggregation efficiency. The microgravity experimernt aims to uncover the relevance of these different mechanisms.

The spreading of viscoplastic droplets has been studied in the drop tower experiment VIP-DROP2. Eliminating gravity allows the exploration of a hydrodynamic regime where the relative contributions of surface tension and the material's yield stress can be freely tuned. In the future, spreading and coalescence of multiple droplets and the investigation of internal stress distributions will be explored in sounding rocket experiments, using microgravity to allow the extrusion of large droplets in the regime relevant for 3d printing where surface-tension and yield-stress effects dominate.

The fluidity of membranes plays a central role in regulating various biological processes, such as cell drug uptake or structural adaptation to stress. Prior investigations have indicated a gravity-induced change in nano-membrane fluidity, and a corresponding change of lidocaine uptake, which is rather counter-intuitive. In the sounding-rocket experiment NyMEx, we study this effect for giant unilamellar vesicles, to verify this result for a model system for cell membranes, with important consequences in the design of drug delivery agents.

[A-196]

THE GREAT GEOMAGNETIC STORM MAY 10-11, 2024 – A SUMMARY

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The sunspot, designated AR3664, is one of the largest and most complex sunspot regions this current solar cycle. It had the size of about 15 Earth's and had been crackling with solar flares for many days while rotating across the solar disk. Many of them X-flares – the strongest class. And just when in rotated behind the solar limb it produced a X8.7 flare – the strongest flare this cycle. On May 8th it hurled seven CME's towards Earth and combined they created one of the strongest geomagnetic storms since 2003. It pushed the auroas extremely far south all the way to Italy, Canary Islands, Key West in Florida and even the Caribbean. The auroras of May 10-11, 2024, were among the most widespread of the last 100 years at least. Thus, several 100 million people got to see the auroras for the first time. In addition the flares and CMEs that weekend had several impacts on our technology systems we rely on in our daily lives.

[A-197]

THE DOCUMENTARY "NORTHERN LIGHTS" – A MAGIC EXPERIENCE

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The 15 minute award-winning documentary takes you on a breathtaking journey through space. By using pedagogic top-quality animations and spectacular solar imagery from NASA satellites it tells the full story of the northern lights from myths to modern science. It includes specially made animations to show how particles from the Sun runs along Earths magnetic field – colliding with atoms and how they emit light. The documentary is available in eight different languages.

TECHNOLOGY & INFRASTRUCTURES FOR BALLOONS 3

TUESDAY 21 MAY, MORNING SESSION – PART 2

ROOM 2

CHAIR: F. VACHER

[A-4]

HIGH-ALTITUDE PLATFORMS AND QUANTUM-SAFE COMMUNICATION (HAPQSC)

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We introduce a 2-axis gimbal design tailored for weather balloon deployment, detailing its construction, and showcasing experimental results. This gimbal features a coarse pointing unit capable of stabilizing a payload within a precision of ±1 degree on both axes. To enhance the stabilization, we integrated an optical design comprising a guide laser, position-sensitive photodiode, and a micromirror device, achieving sub-mrad pointing precision for optical payloads. This innovation enables the use of conventional weather balloons for near-space tests previously exclusive to larger super pressure balloons, especially those demanding high-precision stabilization of optical payloads.

Our design is pivotal for gathering data on scintillation and fading measurements crucial for optical ground-to-satellite and satellite-to-ground communications. Furthermore, it offers an environment to validate new quantum-safe optical communication protocols in near-space conditions. We conclude with empirical results from recent deployments within Switzerland.

[A-19]

ATTITUDE CONTROL SYSTEM ARCHITECTURE OF THE DICOS MISSION: AMBITIOUS SUB-ARCSECOND POINTING USING ADAPTATIVE OPTICS

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DICOS is a balloon experiment in development to demonstrate very fine pointing and wavefront control for future astronomy missions, like coronography imaging. Such an ambitious mission requires very accurate pointing performance under the tenth of arcsecond. An innovative attitude control system architecture built on the legacy of the FIREBall and PILOT balloon astronomy mission will be discussed with the addition of an extra control stage using adaptative optics. The goal is to reach 10 marcsec with a 50 Hz bandwidth fed by a 500 Hz ecartometry signal.

The main features and challenges of the architecture will be addressed during the presentation. The main results achieved on ground will be presented as well as a plan of the next milestones before a first demonstration flight, foreseen in 2026.

[A-25]

POINTING & TRACKING SYSTEMS FOR ASTRONOMICAL INSTRUMENTATION ON STRATOSPHERIC PLATFORMS

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The Coronal Magnetograph (CorMag) experiment is a solar coronagraph for a stratospheric balloon platform (see Fineschi S. et al., presentation at this conference). The observation of the solar corona with CorMag requires a pointing accuracy of +/-1 arcmin and a pointing stability of +/- 10 arcsec/min. These two values have to be considered as the APE (Absolute performance Error) and the PDE (Performance Drift Error). The experiment has been designed to match these requirements on a generic stratospheric platform and optimized for the specific gondola, Carmencita, provided by the CNES (Centre National d'Etudes Spatiales, France) for two flight campaigns from Timmins, Canada, in 2022 and 2023.

An altazimuth fork mount in closed loop with two sun sensors, one "coarse" with a field of view of +/- 60 deg and a resolution of 0.01 deg and one "fine" with a field of view of +/- 2 deg and a resolution of 0.0001 deg, is used to guarantee the required pointing accuracy.

This talk is focused on the description of the system and on the analysis of the performances achieved during the two flights of CorMag. The analyses of the Power Spectral Density and of the diffraction pattern of the scientific images, are presented and compared. The results of the CorMag pointing systems are also compared with the gondola pointing errors in order to have a complete picture of the instrument pointing capabilities and identify the actions to increase the performances.

[A-104]

DEVELOPMENT AND IN-FLIGHT PERFORMANCE OF A REACTION WHEEL-ONLY STABILISATION SYSTEM FOR THE LIGHTWEIGHT BALLOON PLATFORM “BUBBLE”

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A system to stabilise and control azimuth rotations of the "BUBBLE" lightweight-class high-altitude balloon platform was developed and tested in flight. The only actuator is a small reaction wheel developed by the University of Würzburg (Chair of Computer Sciecnce VIII) for the nanosatellite SONATE-2. Flight train torsion characteristics and gondola moments of inertia were determined. The platform motion was analysed and various flight phases and oscillation modes identified. From this, a detailed Matlab-Simulink model was developed. Application of the simulation to flight data validated the model and yielded further significant insights into the mechanisms governing the gondola motion. Control laws for azimuth rotation damping and target pointing were developed. These include logic to achieve and maintain control despite the relatively low momentum capacity of the reaction wheel. The laws were implemented on an Arduino microcontroller platform and their performance evaluated in simulations, ground tests and finally a test flight. Results from these tests are presented. During the final portion of the flight, several periods of successful pointing for minutes at a time were achieved. This demonstrates the feasibility of the concept but also highlights further improvements, in both hard- and software, that are needed for a fully operational system.

[A-133]

BALLOON-BORNE FAR INFRARED ASTRONOMY: DESIGN CONSIDERATIONS FOR A 5 M APERTURE TELESCOPE WITH CLOSED-LOOP IMAGE STABILIZATION

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With the retirement of SOFIA, the only remaining platforms for far infrared astronomy are balloon-borne telescopes. New space-based far infrared observatories will likely not launch before the late 2030s, making the far infrared community further reliant upon balloons for the following years. Within this current context, we are studying the possibility of flying very large aperture far infrared telescopes, capable of improving upon the spatial resolution and confusion limit of SOFIA and the Herschel Space Observtory, on balloon platforms. As part of these efforts, we have carried out feasibility analyses of constructing a 5 m circular aperture, full CFRP telescope that satisfies both the requirements on diffraction-limited optical quality in the far infrared as well as the mass constraints on current Zeo-Pressure Balloon platforms. We have furthermore analysed and simulated (partly) closed-loop image stabilization techniques within the optics of such a telescope, using visible-light imaging along with robust star tracking through the far infrared optics.

This contribution details the potential design of a heavily lightweighted 5 m diameter CFRP primary mirror, supported by finite element analyses predicting expected deformations. Optical simulations of the deformed system show the achievable image quality in the far infrared.

Complementarily, we show via detailed simulations using the expected visible light image quality that centroid tracking with fast visible light cameras can be performed through the far infrared-optimized telescope and henceforth used as closed-loop information for image stabilization.

As a summary, a potential full layout of a 5 m aperture balloon observatory incorporating the abovementioned elements will be presented.

[A-174]

THE THAI-SPICE BALLOON MISSION: CURRENT STATE AND FUTURE PLANS

Eliot F. Young[1], Jack Fox[2], Viliam Klein[1], Michael Skrutskie[3], Robert Woodruff[4], Michael Grusin[5], Chase Henley[1], Matthew Nelson[3], John Wilson[3], J. Matthew Hardy[6]

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(3) University of Virginia
(4) Woodruff Consulting
(5) Flying Circuits
(6) Blue Origin

THAI-SPICE (*Testbed for High-Acuity Imaging- - Stable Photometry and Image-motion Compensation Experiment*) is a NASA-funded balloon mission with three main goals: to validate thermal models at altitudes between 33 – 37 km, (particularly with passive cooling measures in place), to demonstrate a no-moving-parts motion compensation system, and to measure optical aberrations that develop in flight with the future goal of correcting them with deformable mirrors. THAI-SPICE requires a nighttime flight. It is slated for launch from Ft Sumner, NM in September 2024.

The THAI-SPICE telescope is an f/4 Ritchey-Chretien with a 50-cm aperture. The telescope feeds an optical bench with four instruments: narrow- and wide-field guiders, a wavefront sensor, and an orthogonal-transfer CCD (OTCCD). The gondola and telescope are stabilized by elevation and azimuth motors with information from interial sensors, differential GPS and the wide-field guider, with rms pointing errors currently less than 40". The residual errors will be corrected by shifting the image on the OTCCD with information from the wide-field and narrow-field guiders.

The THAI-SPICE thermal experiment consists of 32 temperature sensors on the gondola and the optical tube assembly, plus three infrared cameras to map the temperature field across the primary mirror and other parts of the telescope. A goal of the thermal experiment is to assess the relative cooling rates at stratospheric pressures due to radiative vs. convective cooling. A second goal is to demonstrate that sun- and earth-shields can passively cool optics significantly. This is an important goal in the context of stable photometric observations of infrared transit lightcurves.

We will report on the state of the THAI-SPICE payload, some lessons learned, and plans for flight in September 2024. We will also discuss a follow-on science campaign that would take advantage of access to the UV spectrum: observations of the Venus cloud tops in the 200 – 240 nm range, where there are diagnostic SO and SO_2 spectral features. THAI-SPICE's spatial resolution comes close to resolving convection cells at the cloud tops, and the ratio of SO/SO_2 (given their different lifetimes due to photo-dissociation) is a proxy for vertical mixing rates. The constraints on vertical mixing would complement the imaging that the NASA/DAVINCI descent probe will obtain.

Technology & Infrastructures for Sounding Rockets 3

Tuesday 21 May, Morning session – part 2

Room 3

Chair: L.K. Scholtz

[A-132]

SUBORBITAL EXPRESS 3 – M15 – A TRUE MICROGRAVITY RIDE SHARE MISSION

Stefan Krämer[1], Gunnar Florin[1], Alf Vaernéus[1], Kenneth Henriksson[1], Christos Tolis[1], Jimmy Thorstenson[1], Cesare Vesco[1], Krister Sjölander[1]

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On November 23rd, 2022, Swedish Space Corporation (SSC) performed the successful microgravity rideshare mission SubOrbital Express 3 – M15 (S1X-3) on a sounding rocket from Esrange Space Center in northern Sweden. S1X-3 outnumbered every earlier SSC mission in terms of experiments. In total 11 different rideshare items - scientific and technological experiments – were hosted in the payload and made SubOrbital Express a true international mission.

Approximately 80% of the payload consisted of the ESA-funded Experiments ARLES-II, CHIP and Neurobeta, and the ESA-funded re-entry experiment Mini-IRENE by the Italian CIRA. The remaining payload capacity provided the same professional experimenting conditions for small-sized experiments by the means of the SSC-developed Shared Module.

S1X-3 utilised the payload capacity to the rim and proofed the acceptance of the ride-share concept by the international science community. The payloads came from three continents and nine countries: Australia, Costa Rica, Italy, Portugal, Belgium, Germany, Switzerland, Liechtenstein and Sweden with researchers from many more countries around the globe.

This paper will describe the challenges of this unique mission as well as the operational outcome.

The mission has been followed by a professional film team leading to a breathtaking documentary published on AmazonPrime and Youtube under the title: Microgravity – How Earth benefits from Space.

[A-47]

MODERNISING THE SOUNDING ROCKET RESEARCH PLATFORM – MORABA ACTIVITIES IN RETROSPECT

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Sounding rockets continue to form a cornerstone of flight-testing capabilities in Europe. They support research areas such as microgravity, aerothermodynamics, atmospheric physics, technology demonstration and astronomy. DLR's Mobile Rocket Base (MORABA) develops and utilizes technologies in medium and large sized sounding rocket vehicles in order to secure the testing and experimentation capabilities for the established research fields. The continuous extension of the performance and flight envelopes through improvements in flight hardware and subsystems of the vehicle, along with thermal protection systems, as well as the development and procurement of new solid propellant rocket motors, allow the advancement of sounding rockets into new experiment classes. Mission and mission operations design is becoming an increasingly important aspect to address requirements extending the existing range of experimental conditions.

We report on important milestones in developments of systems and subsystems for sounding rocket platforms of the recent two years. These include the results of the STORT mission, the first three stage rocket since more than 20 years for MORABA. The Red Kite qualification static firings at Esrange as well as the test flight from Andøya are significant highlights. First operational results from the MAPHEUS 14 mission of the Red Kite motor in a two-stage configuration will be discussed together with the renewed usage of the Black Brant V rocket motor. The improved flight-performance measurements lead to updates of performance predictions for microgravity and hypersonic missions with those vehicles. Further, mission preparations for remote locations and the resulting new opportunities are highlighted. The development status for supersonic parachute recovery systems will be provided and future plans for service modules, communication strategies and tracking of scientific payloads are presented for discussion and technical exchange.

[A-101]

BROR, ORIGIN & SYSTER – UPDATES ON THE SUCCESS OF THE NATIONAL PROGRAM FOR BALLOONS AND SOUNDING ROCKETS FROM ESRANGE

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The Swedish national programme for balloons and rockets, instituted by the Swedish National Space Agency (SNSA), is a great opportunity for Swedish scientist to do research using sounding rockets or stratospheric balloons from Esrange as platforms for their research missions. The initiative also offers great opportunities for internationally collaborations which has been important for the success of the programme so far.

Five sounding rocket missions in plasma physics and atmospheric research as well as four balloon missions have been successfully completed within the programme to date. For the coming period, another two rocket missions are on-going, with a total or three rockets planned for launch from Esrange in 2025.

BROR (Barium Release Optical and Radio rocket experiment) was an exciting mission with a principal investigator from the Swedish Institute of Space Physics. For the first time in decades a vapor trace payload was launched on a sounding rocket from Esrange providing observation targets for numerous advanced ground based instrumentations. This scientific mission was done in collaborations with EISCAT as well as internationally with the Dept. of Physics & Astronomy, Clemson University, USA.

ORIGIN (Oxygen and its Role In Generating and Influencing Nightglow) is a sounding rocket mission for the Metrological Institute at Stockholm University (MISU) based on the same scientific platform developed for O-STATES in 2015. Instruments on-board are provided by MISU, KTH, IAP, and IRS. As in 2015, two consecutive launches with on-site refurbishment of a single payload between the two flight is baseline. Planned launch for early 2025.

SYSTER (Systematic Study of lower Thermosphere Energetics by a Rocket) a mission with the Space and Plasma physics department of KTH, Royal Institute of Technology. This mission is done in close international collaboration with the important multi institution COUSINS instrument package, funded by NASA and lead by CU-LASP US, as well as instruments from MISU, KTH, IRS, IAP and UC CA. Planned launch for November 2025.

This paper reports on activities within this programme. It reports on missions started or completed since the last report in 2022. The main topics being the successful BROR mission and upcoming ORIGIN and SYSTER missions, focusing on the related technical solutions and results.

[A-118]

TEXUS – READY FOR THE DIGITAL FUTURE

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In December 1977 the first TEXUS rocket was successfully launched from the Esrange Space Center in Sweden with the German Space Agency DLR as customer. It marked the beginning of the successful Sounding Rocket Program for research under microgravity conditions at Airbus. Until end of 2023 a total of 6 MiniTEXUS, 58 TEXUS and 9 MAXUS missions were flown for DLR Space Agency and the European Space Agency ESA under Airbus responsibility.

In 2022 and 2023 two TEXUS rockets with a total of seven experiments onboard were successfully flown for DLR and ESA. Seven more experiment modules developed and provided by Airbus are scheduled to fly on three missions in early 2024:

- TEXUS 59 with two experiments for ESA and one experiment for DLR,
- TEXUS 60 with two experiments for and one experiment for DLR/JAXA,
- Suborbital Express 4 / MASER 16 under responsibility of SSC with one experiment for ESA.

The payload composition of the TEXUS 57 and TEXUS 59 missions and the participation in the S1X-4/MASER 16 mission have been implemented by applying the “flight ticket approach” jointly with our partner, the Swedish Space Corporation SSC. Together we offer the provision of an experiment module together with the share of the required services for the launch and mission to the customers. It is our obligation to determine the best suitable payload configuration based on the customers’ programmatic demands and experiment requirements from the science teams.

The presentation will provide an overview of recent and future missions and the experiments flown onboard. Today an established feature on all TEXUS missions is the “Ethernet for TEXUS (E4T)” which paved the way to new services which will be highlighted. Another new development is the TEXUS cloud service which will be fully accessible for the TEXUS 59/60 double campaign, scheduled for January 2024. Scientists can access their experiment data during the integration and test phase and especially during the microgravity flight from anywhere in the world via an internet connection.

[A-134]

SUBORBITAL EXPRESS 4 – M16 – THE NEXT INTERNATIONAL SOUNDING ROCKET RIDE-SHARE MISSION

Stefan Krämer[1], Gunnar Florin[1], Alf Vaernéus[1], Christian Lockowandt[1], Jianning Li[1], Jimmy Thorstenson[1], Christos Tolis[1], Cesare Vesco[1], Andreas Schütte[2], Krister Sjölander[1]

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In 2021 SSC signed the contract with ESA for development and flight implementation of the second batch of the E3P Period 2 funded microgravity experiments JACKS, T-REX, micACTin, NeuroBeta and LiFiCo together with the partner Airbus. The experiments were allocated to 3 separate missions: TEXUS 59 and SubOrbital Express 3 and 4 with the scientific merit and the optimal utilization of the sounding rocket vehicle payload capacity.

The last mission for implementation is the SubOrbital Express 4 by SSC. It will host the experiments JACKS (developed by AIRBUS), micACTin and LiFiCo (developed by SSC). Furthermore, S1X-4 provides also the flight implementation under DLR funding of the German/Japanese experiment DUST-II developed by JAXA and Hokkaido University.

Again, the SubOrbital Express program shows the broad appreciation of the rideshare approach on microgravity sounding rocket missions by the space agencies and scientific community.

This paper will provide an outline of the mission composition, the experiments and potentially the first operational results of the flight, scheduled for spring 2024.

PHYSICAL SCIENCES 1

TUESDAY 21 MAY, AFTERNOON SESSION – PART 1

ROOM 1

CHAIR: A. PETERS

[A-186]

LESSONS LEARNED FROM MAIUS-2: A DUAL SPECIES ATOM INTERFEROMETER PAYLOAD

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(6) Simulation and Software Technology, German Aerospace Center Brunswick
(7) Institute of Laser Physics, Universität Hamburg
(8) Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin
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In 2017 the MAIUS-A experiment demonstrated the first Bose-Einstein Condensates and Atom Interferometry in Space. Moreover this was the first time the experiments in the challenging environment aboard a two-staged VSB30 sounding rocket. While MAIUS-A used Rubidium 87 atoms, the successor payload MAIUS-B was designed to handle mixtures of Rubidium 87 and Potassium 41 atoms.

This paper gives a short summary of the scientific payload design accommodating all necessary instruments for dual species operation and performed on-ground verification and tests. Furthermore it introduces the scientific program for the first out of two planned flights. This program comprises re-capture experiments of atoms in a magneto-optical trap during the boost phase of the rocket and experiments to investigate dual species mixtures in microgravity.

In the main part of this paper the performance during the flight and in particular the cause for a malfunction prohibiting potassium experiments is discussed. As part of this discussion the environmental conditions as hull and air pressure and air temperatures of the scientific payload during the flight will be evaluated. Furthermore important lessons learned from this unique mission are presented and the impact on similar experiments is addressed. The paper closes with an outlook to the future use of this payload.

[A-159]

GENERATION OF QUANTUM MATTER IN SPACE – EXPERIMENTAL RESULTS OF THE MAIUS-2 MISSION

JONAS BÖHM[1], BAPTIST PIEST[1], PRIYANKA LAKSHMI GUGGILAM[1], THIJS WENDRICH[1], ALEXANDROS PAPAKONSTANTINOU[1], MICHAEL ELSEN[2], JENS GROßE[2], KLAUS DÖRINGSHOFF[3], ANDRÉ WENZLAWSKI[4], ERNST M. RASEL[1], AND THE MAIUS-TEAM[5]

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(5) The MAIUS project is a collaboration of LU Hannover, HU Berlin, FBH Berlin, JGU Mainz and ZARM at U Bremen. It is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WP1435.

Precision measurements play a key role for progress in both applied and fundamental sciences. As a quantum sensing method, atom interferometry (AI) emerges as a promising complement to classical methods such as light interferometers. AI can not only enhance the sensitivity of a measurement but also enables exploration into quantities and theories influenced by gravity, e.g. for testing the universality of free fall, the detection of dark energy or determining the gravitational constant.

Conducting such experiments in microgravity settings, such as on a sounding rocket or orbital platforms, holds immense interest. This is because the sensitivity of these interferometers correlates with their duration, a factor constrained by gravity on the ground. Additionally, Bose-Einstein condensates (BECs) derived from cold atoms present an optimal foundation for prolonged atom interferometers in microgravity due to their inherent physical characteristics.

Efforts to implement atom interferometers on microgravity platforms were pursued through miniaturized BEC experiments within the QUANTUS (Quantengase unter Schwerelosigkeit - Quantum Gases in Microgravity) consortium. The MAIUS-1 (Matter-Wave Interferometry under Microgravity) sounding rocket mission, a part of this collaboration, achieved a milestone by demonstrating the creation of a BEC and matter wave interferences in space [1, 2]. Building upon this success, the subsequent mission MAIUS-2 expanded the setup by introducing another atomic species to generate Rb-87 and K-41 BECs aboard a sounding rocket. This progression contributes to the implementation and operation of dual-species interferometers on satellites or space stations, such as CAL (Cold Atom Laboratory) [3] and BECCAL (Bose-Einstein Condensate and Cold Atom Laboratory).

This presentation details the experiments and their outcomes conducted during the MAIUS-2 sounding rocket flight. This encompassed magnetic trapping of Rb-87 atoms and subsequent microwave evaporative cooling to the phase transition from a thermal ensemble to a Bose-Einstein condensate. The experiments were executed within a compact, robust, and autonomously operating setup designed to meet the demands of generating Rb-87 and K-41 BECs with high repetition rates aboard a VSB-30 vehicle.

[1] D. Becker et al., Nature 562, 391-395 (2018).
[2] M. D. Lachmann et al., Nature Communications 12, 1317 (2021).
[3] Elliott, E.R. et al., Nature 623, 502–508 (2023).

[A-128]

SOUNDING ROCKET EXPERIMENT PARAMETER OPTIMISATION UTILIZING THE DROP TOWER FACILITIES

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An experiment to be flown on a sounding rocket mission is usually designed in a way that it operates autonomously throughout the flight. Uplink commands can be used to adjust experiment parameters, but this requires a fast and secure evaluation of the monitored data by the science team and clear decisions including certain risks.

To being able to define initial experimental parameters or to verify the correct function of processes and subsystems, thorough and extensive ground-testing is being performed before the systems are ready for flight.

Nevertheless, many initial parameters and experiment starting conditions are already influenced or even depending on the microgravity environment. A secure verification of the functions is impossible under laboratory conditions.

Through the years 2022 and 2023, SSC performed two successful drop tower campaigns at the facilities of ZARM within the development phases of the CHIP and LiFiCo experiments und ESA contract. The experiment parameters defined by the science teams could be verified, adjusted and thoroughly tested on the experiment breadboard hardware using the drop- and catapult modes of the drop tower as well as the high repetition rate of the new GTB-Pro.

This paper discusses the approach of utilizing the Drop Tower facilities for parameter optimization and presents the positive impact of early testing under relevant environment on the examples of the CHIP and LiFiCo experiments.

[A-130]

CHIP – THE IMPOSSIBLE EXPERIMENT

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At the beginning stands an idea to conduct an experiment under microgravity conditions investigating the influence of electric charges on particles in the process of planet formation by a science team of the University Duisburg-Essen, selected by ESA and funded within the E3P program in 2020. SSC was contracted to design, built, and fly the experiment on one of the available sounding rocket ride-share missions.

Throughout the requirements definition it became more and more clear that the experiment is demanding an environment which is in strong contrast to the definition of a microgravity mission: Commanded excitation of the particles by vibrations throughout the 6 minutes of undisturbed experimenting phase.

It turned out that the technical solutions had to be highly advanced and complex to host the CHIP experiment on a regular microgravity sounding rocket mission without jeopardizing the µg environment for all the other experiments on board. With this in mind the design of a 3-stage damping, and isolation system started.

Concluding, the affords lead to an successful experiment and mission. The CHIP science team was able to freely reinitiate and control the experiment parameters throughout specific phases of the flight. The repetitive sequences of vibrations were isolated to the highest extent possible and allowed the remaining experiments to perform undisturbed.

This paper will evaluate the technical challenges during the design phase and the specific solutions having been developed for CHIP. Furthermore, it discusses the operational result of the flight on SSC´s SubOrbital Express 3 M15 in November 2022.

[A-22]

THIN LIQUID FILM COATING AND DRYING UNDER MICROGRAVITY CONDITIONS (LIFICO) NEED OF SOUNDING ROCKET EXPERIMENTS: WET CHEMISTRY DEPOSITION

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The LiFiCo project is part of a multi-disciplinary research programme, part of the prioritised research area *Materials Research* at Karlstad University, in which scientists from different fields, e.g., chemistry, materials physics, and modelling, develop projects in the field of molecular interactions under normal and microgravity conditions. The project aims primarily at a better fundamental understanding and a better control of the molecular interactions yielding the structures found in the molecular blend thin films making up the active layer of an organic solar cell. The evaporation of the solvent during drying causes a fast-developing concentration gradient, eventually leading to an evolving phase separation. Due to the fast solvent evaporation, the phase separation process is arrested before it reaches completion. This partial phase separation will result in a specific film structure, the film morphology. It is of both fundamental and applied interest to be able to control and manipulate the film morphology, as well as developing means of performing wet chemistry preparations under microgravity conditions.

In the case of an organic solar cell, the deposited solution contains donor, acceptor, and sometimes additional compounds, and the active layer morphology is shown to be decisive for the device performance. It is known that the kinetics of phase separation is slowed down under microgravity conditions, while the evaporation kinetics remain unchanged. Microgravity conditions, hence, make it possible to follow the initial stages of the morphology formation in closer detail. By applying microgravity conditions in preparations during parabolic flights, we have already found differences in morphology related to the slower phase separation, but also that the short time-span of microgravity under these conditions is not enough to ensure complete drying. To ensure that the whole drying process is performed under microgravity conditions, we need to perform the process during sounding rocket experiments.

To make it possible to realise the deposition of the solution containing donor and acceptor, a new experimental unit was developed in collaboration with ESA and the Swedish Space Corporation. This equipment, relaying on flow-coating onto a glass substrate, makes it possible to create a gravitational field aligned with the experiment cell. This field is necessary during the flow-in and flow-out of the solution, in order to create a direction for the liquid flow. The equipment is presented in contribution A-52.

The new experimental equipment's functionality was tested in October 2023 with drop-tower experiments at ZARM in Bremen. These experiments showed that the experimental set-up works as predicted and also yielded valuable information on flow-patterns and wetting phenomena.

The LiFiCo project is to be part of the sounding rocket mission Suborbital Express 4-M16, scheduled for launch at Esrange in the asutumn 2024. In this contribution we will summarise the results from the preceding parabolic flight campaigns (70th and 78th ESA Parabolic Flight Campaigns), and the conclusions from the drop-tower experiments at ZARM.

[A-105]

IMPACT OF GRAVITY ON CONSTRUCTION MATERIALS

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Construction materials are essential for the future exploration of the solar system as well as in their impact on the climate where traditional building materials like concrete consume a significant fraction of the CO_2 budget of the world. Investigations in microgravity or reduced gravity can help clarify the mechanisms at play during the solidification of binder-based materials. After a number of earlier attempts, two such sets of experiments have been conducted successfully on board the International Space Station ISS recently: The NASA project MICS (Microgravity Investigation of Cement Solidification) focused on the behaviour of cement as the essential binder with the crew-operated experiments conducted in simple pouches. On the European side, project MASON (Material Science on Solidification of Concrete) introduced a concrete mixer, also to be handled by the crew, which allows for the production of samples of a well-defined shape.

Results from the MASON experiments shall be reported as well as a review shall be given about the overall state of knowledge from microgravity investigations of binder-based construction materials. Most obvious differences between experiments conducted in 0g versus 1g include typically higher porosities for the 0g-samples as well as a mostly homogeneous distribution of the pores inside the material. In terms of mechanical strength, up to 20% higher Young's moduli can be found in early measurements of some ISS samples. In addition to those macroscopic effects, the microstructure of cement and concrete is expected to develop differently in space and on Earth motivating detailed studies of the resulting materials.

In order to elucidate further the physical mechanims in building materials, processes at various time scales shall be discussed from the scale in parabolic flight campaigns or drop towers all the way to space stations with sounding rockets in between. For all those platforms, benefits from experiments in 0g and 1/6g shall be addressed for both binder-based materials as well as for similar processes during sintering of materials. Future experiments on either method of solidification or even combinations thereof shall be presented as a conclusion.

ROCKETS & BALLOONS IN SPACE EDUCATION 2

TUESDAY 21 MAY, AFTERNOON SESSION – PART 1

ROOM 2

CHAIR: T. GANSMOE

[A-129]

FUNDING A STUDENT ASSOCIATION THROUGH A CONTINUAL HIGH-ALTITUDE BALLOON PROGRAM

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KSat e.V. is a student association at the University of Stuttgart, with currently over 150 active members. It enables students to participate in space related projects and gain valuable knowledge in the sector. KSat acts as an administrative entity to four space projects: Two REXUS high altitude rocket experiments (FerrAS and FINIX), a three unit CubeSat (SOURCE) in cooperation with the Institute for Space Systems at the University of Stuttgart (IRS) and the titular high altitude balloon BUBBLE.

The financial needs for the REXUS projects and SOURCE are met by REXUS and ESA's 'Fly your Satellite!'-program respectively, while BUBBLE is funded by the KSat itself. During the early launches of the BUBBLE program, it became apparent that through efficient and careful planning the launches as paid for by the Institute for Space Systems could not only cover the expenses but yield a net profit that at the time was reinvested into project development. Thus, the idea of BUBBLE as a service emerged. So far, most payloads flown on BUBBLE were provided by research institutes friendly to KSat and other student associations, but extending into a commercial market would not only make testing opportunities more accessible to industry and researchers alike, but also provide funds to benefit the program itself as well as an overarching student society.

This paper draws from eight previous light high-altitude balloon launches financed by a student association and entirely executed by its members, analyzes the cost of hardware, operations, administration and insurance and studies the feasibility of a – in the context of the balloon program itself – for-profit operation of a high-altitude balloon to fund a non-profit organization that benefits the education and training of the next generation of engineers in space and stratospheric research.

[A-170]

TESTING ALGINATE AND MONTMORILLONITE NANOCOMPOSITE FOAM AS A THERMAL PROTECTION SYSTEM FOR SOUNDING ROCKETS: THE SHEAR PROJECT ON REXUS 32

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The SHEAR project is an exciting venture that has attracted the attention of scientists, engineers, and students alike. Developed by the Delft Aerospace Rocket Engineering (DARE) student society, this project aims to test the suitability of alginate and montmorillonite nanocomposite foam as a thermal protection system for sounding rockets. The project is built on prior ground testing, which has shown that the material is capable of withstanding high thermal loads. However, to truly prove the viability of the material for use in flight conditions, it is necessary to gather data during flight. By integrating five samples of the novel composite foam into a sounding rocket, SHEAR will gather temperature data during flight to increase the technology readiness level of the upgraded heat shield. The post-flight analysis of the collected data will provide valuable insight into the usability of this material as a heat shield. The data will be compared with on-ground tests and simulations, allowing the assessment of the material's performance under actual flight conditions.

The SHEAR project is set to take place aboard the REXUS 32 rocket as part of the German-Swedish programme REXUS/BEXUS which allows students from universities and higher education colleges across Europe to carry out scientific and technological experiments. Prior to the scheduled launch in March 2024, SHEAR will undergo extensive design reviews and numerous acceptance-level testing. These tests are necessary to ensure that the experiment is safe, reliable, and capable of achieving its goals. The ultimate aim of the SHEAR project is to expand the flight envelope of existing and future DARE sounding rockets. If successful, this project could pave the way for the use of alginate and montmorillonite nanocomposite foam as a thermal protection system for a wide range of space exploration missions. The knowledge gained from this project could also have implications for other areas of materials science and engineering.

The focus of this paper is on the main phases of the SHEAR experiment. Firstly, the requirements compiled from the mission objectives are presented. Following from this, the design considerations taken through a careful selection of experiment configurations and manufacturing methodologies are outlined. The experiment is then tested in the CubeSat Support Facility and the results are used to help in verifying and validating the design. Lastly, this cycle is iterated until all requirements are sufficiently fulfilled with a proper margin of safety, which will ensure that the final design is fail-safe and suitable for the required application.

[A-100]

REXUS30–IMFEX: LUNAR REGOLITH FIBER PRODUCTION FEASIBILITY STUDY ONBOARD A SOUNDING ROCKET

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As space agencies around the globe are increasingly interested in establishing a permanent lunar base, large-scale missions may massively benefit from In–Situ Resource Utilization (ISRU) practices to produce various goods on the lunar surface, therefore reducing the number of required launches.

Under the REXUS/BEXUS program, a student team designed, built, tested and performed an experiment called IMFEX (ISRU MoonFibre Experiment) capable of producing fibers under microgravity and at terrestrial gravity using a lunar soil simulant as a base material. In March 2023, the IMFEX project successfully demonstrated the production of endless fibers from lunar regolith (ISRU) in microgravity on a sounding rocket launch. These fibers may provide an excellent choice for reinforcing lunar habitats and serve as hydroponic substrates, filter and insulation materials.

The technologies used to melt lunar regolith simulants and create continuous, thermally equilibrated fibers, automate and supervise this process are elaborated in detail. In order to evaluate the influence of gravity on fiber quality during the fiber formation phase, the fibers produced under microgravity are compared with those produced under terrestrial gravity. To predict the process performance under lunar gravity, the fiber properties are then interpolated based on comprehensive material characterization (Scanning Electron Microscopy, Energy Dispersive X-Ray, X-Ray Diffraction).

[A-175]

RESULTS OF THE CARBON REINFORCED ADDITIVE MANUFACTURING TECHNOLOGY EXPERIMENT ON BOARD REXUS 31

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The application of continuous fibres in composites enables the production of materials with improved material properties. An ongoing area of research is the production of fibre-reinforced composites through additive manufacturing. Recent studies have shown that during the in-situ impregnation process, voids can form at the fibre-matrix interface. This is disadvantageous as materials with higher void fraction have poorer material properties, including reduced tensile strength. Manufacturing under microgravity could potentially influence the void fraction. When in a molten state, the used polylactide acid (PLA) filament behaves like a non-Newtonian fluid, thus showing increased wettability in microgravity. This could potentially result in a better impregnation of the fibre.

The aim of the Carbon REinforced Additive manufacturing Technology Experiment (CREATE) is to gain an improved understanding about the influence of gravity on fibre-matrix impregnation in additive manufacturing of fibre composites. In the experiment, PLA is co-extruded with a continuous carbon fibre bundle during flight on a sounding rocket. In order to exclusively investigate the gravitational influence, the experiment is carried out within a sealed module at 1 atmosphere, maintaining all variables other than gravity similar to manufacturing conditions on Earth. Key parameters such as nozzle temperature as well as ambient pressure and temperature are recorded and stored. Additionally, thermal and HD images of the extrusion process are taken. The experiment is conducted under both Earth gravity and microgravity conditions to allow a comparative analysis of the results. A REXUS sounding rocket is utilized to achieve the microgravity environment. The launch of REXUS 31 is scheduled for March 2024.

In the evaluation, the samples are examined microscopically and mechanical properties like tensile strength are measured. A comparison with the samples produced on ground at 1 g shows the influence of gravity on the fibre-matrix impregnation and the material properties.

Atmospheric Physics & Chemistry 2

Tuesday 21 May, Afternoon session – part 1

Room 3

Chair: F.J. Lübken

[A-167]

PREPARATION FOR THE COLLECTION AND ANALYSIS OF MESOSPHERIC DUST WITH THE MXD2 ROCKET CAMPAIGN

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To prepare for the MXD2 rocket campaign that is planned for launch in summer 2025 from Andøya, North Norway, we prepare the analyses of mesospheric dust samples. We investigated the aerodynamic conditions at the MESS sample collector instrument and simulated the dust entry conditions for different dust sizes, rocket velocities and altitudes. We find that the particles are slowed down in the instrument which makes it more likely that they stick to the collection surface. This deceleration however heats up the particles and we estimate these temperatures. We investigated the analysis of collected samples using analogue samples that were produced in the laboratory. The dust was deposited on standard TEM grids consisting of a metal mesh and a film on top. In laboratory studies with standard and advanced TEM we could investigate the size distribution of particles and infer information on the material composition without destroying the samples. Further analysis techniques may provide more composition information, however on the cost of destroying the samples.

[A-176]

SMALL-SCALE FLUCTUATIONS IN ELECTRON DENSITY OF THE TURBULENT LOWER IONOSPHERE

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Neutral gas motions have an essential effect on dynamics and structure of the lower ionosphere. In particular, neutral gas turbulence can produce fluctuations in the electron density of ionosphere below turbopause level (100-120 km). Because of strong collisional damping at levels of the lower ionosphere not always theory of plasma instabilities can be used to explain the generation of fluctuations in electron density. In this report we discuss small-scale electron-density fluctuations resulted from turbulent mixing of the gas in the lower ionosphere. The length-scales of fluctuations were restricted to the inertial range of turbulence and were smaller than the local scale of mean plasma-density gradient. We considered the spectra of plasma fluctuations expected from measurements during rocket experiments and their dependence on the intensity of turbulence. The consideration was based on the analytic expression for the 3D spectrum of fluctuations induced by neutral turbulence in the ionosphere. The derivation of this expression from three-fluid equations and the use of statistical theory of turbulence is briefly described in the report. It was taken into account that spectrum of random velocity field of gas obeys the power law of Kolmogorov turbulence. The expression gave opportunity to write a formula for evaluation of the rms level of electron-density fluctuations in the given wave-number range. Variability of the 1D spectra expected from experiments was analysed for an irregularity layer in the altitude range 95-105 km under intensification of turbulent mixing. It was shown that the enhancement of turbulence results in the rise of the rms fluctuation level and in decrease in the slope of the 1D spectrum of fluctuations.

[A-160]

SYSTER SOUNDING ROCKET

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The Systematic Study of lower Thermosphere Energetics by a Rocket (SYSTER) experiment is a multi-payload sounding rocket study of Joule heating in the auroral region, to address the following questions: (i) What is the altitude distribution of Joule heating in the evening sector of the auroral zone? (ii) How well do different estimates of Joule heating agree with each other, and what are the sources of any discrepancies? (iii) What is the contribution of small scale structuring in plasma, currents and electric fields to the energetics of the lower thermosphere? SYSTER will use a suite of instruments to simultaneously measure electric and magnetic fields, plasma parameters, auroral electron and energetic electron precipitation, neutral gas density, temperature and winds, ion drifts. The SYSTER sounding rocket is planned to be launched in the autumn of 2025.
The presentation will describe the instrument payload and the closure of science objectives.

[A-116]

SOUNDING ROCKET MISSION DEFINE

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A new sounding rocket mission DEFINE (Density Field in the MLT: Neutrals, Electrons, and trace gases. Radiative and dynamical balance) was initiated by IAP and funded by the Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag (DLR grant 50OE2301). The aim of the DEFINE project is to quantify the density field of the mesosphere and lower thermosphere (MLT) by means of high-precision in-situ measurements. The concentration of neutral gas, electrons, ions, and atomic oxygen in the lower thermosphere (up to about ~160 km) is to be measured simultaneously with high precision for the first time. Simultaneous measurements of densities and temperature will significantly improve our understanding of energy balance and composition in this region. The combination of these measurements with observations of Airglow will enable a quantification of the radiation and chemical contributions to the energy budget.

The DEFINE rocket campaign is to be conducted in early 2025 at the Andøya Space in close coordination with the Swedish ORIGIN mission which will be conducted at ESRANGE at the same time. Such simultaneous salvo in northern Scandinavia from the places separated by about 250 km, will ensure coverage of observing gravity waves along their propagation. From the ground-based observations by lidar, radar, and Airglowin Andenes, Kiruna and Skibotn, horizontal extents of gravity waves parameters can be derived. The horizontal variability of the Airglow (i.e., corresponding photochemical processes) will also be investigated for the first time with high-precision measurements. By simultaneously launching similarly equipped payloads from Norwegian and Swedish rocket ranges, it will also be possible for the first time worldwide to measure the observed structures in their horizontal distribution over a distance of about 250 km. This will allow us to clarify the role of such horizontal structures in the atmospheric system and assess their importance for atmospheric (in particular climate) models.

In this paper we present the scientific concept, instrumentation, and discuss challenges in realization of such highly ambitious goals.

[A-94]

ADVANCING IN-SITU MEASUREMENTS OF ATOMIC OXYGEN IN THE ATMOSPHERE: THE FIPEX INSTRUMENT

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Quantification of atomic oxygen (AOX) is of utmost importance within atmospheric research as it affects numerous research fields, from the investigation of space weather to the monitoring of corrosive effects on functional surfaces. In the past 12 years, the High Enthalpy Flow Diagnostics Group (HEFDiG) at the Institute of Space Systems (IRS) has been developing solid electrolyte sensors (FIPEX) for the measurement of AOX fluxes and number densities aboard sounding rockets. Since then, FIPEX was successfully flown on several flight campaigns, most recently on PMWE.

The FIPEX instrument is a solid electrolyte sensor in an amperometric mode of operation that is designed to selectively measure AOX over several orders of magnitude. It is small, lightweight and has a very low power consumption which allows for an instrumentation that consists of multiple sensors on a single payload providing both redundancy and comparability. FIPEX sensors are subject to continuous developments mainly focusing on faster response times. This is of particular interest for measurements in fast changing environments, e.g. aboard sounding rockets, since it contributes directly to the accuracy of the measurement.

Recently, a new manufacturing method for the sensor electrodes was established. The resulting FIPEX sensors have porous thin-film electrodes and were demonstrated on the PMWE mission where they provided superior data in terms of accuracy and coverage. Since then, further development allowed to control the electrode porosity which was found to be the main driver for the response times of FIPEX.

This paper focuses on the assessment to quantify the response times and investigate the transient processes behind them. The step response of FIPEX for a change in AOX particle flux is investigated for the first time. For this, the sensors are exposed to a particle beam at fluxes similar to what is experienced aboard sounding rockets. A camera shutter with an opening time of roughly 10ms is mounted in front of the sensor. By opening and closing, it blocks and releases the beam periodically which equals distinct steps in the AOX flux. Several sensor surfaces are compared to assess the potential influence of the electrodes on the transient behaviour. The goal is to define optimal electrode parameters for the application in atmospheric research balancing fast response times versus signal stability and signal-to-noise level.

As part of the upcoming DEFINE and ORIGIN missions, FIPEX will provide AOX measurements on all payloads. This paper contributes to the preparation of both the payload hardware and the accuracy estimation for the evaluation of the atmospheric data.

PICO Posters Sessions

Tuesday 21 May, Afternoon session – part 2

Room 1

Chair: A. Frenea-Schmidt

Physical Sciences

[A-27]

UNDERSTANDING PHASE SEPARATION IN THIN FILMS UNDER MICROGRAVITY FOR SOLAR CELL APPLICATION.

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Solution-processed polymer organic photovoltaic devices have gained serious attention during the last decade and is one of the leading low-cost next generation photovoltaic technologies. The active layer of a polymer solar cell consists of a thin solid film of an electron donor blended with an electron acceptor. The morphology of the active layer is one of the important factors for the solar cell performance. To control the morphology, a fundamental understanding and control of the molecular interactions that contribute to the formation of structures within the molecular blend thin films is needed. The rapid evaporation of the solvent during the drying process induces a swiftly developing concentration gradient, ultimately leading to an ongoing phase separation in the film morphology.

In this work, we aim to use microgravity conditions to study the slowed down phase separation kinetics. Under microgravity conditions, it becomes feasible to observe the initial stages of morphology formation.

We have already seen differences when thin films were prepared under microgravity conditions under parabolic flights. Slower phase separation was seen for film prepared under microgravity as compared for films prepared under 1g. But also due to the short time span of 0 g and hyper-gravity phase it was challenging to ensure that the films completely dried under 0 g. In order to guarantee that the entire drying process occurs under microgravity conditions, it is necessary to perform the fabrication process during sounding rocket experiments. This will give us a longer microgravity stage, and therefore a deeper understanding of the morphology formation and phase separation at a molecular level. These experiments will be performed in the next rocket campaign with ESA.

Physical Sciences

[A-60]

MOLECULAR AND FUNCTIONAL IMPLICATIONS OF MICROGRAVITY ON HUMAN AND MOUSE NEURAL STEM CELLS

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Space travel resembles exceptional physiological stress on the human body. Differences in gravity can cause numerous pathophysiological conditions. It is, fundamental to understand better the implications of microgravity (µg) on a cell-morphological level before thinking about future long-term space travel.

The disease, Type-1 Diabetes, can be characterized by the destruction of endocrine pancreatic Beta cells. Consequently, Insulin production gets impaired, and Glucose homeostasis deteriorates. Boundary cap neural crest stem cells (BC) are a transient type of pluripotent stem cells during neural development that can differentiate into glia and neurons. BC have been shown to enhance grafts' Beta cell function, proliferation, and cell mass when cotransplanted with pancreatic islets in mice or cocultured in-vitro.

Aboard the MASER14 sounding rocket, BC were subjected to short-term microgravity and compared to controls that stayed on Earth and simulated microgravity. Space-BC showed clear morphological alterations after the short space flight, such as increased proliferation capacity and vast gene expression changes. Specialized experimental hardware aboard the MASER15 rocket allowed the discern between actual spaceflight conditions and simulated regular gravity onboard centrifuge and further investigate our previous findings and the potential synergy between µg and BC for Pancreatic Islets and Beta cells.

Remarkably, BC proliferation was increased in cells from the MASER14 trip compared to the control. The effect was even more pronounced in cells aboard the MASER15 compared to all other groups. Space BC exosomes showed changes in gene transcripts involved in cell-cycle control and, the only upreultated gene transcripts was a transcription factor associated with cell pluripotency and neuronal fate. Microgravity positively affected the survival and mitochondrial function in Beta cells as determined through fluorescence-activated cell sorting compared to the onboard 1g reference group.

Our findings highlight a potential beneficial effect of microgravity on cells albeit the widely established systemic negative impact on tissues and the human body in general. Interestingly, some effects appeared later, and other features showed immediate effects that eventually subsided after some time, thus suggesting the relevance of the time profile. Our findings outline a holistic view of the potential beneficial implication of microgravity on stem cells' molecular and functional properties.

Physical Sciences

[A-126]

THE MAIUS-B LASER SYSTEM

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The first production of a Bose-Einstein condensate in space during the MAIUS-1 sounding rocket mission in January 2017 heralded a new era of scientific exploration. The achievement laid the foundation for more advanced experiments with ultra-cold matter beyond Earth's atmosphere.

The MAIUS-2 mission aimed to take it a step further by creating mixtures of ultracold rubidium and potassium atoms directly on a sounding rocket. Using high-altitude flight, the apparatus sought to investigate the behavior of quantum mixtures in microgravity conditions. That endeavour not only provided a unique research opportunity but also aimed to demonstrate technology readiness for development of compact and robust platforms suitable for investigating quantum properties of mater in space.

To achieve this objective, an advanced laser system was developed. This system serves the dual purpose of providing the necessary light for laser cooling of both rubidium and potassium and enabling the detection of Bose-Einstein condensates. The system was launched as a part of the payload of the MAIUS-2 mission on the 2nd of December 2023.

We report here on the system’s performance, its assembly process, and employed technologies neccessary to assure that the system could face the demands of the mission.

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Physical Sciences

[A-151]

RESPONSE OF TARDIGRADES TO CONDITIONS AT HIGH ALTITUDE DURING SOUNDING ROCKET FLIGHT

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Research sounding rockets provide an unique opportunity to study adaptations of invertebrate animals to extreme conditions, by enabling their exposure to multiple severe stressors at the same time. This study demonstrates a successful framework for collaboration between teams with experience in flight experiment operations from student research group at Poznan University of Technology (PUT RocketLab) and space biology researchers during "The Spaceport America Cup-Intercollegiate Rocket Competition" in July 2023.

Organisms with the highest chance of survival in such harsh environments are called extremophiles. Tardigrades (water bears) are one of such group of microscopic animals, commonly used as models for astrobiological studies, due to their extreme abilities to cope with various environmental stresses. Thanks to their exceptional cryptobiotic capabilities, they have been recorded as enduring a wide variety of extreme conditions, including both high and low temperatures and pressures, various types of radiation, as well as exposure to various chemical compounds. The most common and well-studied form of cryptobiosis is anhydrobiosis, which allows tardigrades to survive without liquid water.

In this study we used eutardigrade species Paramacrobiotus experimentalis Kaczmarek, Mioduchowska, Poprawa & Roszkowska, 2020 from Madagascar. Specimens of this species were introduced into the state of anhydrobiosis, using the standard anhydrobiosis protocol. and loaded into the sounding rocket as biological payload. The presented data is made up of the results from two different groups: one equipped with a radiation shield and the other lacking it. This has allowed a comparison between specimens shielded from radiation and those fully exposed to it, experiencing radiation of a magnitude of 12 μSv/h. Aside from radiation, tardigrades were exposed to prevailing weather conditions (35°C, 780 hPa) during preparation to launch. The rocket experienced 9 G vertical acceleration, reaching a speed of Mach 1.55 and an altitude above 9 km in 42 seconds. Tardigrades in the warhead that was shot away from the rest of the rocket were subjected to a momentary acceleration of about 20 G before falling to the ground.

The obtained results showed that specimens from both experimental groups have generally survived the launch and were subsequently successfully recovered. These data indicate that tardigrades performed equally well in three control and two experimental groups i.e. in rocked and on Earth, while in the state of anhydrobiosis, further reinforcing their status as a suitable model organism for astrobiology research concerning extreme stressors.

[A-8]

CATS: EMPOWERING THE NEXT GENERATION OF ROCKET SCIENTISTS THROUGH EDUCATIONAL FLIGHT COMPUTERS

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The Symposium on European Rocket and Balloon Programmes and related Research serves as a vital platform for the exchange of knowledge and experiences in the field of aerospace research and education. Within this context, we present CATS, a swiss company specializing in the production of flight computers tailored for model sounding rockets. CATS aims to advance educational programs by providing students and educators with the tools to explore the fascinating world of rocketry, inspiring the next generation of scientists and engineers.

At the heart of CATS' mission is the commitment to advancing STEM education by making rocketry accessible to students of all ages and backgrounds. The company's flight computer offers a reliable and user-friendly solution for model sounding rockets, ensuring that learners can embark on exciting projects without the need for extensive technical expertise. These devices empower students to engage in hands-on learning, deepening knowledge in physics, engineering, and computer science.

CATS flight computers are designed to support various educational aspects, including:

Hands-On Learning: CATS flight computers provide a practical and user-friendly way for students to apply theoretical knowledge to real-world projects. By designing, building, and launching their own sounding rockets equipped with CATS flight computers, students gain valuable insights into the principles of aerodynamics, propulsion, and data analysis.

Data Collection and Analysis: The flight computers capture and transmit a wealth of data during a rocket's flight, enabling students to delve into the intricacies of data collection, analysis, and interpretation. This experience fosters skills in critical thinking and problem-solving.

Interdisciplinary Education: CATS' technology encourages interdisciplinary learning, bridging the gaps between physics, engineering, and computer science. Students gain a holistic perspective of how these subjects converge in aerospace engineering.

CATS is proud to be at the forefront of providing the tools necessary to nurture the aerospace leaders of tomorrow. By focusing on educational aspects and removing barriers to entry, CATS empowers educators to create inspiring and engaging rocketry programs that prepare students for the challenges and opportunities of the future. Along these efforts, CATS' flight computer was selected as the official logging and tracking solution for the European Rocketry Competition (EuRoC) 2023, providing our flight computer to over 20 university teams across Europe.

In this paper, we want to present the results from the rocket flights at EuRoC 2023, as well as our open source hard- and software and showing how our flight computer can be used as an educational tool.

[A-15]

BALLOON'AASC3, ONE STEP CLOSER TO SPACE

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Sounding balloons, which can reach altitudes of up to 30km, are ideal for testing modules in extreme environments at pressures and temperatures close to those in space. This paper presents the realisation of a sounding balloon gondola set up to test modules present in the NanoNAASC CubeSat to be launched in 2025 by the Nouvelle-Aquitaine Academic Space Center (NAASC). The main aim is to use prototype payloads already designed by NAASC, but also to design certain devices from scratch, such as power and measurement boards. The aim of this article is to provide feedback and explain all the design stages up to the launch and analysis of the sounding balloon's results.

The team consists of around ten students, mainly from two engineering schools on the Bordeaux campus: ENSEIRB-MATMECA and ENSAM. This group of student engineers is supervised by a teaching team made up of research engineers and teacher-researchers. To carry out this project, we took over and adapted NanoNAASC payloads, designed a thermally viable nacelle for the electronics and designed the power supply, sensor cards and on-board computer in the same format as that of the nanosatellite, the PC104.

The project was divided into 6 main stages: concept and design, equipment production, integration, final testing, release and analysis of results. The main experiments include telecommunications modules: a location module supplied by CNES and another using LoRa technology for downlink communications, while a specific module, ELIoT, designed for the nanosatellite, is being tested for uplink communications. At the same time, a characterisation of the atmosphere is being carried out, involving measurements of temperature, pressure and UV radiation.

The sounding balloon was flown in May 2023. The project was a great success: the flight went off without a hitch with the help of people with the rights to launch a stratospheric balloon. We were then able to validate the operation of certain devices, such as our LoRa transmission module for sending the GPS coordinates of the gondola. In addition, we recovered temperature and pressure data consistent with that in the literature. Finally, we were able to confirm the effectiveness of our thermal system, which maintained a core temperature of around 20°C throughout the flight. This balloon is a significant milestone in the projects of the Nouvelle-Aquitaine Academic Space Center, paving the way for more advanced payload testing.

[A-39]

X- AND GAMMA RAY SPECTROSCOPY MEASUREMENTS ON THE 2019 AND 2022 HEMERA (HIGH LATITUDE) BALLOON FLIGHTS

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Hands-on space education projects have long been recognised as powerful tools for advanced learning, both in tertiary and in secondary education. For high school projects, the flight platform of choice is the weather balloon: very low-cost and highly flexible. These obvious advantages are partly offset by the limited flight duration (<3hrs) and payload capability (+/- 2,5kg). The mass constraint is usually a minor concern as most high-school space projects consist of little more than a sensor breakout board and a microcontroller unit, usually an Arduino variant or one of the RaspberryPi versions. There are nonetheless experiments within reach of high-school students that could benefit from a somewhat larger payload capacity and/or prolonged flight duration.

One such instrument is the scintillation gamma spectrometer, which is a significant step up from the more often used counting radiation detectors (Geiger-Müller Counters or encapsulated photodiode / solid state detectors). In this type of gamma spectrometer a scintillation crystal – often NaI – captures hard X or soft gamma photons and converts (part of) their energy into visible light photons that are then counted using a photomultiplier tube to produce a measurable signal. As crystal size increases, so does the number of events per second, improving both spatial resolution during balloon ascent and overall stochastic significance of the measurements.

Such a gammaspectrometer was developed in the past and flown from both mid-latitude (Brussels, 51°N on Asgard-X in 2021) and high latitude (Esrange, 69°N on Hemera-2019) launch sites. The comparison between both datasets was reported in an earlier paper, showing that the Regener-Pfotzer maximum detected with Geiger Counters and solid state detectors was due to low-energy photons (X-rays) as the higher energy data failed to show any significant increase. Also, the lower energy events being by far the most numerous regardless of altitude, their occurence and variation would dominate the overall number of events at any given altitude.

After the 2021 flight over Belgium, the instrument was refurbished and reflown on the Hemera-2022 flight from Esrange in arctic Sweden. The thermal insulation of the NaI crystal was improved to mitigate the reported temperature dependent response of scintillation crystals. Indeed, during ascent the crystal would reach its lowest temperatures just when radiation levels reach peak intensity, i.e. between the tropopause and the altitude of the Regener-Pfotzer maximum. In this paper, the results of this reflight will be presented, discussed and compared to the 2019 data.

[A-40]

BUILDING A DETECTOR FOR STRATOSPHERIC THERMAL NEUTRONS WHILE IN HIGH SCHOOL

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The value of hands-on space education has led to a plethora of projects such as 'Rexus/Bexus', 'Fly your Satellite', 'Spin Your Thesis', 'Fly Your Thesis' and others, targeting students in tertiary education. For secondary education, the only commonly available flight platforms that offer access to near-space are weather balloons, such as those used in the 'Asgard balloons for space education' programme.

Most high school payloads use off-the-shelf sensor breakout boards and build the rest of the electronics and hardware around that. In this paper, an example of a clear breach from this traditional approach is presented, using a Boron-10 neutron detector tube as the sensor but having the design and development of all supporting electronics be the core challenge of the project.

The sun is a source of neutrons during solar events. With a half-life of +/-15 minutes and travelling at about 40% the speed of light, close to 70% of those neutrons decay before reaching Earth. For Mars, the travel time is longer and even more 'solar' neutrons will decay underway. For deep space sources, travel times rise again – this time by many orders of magnitude - and virtually all neutrons will undergo decay long before reaching the Solar System. Therefore, atmospheric neutrons (on Earth or Mars) either originate from the sun or are secondary particles formed in the atmosphere through what are known as atmospheric showers. Energy-rich particles of either solar or cosmic origin collide with the atmosphere, triggering an avalanche of secondary particles, including neutrons. This process dissipates the energy of the initial primary particle while multiplying the particle count until the energy is no longer sufficient to sustain the cascade, resulting in a decrease in particle count through absorption. This phenomenon gives rise to the Regener-Pfotzer maximum at an altitude of 18k-20km, on which our as well as other (student) teams have reported on several occasions in the past.

The challenges discussed in this paper include first and foremost technical issues involving the multi-kV voltage supply required by the tube to generate an electric field strong enough to produce a detectable voltage drop, the cutoff system and amplification circuits used to select voltage drops indicative of a neutron capture event. Calibration issues and neutron energy considerations will also be covered, as will – time permitting – a 'first results' report on data gathered during the Asgard-13 balloon flight over Brussels, scheduled for late April 2024.

[A-93]

GRAVITY ESTIMATION FROM LOW-COST IMUS ABOARD BEXUS 32

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The miniaturized multi-Sensor Box for spaceborne Geodetic Applications (SBGA) aimed to measure the vertical profile of Earth's gravity field and assess the applied instruments' performance. For this purpose, it is equipped with two low-cost IMUs, a magnetometer, a barometer and two GNSS receivers. During the ascent of the BEXUS 32 balloon to an altitude of 27.6 km, continuous data on the accelerations, rotational rates, and positions of the experiment box were recorded.

An extended Kalman filter is designed to integrate the recorded measurements. It estimates the position, non-gravitational accelerations as well as gravitational accelerations in the form of a state vector from which we eventually derive the gravity gradient. This shows the decreasing gravitational acceleration with increasing height during the ascent phase of the balloon's flight. The result is compared to the global XGM2019 gravity field model to validate the performance of the applied instruments and the developed algorithm. This is expected to provide valuable insight on the operation and capabilities of small, cost-effective sensor boxes for airborne gravimetry and CubeSat applications.

The key elements presented in the article show the mechanical and electrical design of the sensor box, the acquired measurements and the architecture of the implemented Kalman Filter along with the generated results.

[A-90]

PEREGRINUS: A HIGH SCHOOL BUILT MAGNETOMETER & RADIATION EXPERIMENT TO ORBIT EARTH ON ARIANE-6

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Hands-on space education programmes for high school students have always been few and far between, compounding inherent drawbacks that are not present – or to a far lesser degree – in tertiary education: the knowledge base the students possess is limited, as are the resources (both financial and knowledge-wise) high schools can muster. Student turnover is high and making sure crucial knowledge is passed on in time to cope is of paramount importance. Recurrent access to flight opportunities has however proven a powerful enabler for growth, both for individual students and for their schools as a whole. Ever more sophisticated instruments flying on ever more challenging flight platforms are possible when hands-on space education becomes part of a school's culture.

A prime example of this is 'Peregrinus': a cooperation between high schools (that had previously gained extensive experience with sounding balloons) to design and build an orbital mission to measure the Earth's magnetic field and the hard X/soft Gamma radiation levels in LEO (Low Earth Orbit). The project was proposed to ESA and Arianespace in response to their late 2021 Call for Proposals for experiments and/or smallsats to be flown on the maiden flight of Ariane-6. It was selected for this mission and will fly one-and-a-half orbit at 580km altitude with a 63° inclination, before burning up on re-entry as part of ESA's space debris mitigation policies.

Delays in Peregrinus' development as well as calendar shifts in the launcher development programme have forced the initial team of students working on mission and circuit design to pass the torch to a second team that, after building the hardware now has to see it through the different tests and prepare it for launch. Yet another team will be in charge of data processing and reporting once Peregrinus actually flies, which is currently scheduled for the summer of 2024.

In this paper, the mission concepts, circuit design challenges and their solutions, hardware production and test operations will be discussed, including thermal-vacuum tests, vibration testing and electromagnetic compatibility (EMC). Special attention will be given to those aspects of the project that have yielded insights and experience that could not previously be gained from the development of balloon-borne experiments, be they destined for weather balloons (as used in the 'Asgard balloons for space education' programme) or the big scientific ZPB's (Zero pressure balloons) as used in the European Hemera or the US's HASP balloon programmes.

[A-97]

THE DLR STERN PROJECT - ENHANCING STUDENTS' SKILLS WITH EXPERIMENTAL ROCKET SCIENCE

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With funding by the German Federal Ministry of Economic Affairs and Climate Action (BMWK) the DLR Space Agency provides German university students the opportunity to develop, build and launch their own rockets at Esrange Space Center in northern Sweden within a three-year timeframe. Designated as STERN program (German: "STudentische Experimental-RaketeN", Student Experimental Rockets) the main objective is to promote student interest in space through practical engagement within a structured project framework like in a real space program. In addition, the program aims to improve academic education related to launch vehicle design and propulsion systems.

The STERN program comprises a project life cycle for space missions that includes preliminary, critical, integration and acceptance reviews as well as a comprehensive integration workshop, a test campaign and the final launch campaign. The student teams prepare detailed technical documentation of their vehicle and subsystems for each major review and present their development progress in front of the review board.

During the first STERN cycle 460 students participated in five teams and launched a total of eight rockets. During this cycle, advancements were made in testing cutting-edge technologies and a new altitude record for hybrid rockets was set by students. In the subsequent STERN 2 cycle, additional student rocketry teams were supported. Despite extraordinary challenges in this phase, three rockets were launched by two teams and an innovative design of a sounding rocket was advanced. The altitude record was surpassed once again and even doubled.

This paper presents the STERN programme as an educational opportunity for students interested in space. It introduces the development and general progress that has been promoted and driven by the second STERN cycle. An overview is skecthed of the practical activities, technical achievements and the operational improvements over the years.

[A-143]

DESIGN OF A LOW COST AMATEUR TEST BENCH FOR MEASURING THRUST AND OTHER DATA OF SOLID ROCKET ENGINES

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When creating a custom solid rocket engine, it is important to test and measure different parameters such as thrust or chamber pressure to ensure that the engine is safe and performing as expected. LEEM UPM has designed an affordable, easy to build and powerful rocket engine "Test bench".

This Test Bench relays in a custom PCB and multiple economical sensors, like weight cell, a gas pressure transductor and many others to get as much information as possible. It possesses a powerful system and radiofrequency communication and has its own interface to monitor all the data gathering during testing, as well as redundant systems to ensure data safety. In order to increase its future capabilities, the bench employs multiple ports including SPI, I2C. It has other capabilities, like remote ignition, and safety protocols.

In order to deploy, it has just 3 parts: the bench box, the ground station and the interface. The interface connects to the bench using the ground station as intermediary. This free to download interface provides you with data saving, custom metadata for the testing and cell and chamber pressure graphs. It also calculates multiple useful parameters of the engine combustion, making the task much easier later.

It has been proved that this economic bench is a reliable device, using the measurements to improve the combustion stability. This affirmation is backed up by several testing times, using static and dynamic load tests to ensure its precision, and numerous solid engine testing, in particular, our "JULIAN" and "CONDE" homemade engines.

In conclusion, this budget "Bench" provides trustworthy feedback and a comfortable method to ignite engines and igniters while getting data, all helped by an interactive interface to run all the graphs and information. It is an indispensable tool.

[A-194]

TOTORO – TEST OBSERVATIONS OF TRANSIENT OBJECT AND RADIO ONBOARD BEXUS 33

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The TOTORO project aimed to design, build and launch a stratospheric balloon experiment dedicated to the registration of the natural emissions in Earth's atmosphere. Main area of interest was registration of Auroral Kilometric Radiation and their analysis, as well as the radio signatures of Transient Luminous Events. The signals (low-frequency radio emissions) were picked up by two different antennas - electrical and magnetic. Signals from both antennas were processed by two independent Software-Defined Radios.

Obtained data was saved in the form of continuous radio spectrums, to be processed on ground (spectral analysis etc.). It was analysed in search of traces of desired natural phenomena, as well as additional information (signal-to-noise ratio at low frequencies, field strength intensities of terrestrial longwave stations etc.). The data could be used as an aid in analysis of similar signals recorded on orbital altitudes. The project also allowed the students to gain important experience in space project management, international cooperation and achieving a scientific goal using engineering skills.

Project was part of the 14th Cycle of the REXUS/BEXUS programme, that is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Agency (SNSA). Vehicle number: BEXUS 33.

[A-34]

NAVIGATION SYSTEM FOR USE ON SOUNDING ROCKETS

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The hypersonic flight experiment STORT was successfully launched on a three-stage rocket from Andøya Space on June 28th of 2022. The STORT flight experiment aimed to investigate aerodynamic behavior, as well as thermal loads on the experimental forebody itself and its canards under supersonic speed within the atmosphere. Furthermore, shock wave boundary layer interaction was studied.

The payload of the rocket was equipped with a multitude of temperature, heat flow and pressure sensors. A dedicated on-board data acquisition system sampled those sensor's data at a high rate and forwarded the collected data to the on-board telemetry system. Additionally, a comprehensive navigation system monitored position, speed vector and attitude of the vehicle over the duration of the flight. Based on the acquired data the angle of attack of the forebody and the Mach number could be calculated. This allows for the correlation of the aerodynamical/thermal behavior of the forebody with the angle of attack, Mach number and the aerodynamical pressure.

The navigation system consists of a roll-stabilized inertial measurement unit (IMU), a multi-constellation GNSS and an additional GPS-only receiver. Moreover, a new IMU system, engineered in house at MORABA, was installed as an experimental passenger. To improve the quality of the navigation data, fusion algorithms between the roll-stabilized IMU and the GNSS system have been performed. The GNSS system was able to receive GNSS satellites signals from the GPS and GLONASS constellation, which guaranteed a high quality of position and velocity vector information with a sample rate of 10 Hz.

In this paper we aim to show the advantage and the improvement due to the data fusion to create an accurate and compact navigation system using both inertial navigation as well as GNSS based data. Furthermore, we intend to show the results of data fusion based on control loops which has been applied in postprocessing.

[A-152]

FLIGHT TELECOMMAND RECEIVER BASED ON OBSOLETE FM ANALOG RECEIVER AND TONE DETECTOR INTEGRATED TO FPGA.

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This article proposes an alternative circuit architecture for rocket flight termination receiver (FTR) designed to enable the use of analog receivers and detectors acquired for missile, airplane, or rocket projects prior to the advent of fully integrated FTRs. The main purpose is to minimize the obsolescence barrier of these analog equipment by using FPGA to decode received telecommands and to offer a digital signal monitoring and processing interface.

The telecommands considered in this work are tone-based encoded, i.e, an FM signal with a UHF carrier is modulated by subcarriers or tones defined by the IRIG 208-85 standard. The tones are sent from the ground station and received by the vehicle in flight. In the presented architecture, the analog FM receiver is such that performs demodulation and tone detection. Although commercially surpassed by more compact and functionally complete solutions, this type of receiver should not be neglected, since is highly qualified, complying with the reliability requirements defined by the Range Commanders Council (RCC). The FPGA completes the system's functionality by decoding the telecommands, including the termination order, according to the sequence of received tones defined by the RCC-313-01 standard. The digital circuit in FPGA is also designed to provide serial data containing the received tones, the decoded commands and analog readings of signal strength and supply voltage. These data can be useful for telemetry subsystems and ground support integration and test.

For proof-of-concept purposes, the circuit is tested by sending an FM signal modulated by the subcarriers, using portable Test Set equipment that triggers each tone. The decoding is then evaluated, taking the RCC-313-01 standard test table as reference. Auxiliary visualization software in LabView allows checking the correct reading of serial data, comparing the expected commands and voltage readings with those shown on screen.

[A-195]

HORIZONTAL SPACEPLANE DEMONSTRATOR 'MIRA' WITH LINEAR AEROSPIKE ROCKET ENGINE

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A spaceplane is a unique concept that combines airplane and rocket launch technologies. This paper gives an overview about the design, integration and flight testing of one such spaceplane demonstrator named 'MIRA'. MIRA uses turbojet engines during take-off, cruise flight, and landing, and a linear aerospike rocket engine (LAS) for the acceleration mission. This paper also delves in to the topic of design and testing of the linear aerospike engine and its propellant supply system on the test stand and its integration into MIRA.

The Linear Aerospike Rocket Engine (LAS) represents a groundbreaking approach to space propulsion, offering versatility and efficiency. The design phase of the LAS involves intricate engineering considerations to optimize performance across a wide range of operating conditions. The engine's geometry is designed to have efficient combustion process to maximize thrust while minimizing fuel consumption. Furthermore, the modular design of the LAS facilitates easy integration into both test stand and spaceplane demonstrator, enhancing mission flexibility and adaptability.

Complementing the LAS is its propellant supply system, a critical system ensuring the precise delivery of fuel and oxidizer to the combustion chamber. Through meticulous design and testing, the system achieves optimized flow rates, regulates pressure, and ensures component durability to maintain engine efficiency and reliability across various operational conditions. Advanced materials and manufacturing techniques are employed to mitigate corrosion, thermal stress, and other factors that could compromise system performance.

The testing phase of the LAS and propellant supply system is comprehensive, encompassing both ground-based trials and in-flight evaluations. Ground tests involved static firing to validate engine performance, while in-flight testing provides real-world data on aerodynamic interactions and system response.

The paper will present design, manufacturing and flight-testing results of the scaled flight demonstrator MIRA. It will furthermore discuss development and testing of the aerospike rocket engine and the architecture of the test-stand. Finally, an outlook will be provided on the next steps on the roadmap towards the spaceplane.

[A-61]

STUDIES OF NOCTILUCENT CLOUDS AND INFRASOUND WAVES FROM THE STRATOSPHERE

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The proposed balloon experiments will study optical phenomena in the mesopause (noctilucent clouds) and infrasound waves propagating in the stratosphere. Noctilucent clouds (NLC) are the highest clouds in the Earth's atmosphere, formed in the summer mesopause at 80-90 km altitude. Three CCD cameras, combined into a single camera system (NLC imager), are to take images of the sky during the whole flight. An occasional occurrence of NLC will be captured both in time and space at scales from five metres to two thousand km, making it possible to study various physical and dynamical processes in the summer mesopause. One camera will be equipped with a narrow-angle lens for studies of small-scale dynamical processes like wave instabilities and turbulence on scales of 5-100 m. Two other cameras will be equipped with wide-angle lenses to capture NLC at larger scales from 100 m up to 2000 km. This will improve our understanding of the middle atmosphere dynamics both at small and large scales. Results of the experiment will serve as input parameters for model simulations on atmospheric gravity wave propagations through the whole atmosphere.

Infrasound waves, having frequencies below 10 Hz, are generated by natural phenomena such as ocean waves (microbaroms), thunderstorms and severe weather, propagating into the mesosphere and thermosphere where some of their energy is dissipated. There are several advantages of balloon borne infrasound sensors compared to sensors on the ground. Some of them are: dramatically reduced wind noise, greater range for direct acoustic arrivals, possibility to record signals that propagate in stratospheric ducts and do not reach the ground, and the possibility to directly measure the energy flux of sound waves in the atmosphere. The current balloon flight will enable investigating the virtually unexplored acoustic wave field in the stratosphere above the North-Atlantic Ocean. Infrasound waves will be measured with a sensor package containing a set of InfraBSU infrasound microbarometers.

The TRANSAT 2024 balloon campaign (operated by CNES) will be held in June 2024. The NLC imager and microbarometers will be installed on a big scientific zero pressure balloon which will fly at around 40 km altitude across the North-Atlantic Ocean from Esrange (northern Sweden) to northern Canada, taking about 4-6 days.

Technology & Infrastructures for Balloons 4

Wednesday 22 May, Morning session – part 1

Room 1

Chair: V. Dubourg

Plenary Invited Lecture

[A-187]

SOME IDEAS ON THE FUTURE OF LONG-DURATION BALLOONING FOR ATMOSPHERIC SCIENCES

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Over the past decade, significant advances in superpressure balloon technologies have been achieved, notably within the framework of the Google Loon project. While the Loon project was primarily designed to enhance the worldwide access to internet, atmospheric sciences could likely greatly benefit from these recent developments. Of direct interest for atmospheric science applications are for instance the manoeuvering and the improved flight duration capabilities. These advances enable nearly year-long superpressure balloon flights in the upper troposphere and lower stratosphere, with capacities to steer the balloons toward areas of particular scientific interests.

The talk will explore how these new balloon technologies could be tailored for addressing scientific questions related to the general circulation of the atmosphere, and be used either to monitor the lower stratosphere or in co-ordinated campaign deployments with other airborne platforms. It will also stress the remaining issues associated with long-duration balloon flights.

[A-16]

THE CNES SUPER-PRESSURE BALLOON SYSTEM DEPLOYED FOR THE STRATEOLE-2 PROGRAM

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The French Space Agency, CNES, has been developing and operating, for about twelve years, super pressure balloons (SPB) that float on constant density (isopycnic) surfaces in the lowermost stratosphere, carrying 40 to 50 kg payloads, during typically three months. These SPBs have been successfully deployed in flotilla of about 20 balloons for different scientific campaigns all over the world, mainly to document the chemistry and dynamics of the atmosphere.

The current SPB system was developed between 2015 and 2019 in the frame of Strateole-2, a project dedicated to coupling processes between the troposphere and the stratosphere in the deep tropics, using several types of in-situ and remote-sensing instruments. The scientific payloads are fully self-standing, but some technical solutions are shared with the CNES housekeeping gondola, such as the renewable power system.

A flight validation campaign took place in Seychelles Islands in Fall 2019. Eight balloons were released from Mahé International Airport between November 11th and December 7th, and flew during several months all around the equator, demonstrating the validation of both CNES and Science systems.

Two years after, for the first scientific campaign, 17 balloons were launched from October 20th to November 26th 2021. Unfortunately, we quickly faced balloon anomalies and we had to shorten the flights, leading to only a one-month flight duration per balloon in average.

Now the most probable causes of the anomalies have been identified, and a quite important correction plan has been engaged to regain balloon envelops manufacturing quality. We are consequently now fully preparing the second Strateole-2 scientific campaign for winter 2025-2026 with an objective of 22 flights.

Thanks to a total of about 1300 days in the equatorial lower stratosphere providing unique science data, scientists of the project wrote a dozen of research articles. Three new instruments including two ones in atmospheric electrical field will also join the eleven existing ones of the early project.

This paper will describe the SPB system, the results of the two campaigns, the renewing of the balloon envelops production chain and the preparation of the second scientific campaign.

[A-20]

THE FIRST EUROPEAN STEERABLE SUPERPRESSURE BALLOON

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The French space Agency CNES and the prime contractor HEMERIA are currently manufacturing the first European Steerable Superpressure Balloon. This aircraft belongs to the "Lighter Than Air" High-Altitude Pseudo-Satellite (LTA HAPS). This project is funded by the French program "Plan de Relance" and by the French Ministry of Defense.

This balloon principle is based on a pumpkin superpressure balloon which includes an internal ballonet. The Ballonet is filled with Helium. A compressor, located at the bottom of the balloon, can blow external air in the superpressure balloon. The balloon can ascend and descend thanks to the air injected and extracted in the balloon.

Mock-ups have been finalized and qualified. The first pumpkin balloon will fly in June 2024 from Kiruna. A second balloon, with a compressor, will fly in the summer 2025.

HEMERIA is responsible for the hardware delivery. The main building block is the pumpkin balloon and is built in its large Ayguevives manufacturing premise. CNES is the HEMERIA customer and is in charge of the launch and flight operations. A high-performance electrical power susbsytem (solar array, battery, power distribution units) is provided by AIRBUS.

This project will be fully presented during this conference. The key strengths of this new stratospheric aircraft are the low cost, the large payload capability and the scalability.

Many applications (scientific, commercial and defense) can be supported by this new European HAPS. Potential use case will be presented. In particular, the route (trajectory) forecasting system will be presented during this conference.

[A-139]

DEVELOPMENT AND TESTING OF AN AUTONOMOUS PARAFOIL RECOVERY SYSTEM FOR HIGH-ALTITUDE BALLOON GONDOLA

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The Small Satellite Student Society of the University of Stuttgart (KSat e.V.) has been launching their sounding balloon system “BUoyancy Balloon Bus Lifted Experiments” (BUBBLE) since 2019, amounting to a total of 8 flights. BUBBLE has been under continuous incremental development; however, the team has recently begun a complete redevelopment of the system, which will represent the next step in the evolution of the project. One of the redevelopments is the switch from a classical round-cap parachute to an actively and autonomously controlled parafoil. This paper aims to give a detailed look at the development and testing of the software algorithms needed for determining a suitable landing spot and for reliably controlling the descend of the gondola. Furthermore, the regulations, electronics and mechanics will be discussed.

There are two main advantages of a more complex actively controlled parafoil over a proven parachute system. Firstly, there is the possibility to avoid landing in non-recoverable areas or areas, in which landing poses a significant threat to people and property. And secondly the possibility to have the gondola return to the launch site or at least greatly reduce the distance recovery vehicles need to cover. The team is in the process of observing the flight characteristics of an off-the-shelf RC parafoil-kit in order to apply the learnings to our own system. Planned are drop tests for observing the deployment behavior of the parafoil on its own and out of a tight package which the team plans to use for storing the parafoil during the ascend. Next up are the development and testing of different kinds of control loops and of the algorithm which selects a desirable landing position. Another key point to consider are the regulations regarding such a technology. The team will look into precedents in Germany for similar system. If none are found, special coordination with the German air traffic control (DFS) will be necessary. A successful approval and flight of a similar parafoil system by another group in Switzerland under the same EU regulations will be used to inform actions that need to be taken for regulatory approval in Germany.

[A-80]

STRATOSPHERIC BEES: SWARM PLATFORMS FOR SCIENCE AND EDUCATION

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Stratobotic is developing a hybrid configuration of a small and reusable High-Altitude Pseudo-Satellite (HAPS) based on stratospheric balloons, called CubeHAPS. The technical patented solution proposed will improve the maneauvrability and the control of the HAPS at high altitudes (15-20km), leading to a more advanced trajectory control capability, with more efficient on-board power generation and saving. An important feature is the CubeHAPS capability to operate in swarms, allowing on one hand to split a complex payload to different smaller parts, and, on the other, to execute simultaneous measurements different points of view. Stratobotic changed the approach to the stratospheric operational mode: no longer a big and complex platform, but many, small and flexible that offer, in the end, a long duration mission opportunity, with high reusability and simplicity, indeed no complex infrastructures are needed to operate them, and the flight authorizations are clear. The technology is total CO2 free. Because of its operational profile, the CubeHAPS are called stratospheric bees.

The hybrid configuration takes the best from the lighter-than-air and heavier-than-air HAPS concepts. Hence, CubeHAPS is composed of a fixed-wing tandem-configuration UAV, that is attached with a cable to one zero-pressure balloon and an optional super-pressure balloon. The concept behind this vertically developed configuration is that Stratobotic takes full advantage of the stratospheric winds direction changes in a small altitude variation, translating in a smaller overall drag to be balanced by the propulsion system. So, CubeHAPS changes its headining and altitude with active control means in all the three directions, at occurrence and cleverly, simplifying the control system. An artificial intelligence software controls trajectory as well as the the maintenance of constellation or swarm.

Today CubeHAPS is in its simplified configuration and despite the lack of full active control means, to be developed within the next 12 months, it is already entering the Earth Observation market. We will discuss its application for education and scientific missions in Italy.

[A-56]

THE AIRLIFTS INITIATIVE FOR AN INTEGRATED EUROPEAN AIRBORNE RESEARCH INFRASTRUCTURE IN NATURAL SCIENCES

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The AIRLIFTS initiative, aims to enhance accessibility to a diverse array of airborne platforms for the scientific community as an integrated European Research Infrastructure. By fostering collaboration among different operators and communities associated with HEMERA, EUFAR AISBL, and Cost Action Harmonious, the initiative will enable an open transnational access to stratospheric balloons, research aircraft, and UAVs. AIRLIFTS covers scientific topics in the Atmosphere, Geosphere, Hydrosphere, Biosphere, and Astrophysical and Planetary Sciences. It will serve as a pivotal proof of concept of airborne research infrastructure, filling a critical gap in the European research landscape.

AIRLIFTS is designed to support groundbreaking activities and foster technological innovations. In this presentation, we offer an insightful overview of AIRLIFTS' capabilities and its anticipated impact on advancing scientific endeavors.

[A-6]

AERIS DATA AND SERVICES FOR EUROPEAN SCIENTIFIC BALLOON EXPERIMENTS ... AND MORE

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The AERIS atmosphere Data Centre (HTTPS://WWW.AERIS-DATA.FR), part of the French Data Terra Research Infrastructure (HTTPS://WWW.DATA-TERRA.ORG), has the objective to facilitate and enhance the use of atmospheric data, whether from satellite, aircraft, balloon, or ground observations, or from laboratory experiments. It generates advanced products and provides services to facilitate data use, to prepare campaigns, and to interface with modelling activities. It consists of four Data and Service Centres (DSC) with strong expertise in data curation, storage, preservation and dissemination: ICARE (Lille), ESPRI (Paris), SATMOS (Lannion) and SEDOO (Toulouse). AERIS has close relationships with different laboratories for transferring prototype products and expertise on data. Most of these data centres are involved in European initiatives and projects promoting the FAIR data principles and participating in the European Open Science Cloud (EOSC). AERIS hosts and manages data from many European projects and Research Infrastructures (ACTRIS, IAGOS, HEMERA...) and is involved in several satellite missions (IASI, CALIPSO, Megha-Tropiques, MicroCarb...).

This presentation of AERIS will focus on the related balloon activities in the Framework of HEMERA project. HEMERA integrates a large community in the field of tropospheric and stratospheric balloon-borne research, in order to make existing balloon facilities available to all scientific teams in the EU The main objective of AERIS in HEMERA is then to make all the scientific and technological data collected during the balloon flights accessible to the whole European scientific community, upon request to the Data Centre. The Data Centre provides now free access and services for data archiving including higher level data products, access or links to large databases of past and ongoing scientific balloon data projects, complemented with access to new data products, together with tools for quality assurance, data analysis and research.

We will present and highlight the HEMERA datacentre (https://data.hemera-h2020.eu/) for which AERIS has implemented a dedicated data catalogue in order to make all the balloon scientific datasets discoverable and accessible. For this purpose, all the metadata describing the datasets are the most complete as possible and made compliant with standard formats and protocols. Online metadata and data provision tool for data provider to be completed with new parameters that have been measured during HEMRA flights have been successfully implemented, in addition to analysis software providing visualization and statistics tools adapted to the different data sets of measured balloon data campaigns.

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Wednesday 22 May, Morning session – part 1

Room 2

Chair: K. Sjölander

[A-33]

DEVELOPMENT AND FLIGHT OF PHOENIX II EXPERIMENT MODULE ON THE TEXUS 60 SOUNDING ROCKET MISSION

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The Phoenix II experiment module is a development cooperation between Nihon University ZARM and Airbus Defence & Space Bremen. The Objective of the Phoenix II is the study of droplet interaction in spontaneous ignition of multiple fuel droplets near the “cool flame” ignitable limit by two-dimensional observations.

This Paper describes the entire development of this experiment in different phases up to the final flight and the evaluation of the results after the Sounding Rocket flight.

[A-92]

SHARED MODULE - THE EASY WAY OF GETTING ACCESS TO SPACE

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Within SSC's SubOrbital Express (S1X) sounding rocket program, SSC offers rideshare service as a complement to the flight implementation of the larger microgravity experiments of ESA, which constitutes the basis for the scientific payload mission.

With the SubOrbital Express 3 mission (S1X-3) in autumn 2022, SSC introduced the brand-new "Shared Module", a new payload platform, hosting multiple small-sized experiments in a joint rideshare compartment.

The basic concept is a shared compartment, housing several small sized experiments from different customers or scientific groups, Standard interface solutions for power, communication, thermal control and mechanical implementation is provided. The Shared Module service also includes a common resource system (e.g. power, lift-off status and telemetry) for basic flight support.

The main objective is to provide sub-orbital flight opportunity with 6 minutes of high-quality undisturbed microgravity environment to a broader audience than a custom-made experiment system, traditionally flown on SSC's SubOrbital Express rockets. This new service may benefit institutions and universities worldwide as well as commercial operators having small-sized or 1U form factor self-contained payloads, designed to fit into the Shared Module payload format.

Each experiment is individually powered by the platform's support electronics and can therefore be individually switched on/off during test and launch campaign. One TM/TC communication line is available for each experiment, when integrated in the module. The communication line can be used for monitoring and control of experiment during tests on ground, and/or live stream data during flight. As additional service, support for biological and life science experiments including late access and fast recovery can be supported by the Shared Module rideshare concept.

The successful S1X-3 microgravity mission – to which in total seven small rideshare payloads from seven countries/three continents participated – is succeeded by the rideshare flight of the Shared Module on the MAPHEUS 14 mission, scheduled for February 2024. This time in total six research experiments will make use of the low-cost flight for conducting experiments in 6 minutes of microgravity conditions.

This paper will present the Shared Module technical approach and its two first flights, focusing on the payload requirements for this typical rideshare mission.

[A-138]

MINI-IRENE. THE SUCCESSFUL RE-ENTRY FLIGHT OF A DEPLOYABLE HEATSHIELD CAPSULE

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The paper describes the main outcomes of the qualification flight of Mini-IRENE, a capsule launched with a Maser sounding rocket on 23rd November 2022 during the SSC S1X3-M15 campaign. The flight has represented the clou of the Mini-Irene Flight Experiment (MIFE) project, funded by the Italian Space Agency (ASI) and managed by the European Space Agency (ESA). The project aimed at increasing the readiness of an innovative technology for deployable atmospheric re-entry heat shields up to TRL 6.

The capsule was successfully launched from ESRANGE with a VSB-30 suborbital rocket, achieving an apogee of 260 km, a peak deceleration of 12g and surviving the landing with successful retrieval. A huge set of telemetry data was acquired, including GPS, attitude, temperature, acceleration measurements. The capsule showed aerodynamic stability at all flight regimes.

This paper, after a quick review of the whole project and qualification process, is focused on the analysis of the re-entry flight based both on recorded data and telemetry data. The recorded data have been retrieved from an Inertial Unit and a sensors suite while the telemetry data were transmitted to ground, by an IRIDIUM system, even in the supersonic regime.

[A-30]

SUSTAINABLE HARDWARE DEVELOPMENT TO STUDY BIOLOGICAL SYSTEMS UNDER ALTERED GRAVITY CONDITIONS

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Crewed spaceflight induces a variety of gravity-related symptoms and health issues in astronauts. Yet, underlying mechanisms are still unexplored to a large degree. In order to investigate the physiological responses of neuronal cells to altered gravity conditions on a cellular and molecular level, experiment modules needed to be developed that provide the required environmental conditions for optimal cultivation as well as in-flight analysis capabilities. Our research aims to understand how neuronal cells change their behavior and might adapt to extreme environments, such as altered (hyper- and micro-) gravity conditions.

We have developed sustainable “frequent-flyer” reusable modules for the utilization on different gravity research platforms. Namely the ZARM Drop Tower (Bremen, Germany), the DLR Short-Arm Human Centrifuge (Cologne, Germany), parabolic flights (Bordeaux, France) and sounding rockets (ESRANGE, Kiruna, Sweden), such as the DLR MAPHEUS rocket.

The BIODECODER module allows in-flight electrophysiological experiments, using a multi-electrode array (MEA) system to measure the synaptic activity in single neurons as well as neuronal networks. The module provides optimal cultivation conditions including thermalization, pressure stability and electromagnetic shielding. The gravity-dependence of neuronal activity changes could be recorded during altered gravity exposure on the drop tower, human centrifuge and MAPHEUS rocket flights (M-12 10/22 & M-13 05/23 & M-14 02/24).

The second module, LIFT, was designed to enable fast and reliable chemical fixation of biological samples during various acceleration phases in rockets flights. Custom-designed cultivation vessels are used to enable low-shear-stress fixation of different cell types during launch (hypergravity) as well as after the microgravity phase. The modularity and reliability of the design were proven already during two rocket launches (M-13 05/23 & M-14 02/24). The versatility of the LIFT module enabled the analysis of two different cell types per flight, including IPSC-derived neurons, motoneurons and primary murine astrocytes.

Both modules are optimized to meet the requirements and constraints of the mentioned platforms, while in parallel creating ideal cultivation conditions starting from sample preparation, transport to the launch vehicle, countdown delays, flight and post-processing. In order to ensure optimal conditions for the rather sensitive cells, an analogue heating system was developed and certified, to meet safety requirements, while in parallel ensuring optimal scientific conditions.

Designing the modules to be suitable for different gravity research platforms increases comparability of results and allows us to answer how altered gravity conditions influence the functionality of cellular systems and thus indicate the corresponding changes in humans on the larger scale.

[A-52]

EQUIPMENT DEVELOPMENT FOR WET CHEMISTRY DEPOSITION AND DRYING UNDER MICROGRAVITY CONDITIONS (LIFICO)

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The LiFiCo project is part of a multi-disciplinary research programme, the prioritised research area *Materials Research* at Karlstad University, in which scientists from different fields, e.g., chemistry, materials physics, and modelling, develop projects in the field of molecular interactions under normal and microgravity conditions. The project aims primarily at a better fundamental understanding and a better control of the molecular interactions yielding the structures found in the molecular blend thin films making up the active layer of an organic solar cell.

The state of the art method to achieve the active layer for research purposes is to deposit a thin film from solution onto a glass substrate, e.g. by dip-coating. In the case of an organic solar cell, the solution contains donor, acceptor, and sometimes additional molecules. The evaporation of the solvent during drying causes a concentration gradient, eventually leading to a phase separated film morphology. It is of both fundamental and applied interest to be able to control and manipulate the film morphology, as well as developing methods for wet chemistry preparations under microgravity conditions. It is known that the kinetics of phase separation is slowed down under microgravity conditions, while the evaporation kinetics remain unchanged. Microgravity conditions hence make it possible to follow the initial stages of the morphology formation in more detail.

Handling liquids in microgravity conditions obviously requires other procedures than in a ground based laboratory. In this project we have enabled thin film coating from solution in microgravity by developing equipment for parabolic flights and for sounding rocket experiments. During parabolic flights the coating process was initiated in the hypergravity phase, while drying of the thin film was done in microgravity conditions. In a sounding rocket mission, Suborbital Express 4-M16, scheduled for launch in March 2024, where a longer period of microgravity will be available, we are able to precisely control the level of gravitational forces in the process. This ensures that any effects of the hypergravity phase is omitted and that the deposited films will have enough time to dry in microgravity conditions.

In this contribution we will present the design of equipment used for dip-coating in parabolic flight campaigns (70th and 78th ESA Parabolic Flight Campaigns”). In addition, a new design for flow-coating using an artificial gravitational field perpendicular to the rocket axis in the sounding rocket mission Suborbital Express 4-M16 will be described, as well as tests for 4-M16 by drop-tower experiments at ZARM in October 2023. Design principles developed in collaboration with ESA and the Swedish Space Corporation will be presented and challenges concerning wet chemistry in microgravity conditions will be discussed.

[A-110]

THE 3D OPTICAL SYSTEM OF THE CHIP EXPERIMENT

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Imaging systems are often a vital part of sounding rocket experiments. In the CHIP (Charges In Planet Formation) experiment*, developed by SSC and launched from Esrange Space Center on the S1X-3/Maser15 sounding rocket on 23 November 2022, four experiment cells, each with a size of 50x50x50 millimetres, contained different kinds of particles/beads, with a size ranging from 150 - 500 µm. These were used to study the agglomeration mechanisms that eventually lead to asteroids and planets. This paper describes the design of the CHIP module optical system, including challenges and lessons learned.

To study the movements of the individual beads, a backlit 3D imaging system was designed. By using two mirrors at slightly different angles, two views were created on a single sensor having an aspect ratio of 2:1. As the recorded images were the actual, and only, deliverable experiment data, the image quality was of high importance.

The challenging requirements were a Field of View (FoV) over the whole cell area, a Depth of Field (DoF) through the whole (50 mm) cell depth, and a resolution of 30 µm. As this necessitated stopping down the aperture quite far, blue light was chosen to reduce the effect of diffraction. A DoF/resolution trade-off analysis was then performed. As the DoF is determined by the Circle of Confusion (CoC) size – itself determined by the size of the entrance pupil – increasing the acceptable CoC eventually resulted in a perceived DoF reaching almost through the whole cell depth, with an acceptable resolution within the required Field of View (FoV).

Diffraction and required resolution also did correspond well to the pixel resolution.

The aforementioned blue backlight plate was custom made in-house, as a COTS backlight turned out not to have an adequately uniform illumination. At a later stage a frontlight was also added, further improving the visibility of the beads.

* By Jens Teiser et al

Rockets & Balloons in Space Education 3

Wednesday 22 May, Morning session – part 1

Room 3

Chair: M. Nuemberger

[A-178]

ENHANCING ROCKET DEVELOPMENT EFFICIENCY: THE SIMLE SIMBA PROJECT

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The SimLE Simba project represents a practical approach in sounding rocket technology, focusing on the integration of automotive industry standards like SOME/IP and SOME/IP-SD. This initiative aims to develop a research platform for conducting Hardware in The Loop (HiTL) simulations, reducing the need for frequent flight tests.

This project is relevant in rocketry as it offers a more efficient and cost-effective way to conduct tests and simulations, minimizing flight-related risks and potential human errors in assembly processes. The platform is being developed alongside the R7 rocket, ensuring a tailored fit for both the rocket's needs and the simulation system.

Currently in the development phase, the project emphasizes early error detection to enhance the final product's reliability. The end goal is to create a research tool that improves testing efficiency and supports the development of a reliable rocket for international competitions, addressing common challenges like mission aborts and failures. This project aims to offer a practical and efficient solution in the field of rocketry.

[A-95]

DESIGN, MANUFACTURE AND IN-FLIGHT OPERATION OF LOW-COST, REUSABLE SOLID ROCKET MOTORS FOR EXPERIMENTAL AMATEUR ROCKETRY

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Experimental amateur rocketry relies heavily on commercially available components due to their affordability and reliability. Yet the restrictive nature of off-the-shelf propulsion systems demand a bounded design of vehicle capabilities and modularity. Therefore decisions early in the design phase of the vehicle are conditioned by inflexible and external factors, i.e. the rocket motor's specifications and price. The objective of this study is to demonstrate the advantage of designing, manufacturing and operating reliable and reusable solid rocket motors (SRM), in a cost-efective manner, including the associated acquisition of knowledge.

The task of building a robust SRM is subdivided in several stages. Firstly, the design phase aims to meet performance and safety requirements. Then, in the manufacturing stage, efforts are made to attain a serviceable and functional motor. To conclude, static fire tests are carried out to characterise the motor and ensure its reliability. The completion of the aforementioned ends with the integration and use of said SRAD (Student Researched and Developed) SRM on our rockets.

The design is carried out using ODEKO which is able to simulate the chemical reactions in the chamber and the nozzle through chemical equilibrium or finite-chemical kinetics. The nozzle geometry optimization and the determination of the propellant grain geometry is also ascertained via ODEKO. The results are compared with open-access software commonly used in experimental amateur rocketry (e.g. NASA CEA).

Material selection and further nozzle geometry refinement is carried out by an in-house heat transfer and structural design code. Designs are developed taking into consideration our team's manufacturing capabilities to ensure the required quality. On-site production reduces project costs and avoids delays. The KNO3-Sorbitol propellant is produced in a secure area where safety protocols are enforced. Temperature, pressure and humidity are monitored, to ensure that the propellant grains pass the quality control.

The SRM has to be tested and characterised before being mounted on a rocket. Therefore, a test campaign of the manufactured rocket motor ensues, to measure their combustion times, chamber pressure, thrust curves, structural integrity and other important parameters.

The main objective of this study is to show that the proposed method is one of the most economical and sustainable way to manufacture SRM for amateur sounding rockets.

[A-144]

PARAMETRIC DESIGN OF A MODULAR, LOW COST, STUDENT DEVELOPED, HIGH POWER ROCKET FOR CUSTOMIZABLE MISSION PROFILES

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Most of the systems embarked on a high performance rocket have to be previously tested in order to correctly develop their task during flight. Our association has developed a rocket that can carry out different subsystem testing and validation missions with the same vehicle design.

The LEEMUR rocket series features a modular design that widens its service range and allows the team to easily refurbish the vehicle within minutes. Both, hardware and software are designed and manufactured entirely by the association, reducing production costs. Additionally, stock of rocket components, avionics subsystems and motors is kept, to ensure a ready to launch rocket at any moment.

The vehicle features a mechanical parachute ejection system which can be easily armed and disarmed allowing an instantaneous set-up in between launches. This makes this rocket highly accesible for subsystem testing and a reliable Can-Sat competition launcher.

The rocket has been used by the team to test different manufacturing methods and validate aerodynamic models. Moreover, the mathematical models of the employed rocket motors have also been compared with the in-flight performance. Telemetry and the avionics systems have been employed under different acceleration rates.

In conclusion, this rocket provides an economical and reliable method to launch amateur experiments and subsystems with several alluring fight profiles.

[A-161]

DESIGN AND LAUNCH OF THE HYBRID SOUNDING ROCKET N2ORTH

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Since late 2019, the Hybrid Engine Development (HyEnD) rocketry team from the University of Stuttgart participated in the STERN II (Studentische Experimentalraketen) program led by the German Aerospace Center (DLR). This program offers students at German universities the opportunity to develop, build, and launch an experimental sounding rocket within a three-year project timeframe. In April 2023, HyEnD successfully launched the hybrid sounding rocket N2ORTH from the Esrange Space Center in Sweden.

The main objective of HyEnD's participation in STERN was to enhance education and gain practical experience in aerospace engineering and related research disciplines. Additionally, the team aimed to surpass the previous altitude record set by their 2016 rocket, HEROS.

N2ORTH's hybrid propulsion system uses liquid nitrous oxide (N2O) as an oxidizer in combination with a solid fuel based on hydroxyl-terminated polybutadiene (HTPB). The " HyLIGHT " engine has maximum thrust of 15kN and is fed by the fluid system which uses a pyrotechnical main valve in blowdown operation. Three flight configuration propulsion system tests were conducted.

The oxidizer tank was developed in-house as a Type V CFRP pressure vessel with an internal ETFE surface coating to ensure compatibility with nitrous oxide. The rocket's primary structure is constructed from composite materials, the design is optimized for weight minimization using modern composite engineering principles. To optimize the rocket for maximum altitude, advanced lightweight design was considered as an overall construction philosophy. To withstand thermal stresses experienced during flight at Mach numbers over three, the rocket features a a cork-based thermal protection system.

N2ORTH's Ground Support Equipment is responsible for fueling, communication, and ignition. The avionics system, consisting of in-house developed modules, controls the power supply, sensor data processing, downlink, and video acquisition.

The two-stage recovery system includes a COTS main parachute and a self-developed and manufactured drogue parachute capable of supersonic descent. Rigorous testing procedures, including drop tests, verified the successful recovery sequence.

During the launch campaign, N2ORTH-SN1 set a new world altitude record for student hybrid rockets at 64.4km. The second launch of a nearly identical rocket experienced rapid unscheduled dissasembly during ascent, this is currently being investigated.

This paper presents the technical progress and the new and improved developments that were implemented as part of the STERN program and have led to the success of the N2ORTH rockets.

[A-120]

DESIGN, DEVELOPMENT, AND TESTING OF A HYBRID ENGINE IN SUB-ZERO TEMPERATURES

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This paper will summarize the design and testing of the "Ursa" hybrid rocket engine. It was developed by students of the Rocketry and Aerospace Vehicle Engineering in Norrbotten (RAVEN), a student association of Luleå University of Technology. The Ursa engine uses paraffin wax as fuel and N2O as oxidizer with a planned thrust of 1000 N. While there are plans for integrating the engine into a rocket the current version is in a battleship configuration with a focus on testing the engine parameters safely.

The focus is on the cold testing environment. In Kiruna, sub-zero temperatures are prevalent for half the year, and can reach as low as –30°C during midwinter. This creates challenges during operation and testing of the hybrid rocket engine. With space ports like Esrange and Andøya Space conducting rocketry operations at similar latitudes this temperature profile is relevant for many test and launch campaigns of small rockets. Problems arising from cold temperatures include changing material properties. This can cause failure of O-rings due to brittleness and shrinking. Similar effects occur regarding the fuel grain. The oxidiser bottle is one of the more temperature sensitive system components, due to the direct correlation between bottle temperature and bottle pressure. Freezing of the valves due to trapped moisture must also be avoided. When the test bench is brought indoors, condensation can occur. As for issues with the electronics, different rates of thermal expansion in different components could cause connection issues. Also, sensors may only be calibrated for certain temperature ranges, and sudden shifts in temperatures could lead to condensation and freezing of electronic components. To address these problems, the components were carefully selected. Furthermore, an efficient production process for the fuel must be found. The test procedures are optimised for the cold environment and include purging of the pipes. Components are insulated or heating elements are added when necessary. All these mitigation options will be validated in tests.

The engine design is presented including the in-house developed software and electronics. On the propulsion side the method for fuel casting of paraffin wax and additives such as carbon powder is described. These results and the mitigation strategies of the issues from the cold environment will be the focus in the final paper. The results from the test campaign will hopefully be of use in the increased industry effort pursuing rocket launches in the cold environment of northern Europe.

[A-70]

DEVELOPMENT AND VERIFICATION OF EXPLOSIVELY ACTUATED VALVES FOR USE IN A SOUNDING ROCKET

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Within the SR Dorado project, which started in July 2022, a pressure-fed, bi-liquid propelled sounding rocket and its corresponding ground support equipment are being devepoled by the Institute of Aerospace Technology (ILR) at Dresden University of Technology (TUD) in cooperation with STAR Dresden, the student space flight working group in Dresden. The rocket will utilize ethanol and liquid oxygen (LOX) as propellants and will generate 3kN of thrust and achieve a flight altitude of at least 5 km.

This paper aims to introduce and discuss the development, manufacturing and experimental verification of explosively actuated propellant and pressurization gas valves, which are part of the sounding rocket's propulsion subsystem. An extensive literature and patent research on the subject of explosively actuated valve designs were conducted and a suitable design was selected based on project and performance requirements. Prominent features include simplicity of design, low hydrodynamic losses and low mass. The propellant valve was designed, manufactured and analytically verified, with the pressurization gas valve being derived from it without independent development. Experimental verification for both valves is scheduled to take place in early 2024. The Results will be presented and analyzed, potential improvements discussed and implemented into the second valve generation.

The SR Dorado project receives its funds from the STERN III programme (Ref.-Nr. 50RL2252) of the German Aerospace Center (DLR). It is so far the only bi-liquid propelled rocked in development within STERN III. Launch is currently set for 2025 and will take place from ESRANGE in Kiruna, Sweden.

Atmospheric Physics & Chemistry 3

Wednesday 22 May, Morning session – part 2

Room 1

Chair: G. Lehmacher

[A-37]

SOUNDING ROCKETS AS AN IMPORTANT TOOL FOR UNDERSTANDING SMALL SCALE DYNAMICS IN THE MIDDLE ATMOSPHERE

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Sounding rockets have been used to measure basic parameters of the Earth's atmosphere since the middle of the last century. First reference atmospheres were essentially based on measurements from sounding rockets. With the development of new technologies, remote soundings started to prevail and to form a global database of measured atmospheric parameters. On the other hand, recent advances in measurement techniques are applied on sounding rockets making them an unbeatable tool for studies of atmospheric dynamics, especially regarding small scales at altitudes above ~50 km. High spatial resolution of rocket measurements can yield unique information of physical processes which are important for our understanding of the middle atmosphere and beyond. Such information is not accessible by other means. Moreover, some scientific questions can only be answered when simultaneous and common volume measurements deliver different parameters related to the phenomenon under investigation. The interpretation of observations on sounding rockets is often successfully supported by measurements by groundbased instruments such as lidars and radars. In this talk, the advantages and capabilities of rocket measurements are briefly summarized. Their potential for our understanding of atmospheric dynamics and its importance on larger scales is discussed.

[A-99]

THE ORIGIN ROCKET PROJECT – OLD AND NEW SOURCES OF OXYGEN NIGHTGLOW

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The ORIGIN (Oxygen and its Role In Generating and Influencing Nightglow) project is planned at Esrange Space Center in early 2025, comprising both sounding rockets and ground-based measurements. We intend to return to some basic nightglow questions, with a particular focus on the major nightglow emissions O_2 Atmospheric Band, O Green Line and OH Meinel. All three emissions serve as a basis for retrieving atomic oxygen concentrations in satellite remote sensing. A major idea of ORIGIN is to simultaneously measure relevant emissions, concentrations of atomic oxygen and hydrogen, as well as neutral and ionospheric background conditions. Central for the optical in situ measurements is a rocket module with active cooling providing space for nine photometers. At the same time, we are still looking for suitable collaborations concerning ground-based spectroscopic measurements.

A general goal of ORIGIN is to revisit and consolidate reactions underlying today's standard nightglow model. A more specific goal is connected to a recently discovered source of excited $O(^1D)$ through the reaction of vibrationally excited hydroxyl OH($v \geq 5$) and groundstate oxygen $O(^3P)$. This discovery has added a new photochemical source of $O(^1D)$ at nighttime, thus leading to a modification of established reaction schemes and connecting the pathways of O_2 and OH nightglow. With two ORIGIN rocket launches we will study the importance of this mechanism for oxygen nightglow generation as a function of altitude and atmospheric conditions.

[A-67]

BALBOA TEST FLIGHTS AND SCIENCE BONUS FOR AIRGLOW

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BALBOA (BALloon-Based Observations for Sunlit Aurora) is a NASA balloon project investigating the dayside solar wind – magnetosphere – thermosphere coupling by imaging aurora in sunlight above the atmosphere. The BALBOA science payload has been developed along with three technical test flights in June 2021, September 2022, and August 2023 from Fort Sumner (~34° latitude), New Mexico. In the first piggyback fight on June 9, 2021, the single instrument operation and the LOS EVTM data downlink passed the test. The second was an LDB flight with pointing control, which confirmed the payload system operation, the downlink telemetry, and the science and the gondola SIP integration. We also found severe sunlight contamination. The third test, a piggyback flight on August 19, 2023, validated and proved the baffle improvement that reduced the stray light by two orders. In addition, we have done two ground-based auroral campaigns for auroral substorm investigation, eleven field tests for instrument development, and two TVCA (Thermal Vacuum Chamber) tests for the thermal solution. BALBOA is now ready for a high-altitude LDB auroral mission in Antarctica. During the low latitude flights for technical tests, we managed to image airglow and dayglow in 1200-1700 nm to obtain as much extra science return as possible. BALBOA recorded gravity waves (GWs) mapped by airglow OH4-2&3-1 in 1500-1700 nm and dayglow O2 at 1270 and 1580 nm from the ground, in the night, in the twilight, and in the air with the solar elevation to be ~60°, respectively. These results raise interesting questions to the airglow community and envision the possibility of dayglow investigation from balloons above the atmosphere.

[A-124]

SPIDER-2 SOUNDING ROCKET: MULTI-POINT ELECTRIC FIELD AND PLASMA MEASUREMENTS IN PULSATING AURORA

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The Small Payloads for Investigation of Disturbances in Electrojet by Rockets 2 (SPIDER-2) sounding rocket was launched from the Esrange Space Center, Sweden, on February 19th, 2020, at 23:14. The rocket was launched into a pulsating aurora event, following a parabolic trajectory with a maximum altitude of 130 km and deploying 8 Free Falling Units (FFUs) which provided *in situ* multi-point measurements of the electromagnetic field and plasma parameters. The main rocket carried an auroral photometer, and a set of plasma probes. The FFUs carried a double probe electric field experiment, and a set of Langmuir probes. Ground based optical data were obtained from all sky cameras and the ALIS4D system.

Here we show the multi-point measurements of *in situ* electric and magnetic fields and their relation to the electrodynamics of the E-region. In addition, we present the electron density and temperature measurements, and the comparison with the optical data.

[A-85]

Aerodynamic Simulations for Rocket Soundings: Enhancing Accuracy through Direct Simulation Monte Carlo

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Sounding rockets face significant challenges in obtaining accurate measurements due to the supersonic shock upstream of their instruments. This shock alters flow properties crucial for neutral, plasma, dust, and trace gas measurements, necessitating correction through numerical simulations.
The Direct Simulation Monte Carlo (DSMC) method has proven invaluable in the transitional regime between continuum and molecular flow. Recent advancements in DSMC codes, including massive parallelisation, new boundary conditions, and adaptive meshing strategies, have enhanced their quality and usability. In response to the unique needs of the sounding rocket community, IAP has embarked on developing an advanced open-source DSMC code.

This paper outlines the initial application of the software, focusing on deriving a precise and efficient correction routine for in-situ neutral density and temperature measurements. The software aims to provide a fast and accurate correction mechanism through an iterative process involving a diverse set of simulations.
We present preliminary results, explore the simulation needs of the community, and outline future steps in the ongoing development of the DSMC software.

Rockets & Balloons in Space Education 4

Wednesday 22 May, Morning session – part 2

Room 2

Chair: R. Hemmersbach

[A-166]

ZAWISZA4000 – UNVEILLING THE DYNAMIC BEAT OF TURBULENCE PROPULSION IN POLAND'S PIONEERING STUDENT LIQUID BI-PROPELLANT ROCKET

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This paper presents a description of the development process of the first Polish student bi-propellant liquid rocket propulsion system, including overview of the design process, analysis of the cold flow and static-hot fire tests data prior to the first flight test of the Turbulence rocket, which uses a discussed propulsion system, during the FAR-OUT 2024. The Turbulence rocket was fully designed by the AGH Space Systems and was chosen to the group of 13 the best projects that will be taking part in this competition.

The heart of the propulsion system, its engine, named Zawisza4000 is the evolution of the Zawisza500. Zawisza500 was the first Polish student liquid-propellant rocket engine. Not only is this engine groundbreaking due to its pioneering role in the Polish space industry, but also due to the solution of the sealed movable piston inside the pressure vessel, which hosts the rocket engine propellants.

In Zawisza4000 project, similar solution was implemented in order to design the first Polish student liquid propelled rocket. The Zawisza4000 engine has an average thrust of 4kN and 40 kNs of total impulse, which makes it the most powerful rocket engine ever designed by AGH Space Systems student organization.

The engine uses ethanol and nitrous oxide propellant mixture. High vapor pressure of nitrous oxide combined with implementation of basic thermodynamics laws allows propulsion system to feed propellants into the combustion chamber without using any additional pressurizing equipment.

The most unique part of propulsion system is its pressure vessel. Turbulence's pressure vessel was designed with a sealed moving piston that separates fuel located at the top from oxidizer in the bottom part. The piston uses two tubes routed through the inside of the tank as guides - one tube acts as a fuel feed line while the other serves purpose as a conduit for cables and an array of magnetic sensors that can monitor the position of the piston which is crucial to calculate the amount of propellants in the tank and ensuring proper O/F ratio.

This paper provides a detailed description of the development process of the first student liquid-propelled rocket in Poland, presenting, among other things, methods for determining the engine's geometry, the testing process including results from cold-flow tests and ignition system tests, paving the way for static-hot-fire tests. One could say, this is a kind of tale about how students fulfill their greatest dream of making history.

[A-65]

DEVELOPMENT OF A SMALL-SCALE TEST BED FOR LIQUID-FUELED ROCKET ENGINES: A PROJECT-BASED LEARNING EXPERIENCE FOR STUDENTS

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University students realize the most educational benefit from their courses when theory is backed up with practice. Through project-based learning, a team of seven Bachelor students at ETH Zurich, together with the Swiss Academic Space Initiative (ARIS), developed a small-scale test bed for evaluating liquid-fueled rocket engine (LRE) designs. The main technical objective was to provide a testing platform to get first-hand experiences with state-of-the-art technologies, such as designing and testing LREs and handling and control of cryogenic oxidizers.

The project was conducted over the course of two academic semesters and was split up into concept, design, and testing phases. All custom parts were manufactured externally over the semester break, and the system was assembled at the beginning of the second semester. The outcome is a mobile test stand for LREs and two distinct engine configurations, both of which were thoroughly tested and validated.

The test stand includes the oxidizer supply system, which uses liquid oxygen, and the fuel supply system, which uses ethanol; both of which being pressure-fed. A data acquisition and control system provide real-time sensing of the system state, remote actuation of the control valves and surveillance. The first engine configuration uses a like-doublet impingement injector for the atomization and mixing of the propellants, and a torch igniter for ignition. The water-cooled thrust chamber was produced out of CuCr1Zr via laser powder bed fusion additive manufacturing and enables firing durations of up to 20 s, as limited by the capacity of the propellant tanks. This setup produced a measured 670 N thrust at 26 bar chamber pressure with a specific impulse of 220 s. The second engine configuration uses an experimental vortex injection system and shows similar performance.

Due to the cryogenic nature of liquid oxygen, the pre-chilling of the oxidizer lines was found to be critical for stable ignition. Two approaches for pre-chilling were tested. The first is a fast cool-down technique, where pressurized liquid oxygen is used to cool down the oxidizer lines to the engine. This was found to only cool the contact surfaces of the pipes and engine parts, leading to an unreliable start-up. The second approach is a slow, unpressurized cool-down procedure, which evenly cools the entire system and results in a more reliable start-up.

Through testing, the system’s reproducibility, reliability, and robustness have been demonstrated. This is shown by 24 successfully conducted firings accumulating 140 s of firing duration. With this test stand, further investigations into certain aspects are planned, including upscaling the engine, demonstrating thrust control, evaluating alternative injection systems, and experimental characterization of the thrust chamber cooling.

In addition to realizing these technical achievements, the team met and exceeded the educational objectives. The students came away with real-world experience with systems engineering, mechanical, electrical, and control system development, budgeting, sourcing and manufacturing real hardware, planning and executing a safe and successful test campaign, and managing a team-based project. Such project-based learning opportunities are critical to ensuring that universities continue to produce graduates with relevant skills and experience to serve industry and society.

[A-76]

FOCUS PROJECT RAPTURE: THE DEVELOPMENT OF A MULTI-MATERIAL LASER POWDER BED FUSION MACHINE FOR ADDITIVE MANUFACTURING OF ROCKET NOZZLES

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Advances in manufacturing technology are enabling the production of highly complex rocket components on time- and price-scales that were once unimaginable. Over the course of two semesters, a team of six Bachelor students at ETH Zurich, in cooperation with the Swiss Academic Space Initiative (ARIS), developed a multi-material laser powder bed fusion (LPBF) machine dedicated to the production of rocket nozzles. Such a machine can drive down the cost and increase the speed of manufacturing nozzles, all while enabling increased performance through the use of composite materials and the internal cooling features. This development was conducted in the framework of an ETH Focus Project, where students learn-by-doing and earn credits by developing a physical product.

The machine architecture is fundamentally different than existing LPBF systems in that it continuously deposits powder as it scans. This greatly reduces the production time relative to conventional single-material LPBF systems. Furthermore, the machine can deposit two materials with radial separation, which is advantageous for rocket nozzles where one may combine materials with high thermal conductivity (e.g., copper alloys) with those with high thermal stability (e.g., nickel-based alloys) within a single process. This architecture is made possible by the annular design that is common to many nozzle designs.

The machine and process needed to be developed from the ground up, encompassing synchronized actuation and laser scanning, design of optical, powder deposition, gas flow, electrical and control systems, and the development of the multi-material LPBF processing strategy. Starting from a list of system requirements, the team applied Agile Product Development practices to manage the risks associated with developing each subsystem. With a “fail fast, cheap, and often” approach, the team was able to prove out the fundamental working concepts of different aspects of the machine and the LPBF process before committing to the final hardware, software, and control system design.

Ultimately, the team succeeded in developing (to our knowledge) the first LPBF machine for continuous production of multi-material rocket nozzles. It has been used to produce several demonstrator parts. The prototype machine is now undergoing extensive testing to understand its processing capabilities and the quality that can be expected of the parts it produces.

Apart from attaining these technical milestones, the team not only met but surpassed the educational goals. The students gained practical experience in systems engineering, mechanical and electrical development, control system implementation, budgeting, sourcing, and manufacturing of tangible hardware. They also learned valuable skills in planning and executing a secure and successful test campaign, as well as managing a team-oriented project. These hands-on, project-based learning opportunities play a crucial role in ensuring that universities produce graduates equipped with pertinent skills and real-world experience, ready to contribute to both industry and society.

[A-48]

FLOW BOILING REGIMES IN MICROGRAVITY CONDITIONS EXPERIMENT (FLORENCE): RESULTS FROM REXUS 27 SOUNDING ROCKET CAMPAIGN

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Thermal management is continuously attracting the interest of scientists in a wide range of applications in the industrial sector, ranging from micro/nanoelectronics development (high power density and very small physical dimensions) to space (absence of buoyancy and need for heat recovery) and nuclear applications (cooling of reactors at high temperatures). In this framework, flow boiling in channels represents one of the most efficient ways to remove heat from hot surfaces, utilizing the fluid's latente heat. Although flow boiling is experienced in many engineering fields and is of large interest in space applications, it has been less studied in reduced gravity, probably due to the presence of additional technical complications due to fluid flow. The understanding, prediction, and control of flow boiling in reduced gravity are strongly hampered by the absence of validated mechanistic and numerical models. Therefore, the creation of reliable and accurate experimental databases is necessary to assess the accuracy of the model predictions. Sounding Rocket experiments of cryogenic chill-down in complex channel geometries have been recently reported and have shown that contrarily to the simple geometry cases, for which the absence of gravity sometimes declines the convective boiling heat transfer, in the fluid system with complex geometry, it is sometimes enhanced. It is important to underline that each of these two experiments was occupying the entire JAXA's sounding rocket S-310-43 (7 m in length and only 310 mm in diameter) and that, to the authors' knowledge, no other breadboards have been developed for the study of flow boiling on sounding rockets.

In this framework, the scope of this communication is first to present the design and the qualification of the FLOw boiling REgimes iN microgravity Conditions Experiment (FLORENCE), which was on board the REXUS-27 sounding rocket in November 2022. The aim of the FLORENCE breadboard is to understand to which extent low-budget and miniaturized experiments can be developed to perform flow boiling experiments in sounding rockets. To this end, we will compare results obtained on ground with the microgravity experiments in terms of wall temperature, heat transfer coefficients, pressure drop and bubble visualizations.

Physical Sciences 2

Wednesday 22 May, Morning session – part 2

Room 3

Chair: T. Trittel

[A-113]

DROPLET EVAPORATION STUDIES IN MICROGRAVITY

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Understanding fundamental scientific principles holds significance in driving technological progress. Recognising this, the European Space Agency (ESA) has identified the need to explore basic physical processes, such as evaporation and condensation. Several physical science modules aimed at acquiring essential knowledge have been proposed as part of this initiative. An example is the Droplet Evaporation (DrE) module, housed in Heat Transfer Host 2 within the European Drawer Rack-2 on the International Space Station (ISS). This module seeks to contribute to understanding the fundamentals of droplet evaporation and heat transfer in space. The module is expected to fly to the ISS in 2024, and experiments should commence in 2025.

Three main fundamental aspects will be investigated in this module. (i) Characterising the vapour cloud behaviour surrounding the evaporating droplet using laser interferometry. (ii) Influence of electrical field on the droplet and the vapour phase (iii) Instabilities in the droplet induced by evaporation and heat transfer. Multiple scientific teams have collaborated to prepare the module for successful operation aboard the ISS. Our team is particularly interested in comprehending the evolution of vapour clouds during evaporation, with a focus on Marangoni convection within the droplet and the effect of the electrical field.

Our research has encompassed two parabolic flight campaigns: Vapour Interferometry in Microgravity (VINNIG 2019) and Vapour Interferometry for Droplet Evaporation Research (VIDER 2022), and we have actively participated in two sounding rocket campaigns: ARLES I and II. Here, we elucidate the advantages and drawbacks of conducting droplet evaporation experiments using these two facilities and expound on the necessity of conducting such experiments aboard the ISS.

Despite having 90 parabolas (~20 seconds of microgravity per parabola), experiments carried out during parabolic flights face challenges from inherent g-jitters. Unfortunately, these disturbances impact droplet evaporation, primarily due to solutal convection in the gas induced by the oscillation of the vapour cloud in response to residual gravity fluctuations. Moreover, interferometry, a technique highly sensitive to vibrations, necessitates specialised dedicated postprocessing methods. Sounding rocket experiments offer the advantage of stable microgravity conditions. However, it is impossible to test all parameters comprehensively, mainly due to time constraints. In addition, fluid circuits operating in microgravity consistently exhibit anomalies, requiring special calibrations in microgravity. Therefore, stable microgravity and an extended duration are essential to conduct sound experiments with outcomes within an acceptable level of uncertainty. Achieving both is only feasible when experiments are conducted aboard the ISS.

[A-23]

INVESTIGATION OF THE INTERACTION BETWEEN SOLIDIFICATION PROCESSES AND PARTICLE TRANSPORT IN THE MELT FOR TERRESTRIC AND MICROGRAVITY CONDITIONS

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In this work the interaction between solid-state particles and the advancing water-ice solidification front is studied experimentally and numerically, both under terrestrial and microgravity conditions. Microgravity experiments in the so-called TEM06-23 module were carried out onboard the TEXUS56 and TEXUS58 missions allowing to analyze in-situ the motion of particles after their injection into the fluid and their behavior with respect to the moving solidification front. For the simulation of the TEXUS sounding rocket experiments, the injection of the particles, their transport through the fluid and their interaction with the interface were modelled.

In basic studies, the thermal conditions of the solidification processes were systematically varied and their influence on the solidification front were investigated. It was found that there is only a minor influence on the solidification process whether the experiments are carried out under terrestrial or microgravity conditions.

In further studies the full TEXUS experiments were simulated including the particle transport. The simulated particle velocities were cross-referenced with high-speed images captured during the experiments. The simulation outcomes align well with the experimental data, particularly in depicting the temporal evolution of the solidification front.

The simulations also underscore the impact of particle injection, causing a temporary small disturbance of the solidification process due to the induced flow. This induced flow results in advective heat transport, thereby altering the local temperature and velocity fields. The disruption is transient, and the simulated particle distribution in the fluid after the injection procedure mirrors that observed experimentally. To investigate in more detail the damping behavior of the flow after the pump for the particle injection is turned off several simulations were conducted. The simulations replicate the observed fast damping of the velocity field after the particle injection.

The experiments agree also to the theoretical considerations that under the given conditions large particles are captured instantly, while the smaller ones are more often pushed ahead by the phase boundary.

[A-32]

SPACE INVESTIGATIONS OF MONOTECTIC ALLOYS (SIMONA)

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Some metallic alloys such as Al with Bi, In, Cd or Pb exhibit monotectic phase-diagrams. Here, the transformation from the homogeneous liquid phase to the solid state (e.g. in casting processes) takes place in a multi-stage cooling sequence - including demixing into two liquid phases, often by droplet formation in a liquid matrix. Each cooling stage involves specific processes that influence the final spatial distribution of the solid phases, which in turn has a major impact on properties of the alloy material. It is therefore of particular interest to understand and, ideally, to influence the formation of the spatial distribution of the solid phases, especially for technically produced alloys: For instance, some industrial parts require a combination of a hard matrix (1st phase) with homogeneously distributed soft inclusions (2nd phase); this combination is often related to a monotectic phase-diagram.

The multi-stage cooling sequence of a two-component alloy with a monotectic phase-diagram begins with a homogeneous liquid phase at higher temperature (stage 1). Within wide concentration ranges and upon cooling, it separates into two immiscible liquid phases – often droplets in a liquid phase (stage 2). When the monotectic temperature is reached the first solid phase is formed (stage 3) and at a lower temperature the remaining liquid solidifies into a second phase (stage 4).

During stage 2 and 3, several droplet processes determine their spatial distribution in the liquid matrix over time: - Nucleation - Migration by gravity/ capillary forces/ convection - Coagulation - Wetting at walls – Solidification.

Using in-situ microscopy, we observe these processes in a transparent monotecticum (succinonitril-water: SCN-H_2O). which serves as a model system for binary metallic monotectica. The mixture is enclosed in a transparent container in which an adjustable thermal gradient can be applied between two opposite sides. The processes inside are recorded in photo series by an overview and the microscopy camera. Sizes (diameters in µm-range) and trajectories of the migrating droplets are determined by image analysis, including artificial intelligence for their recognition.

To neglect gravity-induced effects (density difference driven droplet migration and liquid convection in a thermal gradient) compared to capillary-force driven droplet motion in the thermal gradient, a sounding rocket experiment was proposed. After detailed preparation of the experiment on ground, the sounding rocket- and reference experiments in gravity are scheduled for January 2024. A summary of the preparation experiments is available, further we intend to present first results on droplet dynamics in microgravity.

[A-73]

CONCURRENT BURNING OF PMMA RODS IN AN EXPLORATION ATMOSPHERE UNDER MICROGRAVITY

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For future human exploration missions, it is planned to reduce the ambient pressure while increasing the oxygen concentration. This poses an enormous challenge for risk assessment, as little data is available on flame spread in microgravity in these exploration atmospheres. The paper summarizes the results of the TOPOFLAME experiment from the sounding rocket flights TEXUS 57 and 59.

The experiment consists of 5 individual wind tunnels that function as combustion chambers. Polymethyl methacrylate (PMMA) rods with diameters between 5 and 25 mm are mounted inside the chambers. The samples are equipped with an ignition wire at the lower end, which was turned away after ignition. The wind tunnels are each supplied via a mass flow controller using a common high-pressure bottle. This allows a defined forced laminar flow to be generated in concurrent configuration, which was at a constant velocity of 20 cm/s during the TEXUS 57 mission and was gradually reduced from the initial 20 cm/s to 10, 5, and 2.5 cm/s during the TEXUS 59 flight. The pressure is kept constant at approx. 70 kPa in the chambers by a common vent line and a control valve. Combined with the oxygen concentration of 26.5 vol.%, this results in a hypoxic exploration atmosphere. The flame propagation is captured with the help of an infrared camera and a camera in the visual spectrum.

The experiments revealed that the drastically increased soot production compared to terrestrial conditions leads to a significantly increased radiation fraction by the gas phase above the sample. This also sheds light on the increased local temperatures under microgravity conditions, which can lead to self-sustained burning of some materials that are not flammable under normal gravity – despite the lower overall mass burning rate observed in microgravity. Furthermore, the flame spread rates of the microgravity experiments at 20 cm/s are compared with terrestrial experiments under natural convection but otherwise identical atmospheric conditions. In some cases, the propagation rate under microgravity reached higher values than under normal gravity, which can be attributed to channel effects in combination with the thermal expansion of the flame.

Rockets & Balloons in Space Education 5

Thursday 23 May, Morning session – part 1

Room 1

Chair: M. Becker

Plenary Invited Lecture

[A-184]

CONTEXT FOR THE MASTER IN SPACE SYSTEMS AT THE UNIVERSITY OF OSLO

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Autumn 2023 the University of Oslo (UiO) established a master in space systems, focusing on the development of satellite systems and space probes. There are several reasons for establishing this new master program at UiO. The Norwegian government has an ambitious strategy for the Norwegian space activities, including the establishment of Andøya Spaceport at the coast in Northern Norway, 69°N. The spaceport will facilitate launches of satellites in sun-synchronous and polar orbits. The government's ambition is also that Norwegian private and public industries will increase their downstream space activites. In addition, the geopolitical situation requires more space infrastructure to ensure the societal security, since Norway monitors large ocean areas in the Norwegian Sea and the Arctic Ocean. Qualified candidates are needed for these activities. The Norwegian Defense Research Establishment (NDRE) conducts extensive space activities and cooperates with UiO on both research and teaching. The space research on UiO have been ongoing for many years, primarily at the Department of Physics and the Department of Theoretical Astrophysics. The new master in space system is offered at the Department of Technology Systems (ITS), which also is the host department for the research-based innovation center for space sensors and systems (CENSSS). CENSSS is funded for 8 years by the Norwegian Research Council and has 9 industrial partners, including NDRE. The center is responsible for the RIMFAX radar on the NASA Perseverance rover on Mars, exploring the subsurface geology.

Several favorable aspects lead to the establishment of a new master in Space systems at ITS, UiO. The candidates will have close contact with well-established research groups, industry, and they will get hands on experience from a practical field-course at Andøya Spaceport/Andøy Space Education. We hope to educate well qualified candidates for the national and international space industry. ITS also cooperates with national universities, e.g. the University of South-Eastern Norway for a course in system engineering, and the Norwegian University of Science and Technology for research. We are currently in dialogue with international universities for possible new cooperation on research and education. The context for, and the content of the program and our future ambitions will be presented here.

[A-108]

SPEAR MISSION INSIGHTS: ENHANCING SUPERSONIC PARACHUTE TEST CAPABILITIES

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The primary objective of the Supersonic Parachute Experiment Aboard REXUS (SPEAR) was to fly and collect in-flight data of a Hemisflo ribbon drogue parachute at supersonic conditions. This drogue was developed in-house for the Stratos III and IV sounding rockets of Delft Aerospace Rocket Engineering (DARE), a student rocketry team in Delft. The SPEAR mission started in September 2018 and launched on REXUS 28 in November 2022 as part of the REXUS/BEXUS program. The mission was therefore constrained by the resources available to a student society, the REXUS vehicle and the timeline of the REXUS/BEXUS program.

The mission succeeded in deploying, flying and observing the parachute in supersonic conditions, marking the second supersonic parachute flight test in Europe. From the flight data valuable information was gathered on the successes and possible improvements of the SPEAR vehicle design and mission concept for supersonic parachute testing. With this information, several points of improvement can be identified and discussed.

This paper describes the key issues identified during the mission and post-flight analysis regarding the capabilities of SPEAR as a supersonic parachute test vehicle. It then presents several solutions and design alterations to improve the vehicle's performance and reliability. The paper also looks into alternative platforms that can be used for a similar test flight and presents different concepts.

[A-135]

EVALUATION OF REXUS FFU EJECTION SYSTEMS: INSIGHTS FROM PAST EXPERIMENTS.

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The German-Swedish student programme REXUS/BEXUS[1] allows university students to carry out scientific and technological research on research rockets and balloons. Free Falling Units (FFUs) can be implemented on REXUS which are ejected from the rocket and can perform research during their own freefall and re-entry.

The design, construction, and testing of ejection systems for these FFUs present a significant challenge for student teams, consuming valuable resources in terms of time and effort. The critical nature of these systems from a flight safety perspective introduces various additional requirements and needs attention and time during design reviews. With limited resources available to the team, this diverts attention from the primary mission objectives and may lower the scientific output. Recognizing the significance of expediting and simplifying the development of an FFU ejection system, teams can draw inspiration from existing systems on previous REXUS experiments.

Many previous ejection systems have successfully held down and released FFUs during REXUS missions, and these systems serve as a valuable repository of knowledge. By examining and learning from the design features and best practices implemented in these systems, new student teams can expedite their own development processes and allocate more time and resources to the scientific core of their experiments. The design of an ejection system should keep the following aspects in mind:

- Stiffness, preventing undesirable movement of the FFU and ensuring structural integrity and load distribution.
- Reliability, ensuring the consistent success of FFU ejection upon actuation.
- Repeatability, emphasizing the ability to assemble the ejection system consistently, is crucial for achieving uniform torque, load distribution, and, consequently, reliable performance to hold down and eject the FFU.

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[1] The REXUS/BEXUS programme is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Agency (SNSA). The Swedish share of the payload has been made available to students from other European countries through a collaboration with the European Space Agency (ESA). EuroLaunch, a cooperation between the Swedish Space Corporation (SSC) and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operations of the launch vehicles. Experts from DLR, SSC, ZARM and ESA provide technical support to the student teams throughout the project. REXUS and BEXUS are launched from SSC, Esrange Space Center in northern Sweden.

[A-179]

REXUS 32 – GAMEON: GLIDER FOR ATHMOSPHERIC MEASUREMENTS AND EXPERIMENTS

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GAMEon denotes "Glider for Atmospheric Measurements and Experiments," incorporating the legacy of a REXUS predecessor affiliated with our Ernst-Abbe-University of Applied Sciences. Building upon prior outcomes, our endeavor focuses on the advancement of a novel experimental platform.

The preceding GAME experiment established the feasibility of a glider transitioning from a sounding rocket to a stable gliding phase. Our current pursuit entails the construction of an atmospheric measurement platform capable of assuming a steady flight posture and operating autonomously. This platform is designed not only to ascertain its position and trajectory but also to capture environmental data such as methan, CO2, temperature and air pressure from different athmospheric layers.

The aim of our experiment is to build an atmospheric measurement platform which, starting from the ejection in the mesosphere, can assume a stable flight position and autonomously navigate to a target coordinate. This platform should not only determine its position and trajectory, but also record environmental data such as the composition of the atmosphere, temperature and air pressure from different atmospheric layers.

A central component of this experiment is also the communication of the glider platform with our ground station. This consists of a purpose-developed radio system, including specially developed antennas a designed for the high-speed dynamics and range requirements of our glider.

The ground station is also part of the navigation system, which ensures that the glider can navigate to a target coordinate. Direction finding using our 4 antennas is combined with data from 8 photodiodes, which determine the glider's relative direction to the sun in order to navigate without GNSS and despite the steep magnetic field lines in northern Sweden

In summary, our ambition is to address the limitations encountered in the GAME project while incorporating the aforementioned functionalities to enhance the glider's utility for expanded capabilities in atmospheric measurements.

Our experiment remains on schedule for completion ahead of the slated rocket launch in March 2024. Progress to date encompasses the completion of the glider's mechanical design, the electronics governing glider control, the ejection mechanism facilitating its release at the rocket's apogee, as well as the development of the antenna, communication systems, control algorithm software, and data link.

[A-168]

FLIGHT SAFETY STUDIES FOR STUDENT EXPERIMENTAL ROCKETS LAUNCH CAMPAIGNS

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To prepare for the arrival and the first launches of student experimental rockets from the Guiana Space Centre, flight safety studies have been conducted to preserve the safety of people and property. These preliminary studies are crucial for addressing the unique challenges posed by the introducing student experimental rockets into an operational space base. Recognizing that even rockets that have undergone all possible pre-flight tests to minimize failures, they can still experience issues. Our study focused on both nominal and degraded flight scenarios. Our methodology employed two distinct approaches to analyze the effects of wind on rocket trajectories. Initially, we used ERA5 wind data, which offers a broad set of wind profiles. This provided an initial overview of the trajectories under various wind conditions. Subsequently, we used a historical dataset of winds from radiosonde measurements, which allow us to use data directly measured on site.

Our calculations generated a wide array of potential rocket trajectories, enabling us to delineate a potential impact zone based on the points of fall. The results indicated that while the ERA5 data offered a valuable overview of the potential impact zone, the radiosonde data let to the identification of more precise and realistic fall points of the rocket. This led to the determination of dispersion ellipses. These ellipses map the potential impact zone regardless of the wind variations that may occur on the day of launch. The uniqueness of this research stems from the meticulous integration of wind data from radiosondes, thereby enhancing the realism and accuracy of our trajectory calculations.

[A-150]

FAILURE INVESTIGATION AND LESSONS LEARNED OF ROACH2 A REXUS 28 EXPERIMENT

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The experiment ROACH2 (Robotic in-Orbit Analysis of Cover Hulls 2) was part of the German-Swedish student programme REXUS and launched on November 7th, 2022. It was developed by a group of students of the small satellite student society of the University of Stuttgart (KSat e.V.). The primary objective of the experiment is to evaluate the feasibility of a rover moving on a spacecraft in reduced gravity and vacuum while data is collected about the traversed surface. The experiment consists of the Rover Holding Mechanism (RHM), the rover itself and the track for the rover to drive on.

The RHM held the rover in place during ascend and released it at the beginning of the experiment time. Then, the experiment suffered an electrical failure for an unknown reason. The ROACH 2 rover went into an unexpected reboot during the apogee of the REXUS rocket and was not able to conduct the experiment. This error never occurred before during bench tests. As soon as the experiments were recovered a visual inspection was conducted, but showed no anomaly in the electronic system, and the structure barely suffered damage. First all components are inspected for functionality separately and later the rover was assembled again for functional testing on the bench and then in the thermal vacuum chamber.

Due to several postponements of the launch due to the corona virus, fire on the launch facility and the beginning of the geopolitical situation on Ukraine´s borders the project posed technical and management questions since a major part of the team members left the team before the launch campaign. Know-how was limited, and team members were supposed to work on systems they had not developed. This led to a non-optimal preparation of the launch campaign. Those issues are further investigated, and also the methods why the team was nevertheless still able to maintain the project while other teams quit. Additionally, the focus of this paper lies in the failure investigation of the project, the approach of trying to reproduce the error, as well as the lessons learned of the project.

[A-89]

EXPLORING THE OPPORTUNITIES AND RISKS IN UTILIZING ARTIFICIAL INTELLIGENCE FOR EXPERIMENT CONTROL

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In recent decades, developing AI systems required substantial costs and human effort, often totaling millions of dollars. However, the emergence of large language models (LLMs) now presents an opportunity for the democratization of AI. While still in the early stages, there are ongoing explorations into utilizing LLMs not just for text generation but for solving real-world problems. AI has traditionally been employed in question-answer scenarios, image and text generation, storytelling, and various applications by tech companies such as web search, ads, sales prediction, and product suggestions.

As AI becomes integrated into daily life, there is potential to derive value from its usage. To unlock this potential, we must explore how AI can be tailored to meet our specific needs. This study focuses on the application of GPT, a prominent LLM, to bridge the gap between cyber-physical systems and scientists conducting experiments in specific environments that require a certain level of software expertise.

In the context of the TEXUS Sounding Rocket Program, which employs OPC UA as the industrial standard for data communication, the research explores the possibility of using GPT to streamline experiment control. The automatic mapping of GPT to OPC UA is seen as a time and cost-saving measure. The key question is whether integrating AI, specifically through LLMs, into experiment control offers advantages. Can AI assist scientists unfamiliar with the system in operating an Experiment Module? Can a natural language approach, such as using GPT, provide direct access to experiment operation comparable to a conventional knowledgeable engineer?

Several aspects need consideration, including defining suitable interfaces, establishing well-defined outcomes from natural language prompts, and identifying relevant concepts. This also entails evaluating the risks associated with adopting such technology. The study delves into whether experiment control can be entrusted to AI and the potential benefits and challenges associated with this approach. The findings of this research contribute to the evolving era of AI, where scientific entities like TEXUS can customize AI to enhance their projects, leveraging novel technology to address specific needs and challenges.

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Thursday 23 May, Morning session – part 1

Room 2

Chair: M. Flugge

[A-50]

LUNAR ANALOG EXPERIMENT PLATFORMS WITH FOCUS ON SOUNDING ROCKETS

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Almost 53 years ago, Neil Armstrong took his famous step on the moon. The return of humans to our Earth's satellite is a declared goal of international space exploration. Many technological and scientific questions have to be answered before a moon station can be operated for a longer time. This requires experiment platforms to simulate lunar environmental conditions.

The LUNA moon analog facility in Cologne will mark an important contribution in preparing for future Moon missions. In a 700 square metre size hall, nine metres high, the special environmental conditions of the moon will be realistically simulated. Moon-like dust, known as regolith, will cover the entire floor of the laboratory, there will be replicas of craters, and a suspension system that will allow astronauts to be lifted to one-sixth of their earthly weight and thus experience and exercise the reduced gravity of the moon.

Complex experiments relying on the actual reduction of the gravitational force cannot be carried out in the LUNA hall. Platforms usually used for experiments in zero gravity must be specifically adapted for this purpose. Parabolic flight missions with Lunar and Mars gravity parabolas have already been practiced for many years. Since 2022, experiments can be conducted under conditions of weightlessness at the new GraviTower in Bremen. ZARM's second drop tower facility daily offers up to 20 experiment runs per hour (over 200 per day) and a microgravity period of max. 2.5 seconds depending on the desired acceleration and deceleration profile. From 2024 on, GraviTower's capabilities are extended to a partial-gravity mode especially providing Lunar and Mars gravity levels (approx. 3 seconds), e.g., to prepare appropriate sounding rocket or space missions.

Sounding rockets can be utilized as a platform providing alternative *g*-levels between 10^{-5} *g* to hyper-*g* with experimenting times of up to 6 minutes. For this purpose, different concepts are feasible like controlled rotation at module level using a centrifuge. Furthermore, the entire payload can be rotated around the longitudinal or transverse axes using cold gas thruster systems allowing simultaneous experiment conditions under various g-leves (i.e. Moon and Mars). Anopher option is to accelerate the whole payload stack in one direction creating a defined residual *g*-force. This paper describes the various technical concepts for missions under moon or mars gravity conditions.

[A-62]

AUTOMATION OF LAUNCH SEQUENCES FOR SOUNDING ROCKETS

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Our study in the context of the master's thesis at the City University of Applied Sciences Bremen addresses the underexplored realm of automating launch sequences for sounding rocket missions as a contribution to the burgeoning integration of automation and digitalization in spacecraft technology. Focused on sounding rockets programmes, the research aims to automate manual execution steps for components like the Go/No-Go System or Countdown Display. Since both the TEXUS Program and the HyEnd Project are launched from SSC ESRange, the study focuses on this launch Site's specifics. The scope of the study will be limited to procedures before lift-off.

The main objective of the study is to adapt automation techniques from larger-scale launch systems like Ariane 5/6 to match the specific requirements of sounding rocket launches. The study aims to craft improved launch procedures customized for sounding rockets by identifying similarities and differences between commercial and sounding rocket launchers and mapping the common aspects into the sounding rocket context.

Anticipated outcomes encompass a generalized workflow of sounding rocket launch sequences, a flexible ground-based procedure adaptable to diverse launchers and sites, and insights crucial for transitioning from ground-based to onboard procedures.

Concrete tasks include dissecting launch workflows, extracting common requirements, and conceptualizing a versatile ground-based procedure adaptable across various sounding rocket platforms as well as outlining initial requirements for onboard software and demonstrating the procedural portability from ground-based to onboard systems.

Model-based Systems Engineering approach is used to describe and simulate the process steps and systems involved in order to determine the software and procedure-based automation, while keeping the Launch Authority in the ground operation. While automation is an important part, Human Interaction will still play a major part in the configuration and during operation.

A corresponding prototype, developed and tested as cross section of the Texus and HyEnd Projects specifics, shall show the principal feasibility of this approach.

To evaluate the achievements, the quality characteristics and metrics applicable for sounding rockets will be identified according to ISO/IEC 25000 and the corresponding attributes will be proved accordingly.

[A-157]

IMPROVING SCIENCE CONDITIONS BY ADAPTING SOUNDING ROCKET UPPER STAGE IGNITION TIME IN-FLIGHT

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The three-stage hypersonics research mission STORT was launched successfully from Andøya Spaceport in June 2022, using a new system developed and qualified by MORABA for the in-flight determination of the time of ignition for the upper stage rocket motor. The system uses the on-board navigation solution to iteratively run numerical simulations predicting and evaluating the flight under the assumption of an instantaneous upper stage ignition, and commands actual ignition as soon as predefined criteria are met. This reduces the trajectory dispersion and thus improves the science conditions during the high Mach number phase of flight. This paper gives an overview over the functional architecture and relevant implementation details as well as the type of suppressed trajectories where this can be applied. The actual flight data is analyzed and compared to the same flight with a fixed upper stage ignition time. A useful metric to assess the usefulness of this upper stage ignition time is proposed, and some lessons learned for multi-stage trajectory design are provided.

[A-154]

VSB-30 SOUNDING ROCKET PERFORMANCE AND TRAJECTORY DISPERSION

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The two-stage sounding rocket VSB-30 has been used extensively for microgravity and hypersonics research missions. From the launch site Esrange in Northern Sweden alone, MORABA has launched 28 microgravity missions to date. This paper provides an overview over flight performance characteristics with a focus on microgravity missions specifically, including overall trajectory modelling, dispersion prediction, and post-flight trajectory matching, while accounting for launcher infrastructure and other constraints. Flight data from past missions is dissected with a special focus on flight performance and microgravity conditions achieved. The current state of dispersion prediction is presented and analyzed

[A-125]

RED KITE SOUNDING ROCKET MOTOR QUALIFICATION

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Red Kite© is a commercially available, serially produced and ITAR-free solid propellant sounding rocket motor in the class of one ton of Net Explosive Mass. It was developed in response to a sustained demand from the scientific community for high performance sounding rocket vehicles. The Red Kite is primarily designed as a powerful booster for military surplus and commercial second stages, but can also be used as a sustainer when boosted by either an even larger motor or by another Red Kite. Typical payloads will range between 200 to 600 kg. When used in a mission design tailored to microgravity research, typical apogees range between 250 to 300 km, while the needs of hypersonic community can be met by a suppressed trajectory design, typically providing horizontal flight at Mach numbers between 6 to 9 in the altitude band 30 to 60 km. Bayern-Chemie GmbH was contracted by DLR in 2020 for the development and manufacturing of the Red Kite solid rocket motor. After initial design and materials selection phases, ground testing of mechanical, pyrotechnical and electrical subsystems was conducted. Finally, two full scale qualification motors were successfully test-fired in August 2023 at Esrange Space Center, with the test models tempered to the upper and lower limits of the operational temperature envelope and after having completed a rigorous protocol of thermal cycling and mechanical vibration representative of loads to be expected during handling, transport and flight. Following successful qualification, serial production was initiated and serial motor number one was released for a maiden flight from Andøya Space Center in November 2023, proving the design in flight with great success. The paper gives a summary of the motor performance, its system component design, the qualification program and its application spectrum for sounding rocket vehicles.

[A-188]

PRACTICAL CONSIDERATION AND ADVANTAGES OF PIEZOELECTRIC BASED SENSORS FOR PROPULSION TESTING

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Rocket motor testing requires measurements of force, pressure and vibration to characterize operational performance. Historically, thrust measurements use strain gage-based technology where Piezoelectric technology offers advantages that should be considered on an application basis. For example, the force piezoelectric technology can be used to measure the thrust generated by a propulsion device, by allowing a quasi-static measurement and provides the capability to follow dynamic fluctuations. Thus, the piezoelectric force technology supports higher frequency propulsion systems where strain gage technology tends to have limitations.

The advantage of Piezoelectric technology includes longevity, modularity, rangeability, high overload capacity, high frequency response as well as ease of use. Piezoelectric pressure sensors dynamically measure combustion instabilities caused by pressure pulsations and acoustic resonances in the combustion chamber, which may reduce engine performance as well as induce structural vibration. Traditional water-cooled pressure sensors have limitations especially in extreme temperature applications where specially developed PiezoStar® flush mount pressure sensors can operate without cooling up to 1000°C and deliver measurement frequencies of 0.5Hz to 20KHz for example. Futhermore, Piezoelectric pressure sensors are also used to study dynamic pressure fluctuations in the feed system under cryogenic environment.

Static pressures are measured with a traditional static piezoresistive sensor and a standoff to reduce temperature effect for a low bandwidth solution. Whereas vibrations are measured with cryogenic, moderate and high-temperature piezoelectric or IEPE (Integrated Electronics Piezoelectric) accelerometers depending on the mounting location. Ideally, such accelerometers have low sensitivity to temperature using PiezoStar® or quartz-based technology to measure operational structural vibration to characterize operation and eliminate conditions which cause catastrophic failures. For each measurand, the paper provides supplementary measuring principles including mounting and installation as well as usage pros and cons to provide a comprehensive review of practical considerations of use for piezoelectric technology as related to propulsion system testing.

Atmospheric Physics & Chemistry 4

Thursday 23 May, Morning session – part 1

Room 3

Chair: M. Ghysel-Dubois

[A-9]

THE NEW LIGH AEROSOL COUNTER LOAC2 FOR THE STUDY OF AEROSOLS UNDER BALLOONS

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Liquid and solid aerosols play a significant role in climate studies and in atmospheric chemistry. In the middle atmosphere, they can originate from volcano eruptions, major wildfires, anthropogenic pollutions, and more rarely form atmospheric entries. The concentrations and nature of the aerosols depend on their sources and on the vertical and horizontal transports. In-situ measurements from all kind of balloons are very useful to better characterize the aerosols up to an altitude of ~35 km.

For that purpose, a light aerosols counter, LOAC, was developed 10 years ago to count and size aerosols from ~200 nm up to ~50 µm, and to determine their main typology (liquid, minerals, carbonaceous). About 200 flights were conducted worldwide using weather balloons to document specific events, as aerosols from the Hunga Tonga eruption. Also, long duration flights were conducted with tropospheric balloon (flights of several hours during the Charmex campaign above the Mediterranean Sea) and with stratospheric long duration balloons (flights of several weeks during the Strateole2 campaign at about 20 km of altitude in the tropical region).

LOAC is now an old instrument, and strong electronic and optical improvements are needed, in particular for the detection and the typology identification of the smallest aerosols in case of small concentrations as those that can be encountered in the background stratospheric conditions. A new generation of LOAC instrument, called LOAC2, was recently developed, using a more sensitive electronics and a new design for the optical chamber. Measurements are now conducted at 4 scattering angles instead of 2 angles with the previous version of LOAC, to better determine the scattering properties of the particles and thus their typology. With such configuration, different families of mineral particles can be identified, as well as black carbon and carbonaceous organic particles.

First technical and scientific flights were conducted under meteorological balloons, and the first vertical profiles will be presented. Also, LOAC2 is involved in the second scientific campaign of Strateole2 in 2025, and in the EarthCARE validation program from mid-2024. The planned strategy of measurement of the EathCARE campaign will be also discussed.

[A-17]

STRATEOLE-2: LONG-DURATION BALLOON OBSERVATIONS IN THE TROPICAL LOWER STRATOSPHERE

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Strateole-2 is a French-US project aimed at improving our understanding of composition, transport, dynamics and physicial processes in the Tropical Tropopause Layer. The originality of the project pertains to the use of CNES long-duration superpressure balloons able to fly for months near either 18 or 20 km altitude. Overall, Strateole-2 will relesase about 50 balloons, and each balloon carry up to four different instruments. Two campaigns have already been performed in boreal winter 2019 and 2021, with respectively 8 and 17 balloons launched from the Seychelles International Airport. The third and final campaign of the project will take place in boreal winter 2025, and is expected to fly 22 balloon.

The presentation will provide an overview of the main scientific achievements obtained so far with the observations gathered during the first two campaigns. An emphasis will be put on the characterization of planetary and gravity wave activity, and their potential interactions with the life cycle of thin cirrus clouds observed in the vicinity of the tropical tropopause.

Some of the instruments that were flown during the first two campaigns encountered a number of issues associated with the drastic environmental constraints encountered during the long-duration flights. These issues and the corrections that are foreseen for the forthcoming campaign will be briefly described. This third campaign also provides an opportunity to fly new instruments addressing processes that were not observed during previous flights, e.g. atmospheric electricity or infrasounds. The presentation will give some details on a newly developed sonic anemometer aimed at better disentangling the air and balloon motions near the Brunt-Väisälä frequency.

[A-21]

AN UPDATE ON THE STRATELEC (STRATÉOLE-2 ATMOSPHERIC ELECTRICITY) PROJECT

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About 45 lightning flashes occur per second all around the Earth with a predominant distribution over the continents and along the inter-tropical band. While different types of Transient Luminous Events (TLEs) induced by lightning flashes can be produced above the thunderstorms, Terrestrial Gamma Ray Flashes (TGFs) are bursts of high-energy photons originating from the Earth's atmosphere in association with thunderstorm activity with a great majority of TGFs occurring in the inter-tropical region. In addition to those radiation bursts, another type of high-energy emission, so-called gamma ray glows, has been observed inside thunderstorms corresponding to significant enhancements of background radiation that last for more than a few seconds. All these connected phenomena remain to be documented both remotely and on an in-situ manner. Balloon-borne missions offer the required in-situ close-range high-altitude measurements of the ambient electrostatic field, conductivity, TGF radiation and lightning occurrence for a better understanding and modeling of these complex phenomena and of their effects on the Earth atmosphere and the global atmospheric electrical circuit.

[A-177]

BALLOON BORNE OBSERVATION OF TROPICAL GRAVITY WAVES: PHASE SPEED AND VECTOR MOMENTUM FLUX.

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Tropical convection excites a broad spectrum of waves. At the smaller scale end, the gravity waves significantly impact the atmosphere, from influencing synoptic systems to being with planetary scale waves an essential driver of the Quasi-Biennial Oscillation (QBO). When the resolution of atmospheric general circulation models usually resolves the large-scale waves, it is too coarse to fully resolve smaller scale dynamics such as gravity waves, which impacts are therefore included using parameterizations. These parameterizations are calling for enhanced observational constraints, as simulation of major features of Earth climate such as the QBO still remain particularly challenging, especially under climate change.

We use high resolution in-situ observations of the whole spectrum of gravity waves in the intrinsic frame from super-pressure balloons of the Stratéole-2 campaigns in 2019 and 2021. The dataset consists of 24 flights in the tropical band, that lasted up to several months each, at around 18 and 20 km of altitude. The gravity waves' momentum fluxes and phase speeds are computed, as well as ground-based phase speeds using the balloons' measurements of horizontal winds. The largest momentum fluxes are associated with intrinsic phase speeds lower than 30 m/s. As convection in the tropics is the main source of tropical gravity waves, we also describe the observed waves sources by the combination of the Integrated Multi-satellitE Retrievals for GPM (IMERG) products to identify convective cells near the balloon position and ERA5 re-analysis to estimate the wind environment and motion of the convective cells. Last, we investigate the component of the observed gravity wave activity that is triggered by these cells acting as an obstacle to the surrounding flow. The balloon-observed wave packets corresponding to this component are selected by comparing their ground based phase speeds with the estimated convective cell motion, direction and momentum fluxes. We further describe these waves through their intrinsic period, horizontal wavelength and location and compute that they contribute up to 12% of the zonal momentum fluxes observed.

[A-145]

THE CANADIAN IMAGING FOURIER TRANSFORM SPECTROMETER FOR AOM: A TEST FLIGHT ON A HIGH ALTITUDE BALLOON

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Environment and Climate Change Canada (ECCC) along with the Canadian Space Agency (CSA) are investigating the concept of flying a high spatial resolution Fourier Transform Spectrometer onboard multiple spacecraft in highly elliptical orbits. The combination of the instruments and the platform will produce almost geo-stationary like measurements of carbon dioxide, methane and other greenhouse gases over the entire arctic. This concept is being studied as part of the larger international initiative called the Arctic Observing Mission (AOM).

In the summer of 2022, our Atmospheric Remote Sensing group at the University of Sasaktchewan was involved with the CSA and ECCC in a prototype demonstration on the intended space based instrument. This demonstration involved a high altitude balloon launch from the CSA base outside of Timmins in northern Ontraio. This presentation will discuss the instrument development and lab characterization that led into the flight, the flight itself and the data collected and finally the analysis of the data with a focus on the challenges created by the balloon environment and the overall successes of the campaign. The balloon environment provided an excellent testing ground and we believe the campaign has successfully identified potential risks and provided a path toward solutions.

[A-198]

THE FUTURE OF NOCTILUCENTS CLOUDS

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Noctilucent clouds (NLC) consist of water ice particles which appear in the summer mesopause region at middle and polar latitudes. They owe there existence to extremely low temperatures. We have applied the background model LIMA (Leibniz Institute Model of the Atmosphere) and a microphysical model MIMAS (Mesospheric Ice Microphysics And tranSport model) to study the long term historical development of NLC. More recently, we extended these studies including future climate change predictions by modifying the concentration of carbon dioxide and methane. Carbon dioxide leads to a cooling of nearly the entire middle atmosphere (fostering the conditions for the presence of NLC), whereas methane is nearly completely converted to water vapor in the mesosphere leading to larger and more abundent ice particles, i. e., to brighter and more frequent NLC. In this study we present model simulations of the future development of NLC. We investigate typical NLC parameters, such as mean particle radius, ice number densities, and backscatter coefficients, and their relationship to background conditions (temperature, water vapor). It turns out that ice particle parameters (size, backscatter) are nearly entirely determined by the amount of water vapor, whereas the (geometric) altitude of NLC is mainly given by a shrinking of the atmosphere (due to cooling) below NLC altitudes. The effective transport of water vapor known as `freeze drying' leads to a significant enhancement (nearly doubling) of water vapor at NLC heights within this century. We will also present results regarding the potential future impact of NLC on the extinction of solar radiation.

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Thursday 23 May, Morning session – part 2

Room 1

Chair: K. Lesch

[A-5]

TRANSPIRATION COOLING EXPERIMENT TRACE – RESULTS OF A REUSABLE HEATSHIELD REENTRY EXPERIMENT ON REXUS 31

Nicolas Heyn, Sebastian Bartel, Julius Wirth, Alexander Kraus, Lukas Gramling, Till Schmitz, Moritz Hoffmann, Steffen Ostwald, Nicolas Pielczyk, Gideon Wiebesiek, Jan David Ullmann, Sebastian Dominik, Rishabh Puri, Valentin Egolf, Hasan Al Jeratli, Julian Wieners, Rico Böhm, Timo Bakr, Jan Lukas Schmitz

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The space industry is moving towards sustainability. Private space companies such as SpaceX set the pace towards reusable launchers, while the "ESA - Clean Space" initiative sets on concepts like "in orbit servicing" and "active debris removal". To reduce costs and therefore allow such projects, reusable spacecrafts are imperative. During atmospheric re-entry of spacecrafts, a heat shield is crucial. Currently deployed heat shields are either single-use and need to be fully replaced or need complex and costly maintenance cycles. Transpiration cooling offers an alternative to these established technologies and thereby enables the next step towards spacecraft reusability and sustainability. For transpiration cooling heat shields, no hardware replacement is needed, and maintenance can be kept to a minimum. The costs of the heat protection system can thus be reduced.

The transpiration cooling effect is achieved by blowing a cooling gas through a porous surface into the boundary layer surrounding the structure to reduce the thermal loads acting upon it. The reuse of the system can simply be achieved by refilling the cooling fluid tank.

TRACE (TRAnspiration Cooling Experiment) is a project developed by a team of students from the Space Team Aachen e.V., an association of the RWTH Aachen University in Germany. TRACE is part of the German-Swedish student programme REXUS/BEXUS, which gives students the opportunity to conduct experiments onboard a sounding rocket. The experiment aims to test and validate transpiration cooling heat shields on a re-entry vehicle in a free flight experiment.

The TRACE free-flight experiment will be carried in the nose cone of a REXUS rocket and jettisoned at an altitude between 70 and 90 km, after which the TRACE capsule will fly back to earth independently. The experiment's shape allows for passive aerodynamic stabilization during entry into the lower atmosphere as TRACE reaches speeds of up to Mach 3.5. At an altitude ranging between 30 and 10 km, the high velocity leads to strong heating of the outer structure. Part of the surface is equipped with new transpiration cooling elements, enabling a comparison of the surface temperature and heat transfer with reference surfaces, resulting in measurements of the effectiveness of the cooling effect. At an altitude of about 10 km, a parachute sequence for recovery will be activated.

The results of the experiment will be presented at the conference and used to guide future designs, to validate assumptions, simulation tools and flight predictions.

[A-119]

Mechanical Design Specifications and Manufacturing Processes Used in the Ferrofluid Application Study (FerrAS) Project

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Novel additive manufacturing processes with Titanium utilized in the Ferrofluid Application Study (FerrAS) project are to be presented in this paper. FerrAS investigates pumping applications based on ferrofluid and is carried out by the Small Satellite Student Society at the University of Stuttgart (KSat e.V.). It is part of the REXUS/BEXUS cycle 14 and will test two pump experiments on a REXUS sounding rocket launching from Esrange (Sweden) in March of 2024.

To carry out the FerrAS experiment, two pressure-tight containments with a combined inner volume of approx. 1,6 dm^3 were required, which were also capable of withstanding an acceleration load of up to 20g during launch. As part of a collaboration with the Fraunhofer Institute for Production Technology (Fraunhofer IPT), these containments were produced from TiAl6V4 Titanium using a Laser Power Bed Fusion (LPBF) process on an EOS M 290 printer.

This manufacturing process permitted many design freedoms, while also imposing a range of limitations and challenges, especially regarding post-processing and thermal warping of printed parts. To counter these effects and therefore ensure minimal deviation from the targeted dimensions, different methods and designs of layer sintering have been explored.

Additionally, a sealing concept for the containments had to be implemented to fulfill the requirement of withstanding a 2 bar pressure difference from inside the containments, double the expected pressure, to comply with launcher requirements. To accomplish these goals, Finite Element Analysis tools were applied to conduct studies regarding modal frequencies, pressure handling and mass optimization. Moreover, pressure tests were conducted with different sealing concepts. The knowledge gained from the numerical analyses and the tests was then incorporated into the design. In addition, generative design tools were used to optimize specific component aspects.

The methodology applied surrounding the novel manufacturing process and the development and testing of the sealing concept are described in detail in this paper. It may also serve as a design guideline for compact and light-weight fluid containments for high acceleration applications like sounding rockets, made from high-tech metal materials.

[A-142]

PR^4: A RADIO INTERFEROMETRY LOCATION TRACKING SYSTEM FOR SOUNDING ROCKETS

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In the modern day world localisation and tracking of objects has become increasingly important. Global Navigation Satellite System (GNSS) based positioning solutions are widely used. However, due to the large acceleration environment, GNSS based tracking provides unsatisfactory accuracy and update rates for use on sounding rockets. The radio interferometry experiment of the Payload for Radio interferometry and Radiation measurement on Rockets Revisited (PR^4), scheduled to fly on the REXUS31 sounding rocket in March 2024, proposes an alternative way of tracking for these rockets. This experiment is a continuation of the work of the Payload for Radio interferometry and Radiation measurement on Rockets (PR^3), which was tested on the REXUS25. PR^4 aims to perform live location tracking of sounding rockets using compact radio transmitters and an array of ground based receiver stations. Accuracy in the order of centimetres to decimetres with an update rate of one kilohertz is expected. The system can be deployed on the launch site and is scalable.

The proposed localisation method makes use of a technique called interferometry, commonly used in radio astronomy. The rocket is equipped with three patch antennas mounted on the outside of the PR^4 module, powered by three transmitters inside this module. Each transmitter broadcasts a monochromatic radio signal with a different frequency. The various ground based receivers measure the phases of the received signals every millisecond. The received phase is dependent on the location of the source, time of transmission and time of measurement. Using phase differences between receivers, the location of the source is reconstructed. The aim is to be able to use both short baseline interferometry and long baseline interferometry. For short baseline interferometry a minimum of three receiver stations is needed for successful tracking, with long baseline interferometry requiring a minimum of four receiver stations. The use of more receiver stations increase robustness and accuracy. The different receiver stations are synchronized using stationary reference beacons, keeping localisation accurate over time.

Ultimately the PR^4 interferometry based tracking system will be developed into a reliable, cheap system for tracking sounding rockets.

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[A-121]

SHAKING UP SPACE RESEARCH: PRELIMINARY INSIGHTS INTO VIBRATION EXPERIMENT IN MICROGRAVITY FROM THE BREMEN TOWER EXPERIMENT

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In the pursuit of advancing our knowledge in space engineering, particularly for rocket systems operating in low Earth orbit, the SLuGG ESA Academy Experiments Program (Solid Lubricants in µGravity from Gdańsk) at Gdańsk University of Technology has undertaken a critical study focusing on the behavior of mechanical vibrations in microgravity. Utilizing an advanced vibrational measurement system, our research team was able to precisely measure and analyze the characteristics of vibrations under highly simulated microgravity conditions, akin to those experienced in space.

The centerpiece of our experiment is a specially designed cylindrical vacuum chamber located in the Bremen drop tower. This setup effectively replicates the microgravity conditions found in space, providing a parallel to the experiences encountered in rocket systems and low Earth orbit operations. The primary goal of our investigation is to unravel how the absence of significant gravitational forces influences vibration behavior. To achieve this, we meticulously observed and recorded the vibrational patterns of a cantilever within the vacuum chamber, ensuring controlled microgravity conditions for accurate analysis.

The preliminary findings from this research offer insights into the world of vibration dynamics in microgravity. These insights are crucial for the design, testing, and operation of rocket mechanisms, influencing decisions that impact the structural integrity and operational reliability of spacecraft. Particularly, our observations hold significant value in understanding the challenges posed by prolonged exposure to the harsh conditions of low Earth orbit.

This study not only enriches our fundamental understanding of mechanical behavior in space but also paves the way for the development of more robust and efficient rocket designs. Our findings are expected to have far-reaching implications for future space missions, contributing to the enhancement of rocket technology and ensuring safer, more reliable space exploration. The SLuGG ESA Academy Experiments Program stands at the forefront of this innovative field, driving forward our capacity to conquer new frontiers in space engineering.

[A-182]

CUBESAT DEPLOYER FOR SOUNDING ROCKETS

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Yes, I know it stupid to deploy a satellite on a suborbital trajectory but hear me out.

Andøya Space has developed a Cubesat deployer for sounding rockets. This deployer will host up to four 1U Cubesats that can be deployed on a suborbital trajectory from scientific sounding rocket launches. A typical suborbital launch will give the Cubesats some minutes of free flight in vacuum and microgravity conditions.

This is primarily targeted at students, but we also see a potential to use this to deploy scientific sub payloads like our 4D space system. And for use as technology demonstration tool for Cubesat technology. Using a suborbital launch for highly experimental and student payload can also be a way to address the increasing problem of space debris.

We have chosen a minimalist design using only a single pyrotechnic wire cutter for deployment and a completely mechanical system with no electronics that utilizes the power of springs for the different actuations. This keeps the development and production cost low. The module fits into our standardised 365mm hotel payload sections as well as NASA standard structure used in their RockSat-X program.

The main difference between our deployer and a traditional orbital deployer, is the need to deploy the Cubesats while the rocket is spinning. We have designed the deployer to work from zero spin all the way up to a worst-case scenario of 6hz spin to account for many different rocket configurations.

This project was the first where we did all the machining in-house with our new CNC machine to verify its capability and to gain experience in designing for inn-house production.

This development project can also be seen as related to the Andøya Spaceport development as we work to better familiarize ourselves with satellite technology and position ourselves for future possibilities.

The CubeSat deplayer is planned to fly on the GHOST student mission in 2025 from Andenes.

Technology & Infrastructures for Balloons 5

Thursday 23 May, Morning session – part 2

Room 2

Chair: S. Roth

[A-14]

ISSUES ENCOUNTERED ON THE ENVELOPPE MATERIALS OF STRATOSPHERIC BALLOONS

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The CNES's balloon department gathers around sixty people specialized in balloon design, flight chain assembly, nacelle architecture, integration & testing, flight physics and operations. The CNES currently uses 3 types of stratospheric balloons for scientific missions: ZPB (Zero Pressure Balloon), SPB (SuperPressure Balloon) and MSB (Maneuvering Stratospheric Balloon). Depending on the balloon type, the materials used for the skin envelope are of different natures: mono-oriented polyethylene films for ZPB, polyester-based multilayer films for SPB and bioriented polyethylene films for MSB. Their specific physico-mechanical properties are chosen according to their mission constraints. (16 to 40 km altitude and from – 110 to -20°C). The films technical requirements are mostly low envelope mass, thermo-mechanical resistance, creep resistance, UV/ozone ageing resistance and gas tightness.

It is rarely mentioned how difficult it is to produce these thin polymer films with such specific criteria. Going through the film qualification process you have to deal with multiple obstacles to obtain a very homogeneous high-performance envelope film which has to last the entire flight time.

The obstacles can be found at various levels. It can come from the film production by showing repeatability issues, process limits, machine obsolescence, production shutdown, raw materials obsolescence or shortage, know-how loss, minimum order quantity constraints and limited standard thicknesses.

The assembly process which enables to go from a film gore to the balloon envelop. During this manufacturing step, it is necessary to preserve the materials integrity and to maintain homogeneous mechanical properties at the assembly interfaces.

There are very important rules while doing quality control tests to verify the films compliance. For instance, the tensile tests method for thin & flexible films must follow minutious handling and operating conditions (sample dimensions, sample tightening, preload, test speed, constant test temperatures, etc.). It is also a challenge to implement the most representative tests to simulate the real envelope's living conditions, such as cycling tensile test methods, biaxal test methods, simulated ageing tests and reduced-scale models. The results from all these tests often generate multiple fracture profiles or complex behaviors that take time to interprete and understand.

Other very common issues are from the material itself as it often turns to be non-compliant to the technical requirements by showing low mechanical results and undesirable fracture profiles (delamination, premature failure, cold brittleness, high anisotropy). Perspectives to solve these recurring problems will be discussed during the presentation.

[A-44]

IMPROVING STRATOSPHERIC BALLOON ENVELOPE: A NEW MULTILAYER PE/EVOH/PE POLYMER FILM

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The French Space Agency (CNES) is a major actor in the stratospheric balloons sector. They have full control over every step of stratospheric balloon missions (assembly, launch, exploitation of collected data). CNES uses Linear Low Density Polyethylene (LLDPE) as the envelope of their Zero Pressure Balloon (ZPB) due to its lightweight, its good thermo-optical, and adapted tensile mechanical properties. Thanks to its practical advantages listed before, LLDPE is considered as the envelope structure of other types of stratospheric balloons such as Ultra-Long Distance Balloon (ULDB – Pumpkin, in development) or Aeroclipper. These types of balloons would have a pressurized structure with helium as supporting gas. For this kind of new applications, LLDPE lacks some properties: a low helium permeability (i.e. high gas barrier) to retain helium as long as possible and improved tensile mechanical properties to support the pressure. Therefore, a more adapted material for these new applications is needed. The study of the microstructure of polymer films can help us find such new material. The use of molecular mobility as a probe of the polymer microstructure is a very useful method in the understanding of polymers physical properties. Various methods exist to make that link between molecular mobility and macroscopic mechanical properties.

The aim of this study is to measure the benefit of a layer of poly(ethylene-co-vinyl alcohol) (EVOH) copolymer to a LLDPE film on its helium permeability. Indeed, EVOH is known to have one of the lowest gas permeability amongst polymers. This multilayer PE/EVOH/PE material is composed of two external layers of LLDPE and one internal layer of EVOH. A comparison of the microstructure – macroscopic mechanical properties relation between the LLDPE currently used for ZPB, a new LLDPE used for the multilayer PE/EVOH/PE and the multilayer film itself will be performed. These measurements will be completed by Dynamic Mechanical Analysis (DMA).

Helium permeability measurements have shown that the addition of EVOH into LLDPE can help reduce by four times its helium permeability. Regarding DMA results, PE/EVOH/PE observe better tensile mechanical properties than LLDPE. These improvements in the material gas barrier properties and tensile mechanical properties make it a very interesting candidate for pressurized balloon applications. To fully understand the macroscopic behaviour of such complex material, the study of its microstructure has been performed to assess the contribution of each layer to the global response of the material.

[A-12]

POLYMERIC ROPES AND TENDONS FOR SPACE APPLICATIONS

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Tendons are widely recognized today as extremely useful elements in many mechanical designs and can be used as means of stiffening and supporting tall constructions (ex. lifts, cranes, tents, bridges, transmission belts and ropes, small satellites etc.). Tendons can also be used in robotic mechanisms and force transmission components. An important application for cords is also in stratospheric balloons used for wide array of research, parachutes (that can be used for landers or probes) and in the future possibly regolith conveyors on moon stations. As polymer materials continue being developed their potential in space applications needs to be researched.

For this study two types of polymer materials were selected: Kevlar (aramid fiber) and UHMWPE (Ultra High Molecular Weight Polyethylene). Both were tested in the form of thin ropes/cords that had the same diameter (0.7 mm) and weave and were produced by the same company (Atwood Rope MFG). Those materials have properties that could allow them to work with a good mechanical properties in outer space environment. Additionally to adapt UHMWPE for withstanding high temperatures (above 150 ˚C) it was subjected to β radiation in order to cross-link the polymeric chains to make it stiffer and more resistant to temperature change.

The materials were tested for tensile strength first in room temperature and then low, cryogenic temperatures using liquid nitrogen cooling (down to −196 °C). Two types of tensile test were performed. One was done using a device made by authors and the other using Zwick Roell (ZWICK 1435) universal testing machine. Differential Scanning Calorimetry was performed to verify the working temperature range for both materials and the effects of cross-linking UHMWPE with β radiation. Additionally different methods of fixing the rope ends were tested for tensile properties and their durability. The results point to both materials being able of carrying load and being resistant to britteling in cryogenic applications. Both materials are able to withstand and carry high loads of even 90 kg and over, depending on treatment and material type. While UHMWPE proved to be up to 100% stronger in cryogenic conditions, Kevlar still performs better at high temperatures. Additionally an approximate 40% raise in strength was observed for cryogenic conditions in relation to room temperature in UHMWPE and a slight raise in case of Kevlar.

[A-82]

THERMAL ANALYSIS OF SUNRISE III AND COMPARISON WITH FLIGHT-DATA

Alejandro Fernández-Soler[1], David González Bárcena[1], Javier Piqueras-Carreño[1], Ignacio Torralbo[1]

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SUNRISE III is the third flight of a solar telescope on-board a Long Duration Balloon that took place in Kiruna, Sweden in July 2022. Despite some issues during the release forced to an early cut off, the mission completed the ascent phase, crucial from a thermal perspective, and temperature data was recorded. The thermal analysis and design of SUNRISE III has meant a challenge. Even though the lunch site and epoch are the same as previous flights, the thermal environment characterization has been redefined through a deep analysis of real data observations, not only for the floating phase but also for the ascent phase. In addition, low temperatures found in the tropopause together with the jet streams that appear at around 12 km caused by the large temperature differences that exist in the atmosphere, could make the system to reach its minimum temperature during this phase. In addition, contrarily to the analytical studies performed for previous SUNRISE flights, in this case, the ascent phase of SUNRISE III has been analysed with ESATAN-TMS combining a dynamic, a geometrical and a thermal model in order to implement the convective effects through empirical correlations. Here, the float and ascent phase thermal analysis are compared with flight data obtained a good agreement that allows to validate the followed assumptions.

[A-51]

EXPLORING NEAR-SPACE DYNAMICS: COMPREHENSIVE INSIGHTS AND ACCELERATION PROFILES IN SMALL STRATOSPHERIC BALLOON MISSIONS

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The utilisation of stratospheric balloons has witnessed a surge in popularity, offering a unique avenue for students to gain hands-on experience in executing missions within near-space conditions. The relatively low initial cost and the challenging environment render it the preferred choice for scientific experiments that aim to validate their adaptability in a space-related context. Thus, a thorough understanding of the environmental conditions to which these experiments are subjected becomes imperative for ensuring the success of such missions. Although there is considerable knowledge regarding the anticipated temperature, pressure, and radiation exposures during these missions, the expected accelerations throughout the diverse mission phases, particularly for smaller balloons, remain relatively unexplored.

In order to address this knowledge gap, a series of missions was performed involving small stratospheric balloons (under 2 kg). The primary objective was to establish typical acceleration values across all relevant flight phases. To accomplish this, state-of-the-art custom-made onboard electronics based on the STM32 microprocessor were designed and deployed, facilitating the measurement of acceleration, angular speed, magnetic field, temperature, and altitude. A small form factor of the device makes it possible to evaluate various shapes and sizes of the gondola, using small and affordable balloon platforms. Complementing this instrumentation, the gondola was equipped with a position-tracking device, enhancing the ability to precisely locate and monitor the balloon's trajectory.

The acquisition of comprehensive information on the additional parameters influencing a balloon gondola during flight serves as a pivotal resource for mission planning and the meticulous preparation of experiments conducted on board. Furthermore, this enhanced understanding of measured variations is of particular significance in the realm of biological experiments, contributing to the refinement of experimental design and data interpretation. The data acquired through this research can be used as a baseline in further efforts to optimise or control the impact of said variations on experiments conducted with the help of small stratospheric balloons.

[A-83]

INFLUENCE OF THE THERMAL ENVIRONMENT DURING THE ASCENT PHASE ON THE DYNAMICS AND THERMAL BEHAVIOUR OF STRATOSPHERIC BALLOONS PAYLOADS

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Stratospheric balloon platforms are essential to space missions for scientific observations. They face significant thermal challenges during the ascent phase of these missions. The combination of the relative wind speed and the extreme thermal conditions can drive the balloon payload to the mission minimum temperatures. Therefore, it is critical that the payload thermal analyses take into account the uncertainties associated with both the thermal environment and the relative wind speed to assess the potential impact on the temperatures experienced.

Based on the ascent rate flight data collected during the BEXUS programme launches from 2014 to 2018 at Esrange (Sweden), a significant variation in the ascent rate profile is observed. The parameters influencing the ascent rate are investigated and the conditions necessary to obtain the ascent rate envelope are established with the aim of performing robust thermal analyses.

In this study, actual thermal environment data are used to determine the extreme environmental conditions, which are combined with an aerodynamic model to characterise the ascent rate velocity and horizontal relative wind speed in the balloon-payload system. This allows the quantification of heat dissipation by forced convection.

Atmospheric Physics & Chemistry 5

Thursday 23 May, Morning session – part 2

Room 3

Chair: A. Hertzog

[A-103]

COMBINING B-ICI AND LOAC ON BALLOONS TO MEASURE CIRRUS PARTICLE SIZE DISTRIBUTIONS

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Cirrus clouds play an important role in the atmosphere's radiative energy balance. The particle size distribution (PSD) of their ice particles is one of the key parameters that determine the cloud's radiative properties. Conditions at cloud formation as well as the stage within its life cycle influence the PSD. Thus, good knowledge of a cloud's PSD helps to better characterize its properties and reduce the high uncertainties they otherwise introduce in climate predictions.

The cirrus cloud ice particles have sizes ranging from few micrometres to more than a millimetre range and cannot be captured by one instrument alone. In-situ instrumentation used on aircraft start measuring reliably around 100 µm. The Balloon-borne Ice Cloud particle Imager (B-ICI) is an in-situ instrument carried by a balloon vertically through ice clouds in the upper troposphere and collects and optically images ice cloud particles starting from around 10 µm up to millimetre size. For even smaller ice particles, where optical imaging is not possible, optical scattering allows detecting and sizing. The Light Optical Aerosols Counter (LOAC) detects ice cloud particles as well as aerosol crossing a laser beam and combines scattering measurements at two different angles to provide both size and indication of particle typology between 0.2 and 50 µm.

Both LOAC and B-ICI have been flown on balloons separately. Here, we combine them so that the whole cirrus size range can be studied. Both instruments are lightweight. The LOAC at 0.3 kg without batteries can be added to the around 3-kg B-ICI so that both can be flown as one package without increasing complexity or cost per launch compared to previous B-ICI flights. We are evaluating data from first flights together launched from ESRANGE Space Center during winter 2023/2024, studying in particular the so-called "overlap" size range where both instruments measure.

[A-117]

CIRRUS CRYSTAL DETECTION AND DISTRIBUTION OVER THE SWEDISH ARCTIC, USING THE B-ICI AND MACHINE LEARNING

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Atmospheric constituents, such as aerosols and clouds, greatly affect the radiative properties of the atmosphere. Clouds play a substantial role in the Earth's radiative balance. The contribution of cirrus clouds to the Earth's radiative budget is yet to be quantified.

Remote sensing techniques are used for observing clouds; however, with the data retrieved with these techniques, detailed information about the inner structure of the clouds cannot be collected directly. Size, density, and morphology of the ice particles impact the single scattering properties that serve as the basis for remote sensing. In order to gain information about these properties and thus improve modeling accuracy, in-situ observations of cirrus clouds are required.

The Balloon-borne Ice Crystal Imager (B-ICI) is an instrument developed to take high-resolution images of the crystals populating these clouds. Analysis of the B-ICI data has been used in previous studies to determine the microphysical properties of cirrus clouds; however, these analyses required manual data processing. Following the advancements in the field of machine learning, a neural network has been trained to address this issue.

Data from measurements taken in the Swedish Arctic in November 2021, December 2021, and March 2022 have been analyzed with a machine learning model. The approach first uses image segmentation to identify particles, then classification of the corresponding categories. The segmentation model was trained on 3000 images from previous launches of the same instrument, where the data had been analyzed manually. A training-validation ratio of 80-20 has been used with the use of TensorFlow, and batch size 4 was used for training the model. The results of this model were then used to classify the shape of the individual crystals, thus categorizing the dominant crystal-habits of the cloud.

Here we present the outcome of such measurements and the application of the neural network for the analysis of the images. With this data, properties of cirrus clouds can be determined for statistical analysis. These results should help to increase the measurement accuracy of remote sensing of similar clouds.

[A-109]

WATER VAPOUR MEASUREMENTS IN THE EQUATORIAL TROPOPAUSE LAYER AND LOWER STRATOSPHERE UNDER LONG DURATION BALLOONS: TAPE RECORDER EFFECT, INFLUENCE OF ATMOSPHERIC WAVES AND DEEP CONVECTION.

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The Strateole 2 project (cofunded by CNES and NSF) aims to probe the equatorial upper troposphere and lower stratosphere (UTLS) using a flotilla of superpressure balloons, carrying, for long duration flights, a set of scientific instrumentations. This project aims to study key dynamical and microphysical processes and their interplays in the lower stratosphere and the tropopause tropical layer (TTL). Strateole 2 relies on three balloon campaigns. The first one took place in 2019/2020 and the second one took place in 2021/2022. A third and last campaign is scheduled by the end of 2025. In this frame, five Pico-SDLA Bi Gaz tunable diode laser spectrometers (GSMA/DT INSU) named Pico-STRAT in the frame of these campaigns, probed *in situ* water vapour at a sampling frequency varying from 4 to 12 minutes below the Zephyr gondola. During the first campaign, the TTL2 flight, carrying Pico-STRAT, lasted 80 days and circumnavigated the equator at an average altitude of 19 km. During the second campaign, 4 instruments (TTL4 and STR4 flights) were launched, probing the TTL at 18 km and the LS at 20 km during 31 to 57 days, mainly overpassing the Maritime continent and Pacific Ocean.

During this presentation, we present the measured in situ water vapour anomalies and their correlation with ERA 5 temperature perturbances, as a signature of atmospheric waves influence. Additionally to the wave-induced signatures, in some cases, a local modulation of water vapour due to very deep convection is observed. In such cases, the hydrating or dehydrating signature is linked to deep convective system overpasses, confirmed by satellite-borne observations from the CALIOP Lidar, and the geostationary satellite HIMAWARI. To estimate the water budget involved in these cases, a mesoscale simulation will be performed and could help to separate, to some extent, the contribution of direct overshooting signature to the wave-induced modulation due to convectively-generated gravity waves.

[A-114]

MEASURING EARTH'S MAGNETIC FIELD USING HIGH ALTITUDE BALLOONS

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ABSTRACT

Earth's magnetic field models that focus on Earth main field such as the International Geomagnetic Reference Field (IGRF) and World Magnetic Model (WMM) are based on low orbit satellites and magnetic observatories measurments. Models that strive to include the anomaly field such as High Definition Geomagnetic Model (HDGM) also use airborne and marine magnetic survey data. These models seem to be more accurate at satellite altitudes of hundreds of km and within the area of the magnetic survey. In this work, we investigate various models accuracies at intermediate altitudes of several km. In order to measure Earth's magnetic field at these altitudes we developed a balloon payload including magnetometer, GPS receiver, telemetry radio transmiiter and batteries. Tri-axial fluxgate magnetometers suffer from manufacturing imperfections that result in high level interference when used on-the-move. Therefore, using a tri-axial fluxgate magnetometer obliged calibration of magnetometer axes including temperature corrections prioir to launching the balloon. We carried out several experiments where payloads were tied to high altitude balloons reaching altitudes of around 30 km. Earth's magnetic field was measured along the balloons' trajectories and compared to several Earth's magnetic field models. We are planning to present the results in the conference.

[A-137]

OREO: A BALLOON BORN PROJECT TO CHARACTERIZE HIGH-ENERGY EVENTS IN THUNDERSTORMS

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Following C.T.R. Wilson's prediction of X-ray emissions resulting from the acceleration of electrons inside thunderclouds in 1925, high-energy events related to bremsstrahlung have been conclusively observed since the 1980s. These phenomena typically fall into two categories: terrestrial gamma-ray flashes (TGFs) and gamma-ray glows (GRGs).

First reported in 1994 by Fishman et al. (Science, 264, 1313, 1994) TGFs are brief (~100 µs) yet bright X-ray bursts with energies reaching a few tens of MeV. They are correlated with the propagation of lightning leaders and occur within thunderstorms. The exact mechanisms behind TGFs are still debated. However, all models agree that a key process is the relativistic runaway electron avalanche (RREA), wherein high-energy electrons are accelerated, multiplied, and emit bremsstrahlung until the electric field collapses.

In contrast, GRGs, manifest as long-lasting X-rays generated within thunderclouds. They share the same energy spectrum as TGFs and are thus assumed to be produced by the same fundamental mechanisms. However, their origin differs as they persist much longer (seconds to minutes), are less intense, and are not directly correlated with lightning leaders.

Detection of such events is typically accomplished via satellite for TGFs or through in-situ methods using balloons or aircraft. In this context, we introduce the OREO project, a balloon-borne campaign funded by the French space agency CNES. This initiative involves the deployment of 3–4 balloons equipped with an electrostatic field mill and a gamma-ray spectrometer (XStorm) into thunderstorms in Aire-sur-l'Adour, France, to conduct in-situ measurements. The objectives of this project are as follows:

- Detecting TGFs and GRGs in close proximity and investigating their production mechanisms.
- Characterize the size and time dynamics of the sources
- Confirming the existence of weak TGFs and GRGs that may go undetected by satellites or at ground level.
- Quantifying the radiation dose and assessing the radiation risk for the aircrews.

Atmospheric Physics & Chemistry 6

Thursday 23 May, Afternoon session – part 1

Room 1

Chair: B. Strelnikov

[A-79]

THE BARIUM RADIO AND OPTICAL ROCKET (BROR) EXPERIMENT: OVERVIEW OF THE SCIENTIFIC RESULTS

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The Barium Release Optical and Radio rocket (BROR) experiment aims to study cross-scale energy transfer processes and small- and medium-scale structures in the auroral ionosphere using active modification of the ionosphere by multiple releases of barium and simultaneous optical and radio ground-based observations of the appeared plasma clouds. The BROR experiment was conducted at 18:23 UT on March 23, 2023, at the Esrange rocket range near Kiruna, northern Sweden. The eight canisters of the payload with the barium-strontium-thermit mixture were successfully released at various altitudes in the range of 130 - 240 km. The ALIS-4D multi-station spectroscopic optical imaging system as well as the ordinary digital cameras located at various locations around the Esrange were used for optical observations of motion of the neutral and ionised barium and strontium clouds. For monitoring the ionospheric parameters during the experiment the EISCAT UHF radar operated the Beata program with the special scanning antenna mode.

This report presents only some examples of the findings obtained during the BROR experiment. In particular, a detailed analysis of the motions of the neutral and ionized clouds in the vicinity of the auroral arc are presented; an anomalous vertical motion of the neutrals near the auroral arc was found from the neutral strontium clouds observation ; the unusual refraction of the sunlight observed with the ordinary digital cameras in front of the release locations indicates the possible formation of a strong shock wave as a result of the barium-thermit mixture release.

[A-71]

DYNAMICS ABOVE THE EPICENTRE OF CLIMATE CHANGE: HIGH ALTITUDE WEATHER PATTERNS AND CLIMATE CHANGE UP TO THE EDGE OF SPACE

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The Arctic has experienced the globally most intense temperature rise since the 1950s, it is the Epicentre of Climate Change. The facilities related to the Esrange and Andøya Special Project (EASP) agreement are located in this region with rapidly warming temperature due to anthropogenic climate change. Greenhouse gases alter energy transfer, global wind systems, and the water cycle in the atmosphere. Researchers study the lower atmosphere extensively, but due to the lack of data the atmosphere up to the edge of space is hardly explored. However, this atmospheric altitude region gets increasingly important for a comprehensive climate analysis and due to impacts by space traffics.

The mesosphere and lower thermosphere above the EASP facilities are characterized by extremely low temperatures (in summer), strong winds (in winter), and large atmospheric variability. It plays a crucial role in regulating middle atmospheric circulation and energy balance. For a long time, sounding rockets were the only tool for investigating the edge of space. They have ultimately provided solid ground for establishing novel remote sensing techniques.

We will present results from rocket soundings in close cooperation with unique ground-based observations focused on small-scale dynamics, i.e., the transition from gravity waves to turbulence. The importance of small-scale dynamics at the edge of space will be demonstrated with unique observations by rockets, lidars, and radars, as well as with high-resolution modelling. Upcoming challenges, e.g., how they will be addressed with new projects, and initial findings will be discussed.

[A-53]

ADVANCING MESOSCALE MLT DYNAMICS ANALYSIS IN NORTHERN NORWAY THROUGH MULTISTATIC RADAR OBSERVATIONS AND PHYSICS-INFORMED MACHINE LEARNING

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The investigation of mesoscale dynamics in the mesosphere and lower thermosphere (MLT) has been a longstanding challenge due to limited observational capabilities, including nighttime and clear-sky constraints for camera observations. These scales, spanning from a few tens to a few hundreds of kilometers in the horizontal plane, have remained beyond the resolution capabilities of general circulation models and are often parameterized. Moreover, the interaction between gravity waves and stratified turbulence at these scales lacks consensus. To address these limitations, ground-based airglow imager cameras and, more recently, space-based airglow observations have been employed for studying these phenomena.

Over the past few years, advancements in the MMARIA concept (Multi-static Multifrequency Agile Radar Investigations of the Atmosphere) and its subsequent evolution into SIMONe (Spread Spectrum Interferometric Multistatic meteor radar Observing Network) at IAP have notably enhanced the quality, coverage, and resolution of radar measurements in the mesosphere and lower thermosphere. The use of multistatic specular meteor radars (MSMR) enables the observation of the illuminated volume from various angles, thereby substantially increasing the count of detected meteors. This increase in meteor detections is crucial for determining horizontally resolved wind fields and their second-order spatial and temporal statistics.

Here, mesoscale MLT dynamics over Northern Norway are presented in four dimensions, utilizing MSMR observations of the SIMONe system in Norway with state-of-the-art physics-informed machine-learning (PIML) techniques. Specifically, line-of-sight wind observations are integrated with fundamental laws of physics, such as continuity and momentum equations, employing neural networks as a functional tool. The results focus on cases studies around the VortEx rocket campaign and 4D wind dynamics around an observed extreme vertical wind event.

[A-106]

ARTIFICIAL BARIUM CLOUDS MOTION AT THREE DIFFERENT ALTITUDES: INITIAL RESULTS OF THE BROR EXPERIMENT

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The Barium Release Optical and Radio rocket (BROR) was launched on 23 March 2023, and successfully created eight barium-strontium neutral and ionized clouds at different altitudes between 130 and 245 km to study small-scale electromagnetic phenomena in the auroral ionosphere. The barium neutral and ionized clouds resulting from the initial three releases during the ascending of the rocket orbit at altitudes of 132 km, 160 km, and 193 km, were clearly and distinctively observed by the ground-based optical camera network as long as a few tens minutes. In general, the neutral barium clouds moved westwards, having either a northward or southward component (the first cloud tilted slightly northward, and the second and third southward), while ionized barium clouds moved in almost the perpendicular direction to the neutral clouds' trace. The velocity of the ionized barium clouds is faster than that of the neutral barium clouds. In this presentation, we will show the detailed motion of clouds resulting from the initial three releases. We also estimate the collision frequency and discuss the electric field at different altitudes.

Rockets & Balloons in Space Education 6

Thursday 23 May, Afternoon session – part 1

Room 2

Chair: T. Gandsmoe

[A-46]

ALMA ON BEXUS 33: RESULTS AND OUTCOMES

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ALMA is a student project at Luleå University of Technology (LTU), Sweden, carried out within the REXUS/BEXUS programme. The project's scientific objectives included finding a correlation between density, size, and composition of aerosols in the troposphere and stratosphere due to global volcanic activity and studying the change in Ozone concentration generated by such activity. The experiment followed two different methods to acquire data. First, an open-source particle counter developed and flown, and second, an off-the-shelf Ozonesonde instrument.

The idea for the project arose after the Cumbre Vieja volcano eruption on the Spanish island of La Palma in September 2021. The project was encouraged as per the worldwide consequences of natural events (such as volcanoes) on the climate and the atmosphere, even after a long period.

The student project has been passed around to many different hands, each with their unique background and perspective. As the project has progressed, it has evolved and improved, but not without encountering its fair share of challenges. What was initially intended to be a one-year master's student project has turned into a multi-year project with more than four rounds of different students. The process of handing over the project to new team members and iterating on previous work has proven to be a constant challenge for the project, with various effects.

Finally, on September 21st, 2023, the project's final version was flown and recovered. Although the launch and recovery were excellent, the results obtained from the flight were limited compared to the project's initial aim. The particle counter did not work as expected for unknown reasons. Two different sets of issues have been identified: The unspecificity of the detector data, where the entire dataset jumps between two distinct values. And critical data setbacks, with LASER performance issues, crimped the dataset with uncertainties and; pressure inconsistencies, where our pressure data showed an unexpected flat trend long before flotation. Secondly, the off-the-shelf Ozonesonde failed to start and did not record any data. Therefore, the authors have tried to emphasise students' experiences and lessons learned throughout the project and potential improvements for upcoming missions related to REXUS/BEXUS, atmospheric measurements, and student-led projects in topics ranging from planning and managing assets and people to experimental procedures and repeatability. Regardless of the practical outcome, this learning outcome is the main takeaway that all the students in the project have felt.

[A-63]

LOW-FREQUENCY WAVE PROPAGATION IN THE STRATOSPHERE: THE SPACIS EXPERIMENT ABOARD BEXUS 33

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Sound propagation in Earth's atmosphere is characterized by significant attenuation, except at the lower end of the frequency spectrum. Frequencies around 20 Hz and slightly higher demonstrate a remarkable range, spanning hundreds of kilometers. Traditional atmospheric studies using helium-inflated balloons primarily focused on short-duration, high-power sounds from events like explosions and volcanic eruptions. However, such experiments lack the granularity needed for in-depth analysis.

The SPACIS (Sound Propagation in the Atmosphere using Complex Infrasound Signals) experiment introduces a novel approach, employing artificially generated, complex low-frequency waves for studies with significantly enhanced granularity. These waves, characterized by extended duration, disperse energy over time, requiring lower transmission power. Deliberate design and synchronization enable precise measurement of actual propagation delays through correlation techniques. Post-processing analysis yields detailed maps of sound velocity, refractive indices, and attenuation along the flight path.

The SPACIS team comprises five students from the Faculty of Engineering (FEUP) at the University of Porto, ranging from the 1st to 2nd grade of Masters in Electrical, Mechanical and Informatic Engineering. This experience was conducted under the scope of the Swedish-German REXUS/BEXUS Programme, during the BEXUS 33 flight on September 21, 2023. SPACIS represents a significant leap in understanding low-frequency wave behavior in the stratosphere, offering unprecedented granularity in data collection and analysis.

Keywords: Balloon Experiments for University Students (BEXUS), SPACIS (Sound Propagation in the Atmosphere using Complex Infrasound Signals), Low-Frequency Waves, Stratosphere, University of Porto, FEUP.

[A-81]

DESIGN AND FLIGHT OF HERCCULES, A HEAT TRANSFER EXPERIMENT ON-BOARD BEXUS 32

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HERCCULES is a stratospheric experiment that was successfully launched from Esrange in September 2023 on board BEXUS 32. It was developed by Bachelor, Master and Phd students from Universidad Politécnica de Madrid to characterize the thermal environment and to study the convective heat transfer throughout the atmosphere. The main goal is to improve the thermal analysis of the stratospheric balloon payloads based on a new developed methodology. The experiment consists of several parts. The Heat Transfer Lab allows for quantifying heat transfer through air in cavities equipped with heated plates in different configurations, where free convection occurs. The Environmental Lab is equipped with COTS radiative measuring instruments, namely a pyranometer and pyrgeometer, which play a key role in completing and validating stratospheric thermal environment characterization models that are currently based on satellite data. Additionally, the Attitude Lab provides the gondola orientation by using commercial photodiodes which would measure of the solar radiation coming from its Field of View with the Earth. All these instruments are controlled by a Raspberry Pi and 3 custom made PCBs located in an electronic box. Here, the analysis and the design of all subsystems will be summarized, and the flight performance will be described.

[A-162]

LIFE AFTER BEXUS: STRATOSPHERIC BALLOON ACTIVITES AT GDAŃSK UNIVERSITY OF TECHNOLOGY

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How do you restart an academic stratospheric balloon programme after taking part in the REXUS/BEXUS programme? How to assemble a new team and share the passion for stratosphere with a new generation of students? In this paper we want to summarise the stratospheric balloon activities at Gdańsk University of Technology held by SimLE Science Club since 2022. We'll outline the challenges of creating a new team as well as the technical details of the devised stratospheric balloon platform which allowed us to send two stratospheric balloon missions with new scientific experiments. Ultimately our efforts lead us to get selected for Cycle 15 of the BEXUS programme with a new payload called STORMDUST.

Physical Sciences 3

Thursday 23 May, Afternoon session – part 1

Room 3

Chair: B. Rattenbacher

[A-68]

DYNAMICS OF 3D GRANULAR GASES OF COMPLEX PARTICLES ANALYZED WITH AI EVALUATION METHODS

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Granular gases are dilute ensembles of granular matter, which exhibit fascinating dynamical behavior far from equilibrium, e. g. unusual cooling properties, violation of energy equipartition or clustering. In granular gases, the macroscopic particles propagate freely in space and interact by dissipative collisions. So far, most studies have been theoretical or numerical, and only few experiments, mainly with non-complex particles, e. g. spheres, have been performed. The experimental realization of excited (permanent energy input) or cooling regimes (no external energy input after excitation) of granular gases in particular requires microgravity of high quality, e. g. on suborbital rocket flights or in drop towers.

In gases of rod-like particles, the mean free path is substantially reduced as compared to gases of spherical grains of identical volume fraction and elongated particles allow the direct analysis of rotational degrees of freedom. Nevertheless, natural granular gases usually consist of much more complex shaped particles. We investigated steady and cooling states of dilute 3D granular gases of spatial crosses (hexapods, particles with six cylindrical arms) on a sounding rocket flight and in a drop tower campaign at ZARM in Bremen. We focus on the energy partition among translational and rotational degrees of freedom, on translational and rotational velocity distributions and the decay of energy after the excitation has stopped.

One particular problem in the data analysis is the reliable detection and tracking of the complex particles in 3D, especially at volume fractions beyond the very dilute limit. We present a technique for automatic 3D tracking of position and orientation of the particles in the ensemble, based on two-perspective video data analysis. Two-dimensional localization of particles is performed with help of the Mask R-CNN neural network. Then, the problem of 3D matching and tracking of the particles is solved by optimization of reprojection errors and object dispacements. Finally, the particle trajectories are analyzed and ensemble statistics can be extracted. Depending on the required accuracy, the system can be used automatically or serve as a base for subsequent manual corrections.

Our studies are funded by DLR within the projects 50WM2340, 50WK2348 and by ESA within project CORA-JACKS.

[A-75]

ROTATIONS, TRANSLATIONS AND EQUIPARTITION IN A HOMOGENEOUSLY COOLING GRANULAR GAS

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One of the most fundamental questions in the investigation of macroscopic, loosely packed multiparticle ensembles such as so-called granular gases is the energy content in the system and the distribution of energies among the individual degrees of freedom. While in atomic and molecular gases, all types of motions, including rotations and translations of the constituents, are equally excited (unless quantum effects have to be taken into account), this is in general not the case in macroscopic systems where the interactions between the constituents are dissipative. We analyse experiments with the simplest form of particles, sphere-shaped elastic objects. Microgravity is needed in these experiments unless the systems are heavily excited with external energy entry.

Previous experiments were performed in the ZARM drop tower in Bremen where microgravity of high quality can be maintained for up to 9.2 seconds. For longer durations, rocket experiments during a suborbital flight are being prepared. In such experiments, one can observe the system beyond the homogeneous cooling limit and study clustering phenomena.

With a special optical observation technique, particle rotations and translations were extracted in the homogeneous freely cooling phase of the ensemble after mechanical excitation. It was shown that the rotational degrees of freedom are on average less excited than the translational ones. The velocity distribution functions and rotational velocity distributions were extracted. They differ from Gaussians in the beginning, after the excitation phase, but gradually approach Gaussian shapes in the cooling phase.

We also introduce a novel, alternative observation technique that allows to record particle dynamics, in particular the rotational motion and collisions, autonomously with intelligent sensor particles. Using an internal board with integrated accelerometers and gyroscopes, the particle rotations and collisions can be detected and recorded without the need of optical observation and complex image processing. The advantage of this method is that it works also for systems with higher particle number densities in the sample containers.

Our studies are funded by DLR within projects KORDYGA (50WM2242) and EVA II (50WK2348). Drop tower experiments were partially funded by ESA within the Drop Your Thesis project SmartDust.

[A-171]

TEAM DROPSTAR – REXUS 32: STUDYING EMULSIONS IN MICROGRAVITY.

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Team DROPSTAR is a student team from Greece that consists of eight members, the majority of whom are undergraduate students in a variety of sectors. The experiment, DROPSTAR, is the first Greek experiment to have been selected to participate in a REXUS flight.

The goal of the experiment is to study the oil droplet coalescence phenomena that take place in an emulsion, under microgravity conditions. During the flight of the rocket, an emulsion is produced using a novel emulsification device, and is studied in situ with two diagnostics: a camera display that records the emulsion during the flight, and a special electric technique, the I-VED Technique, that measures the changes in the impedance of the emulsion.

By designing and conducting DROPSTAR, the team hopes to contribute to the existing data regarding coalescence phenomena and expand their study in microgravity conditions.

[A-163]

Preliminary Results of Novel Ferrofluidic Systems Tested on a REXUS Sounding Rocket

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The Ferrofluid Application Study (FerrAS) is a technology demonstration project of the Small Satellite Student Society of the University of Stuttgart (KSat e.V.) and part of the REXUS/BEXUS Cycle 14. The objective of this mission is to validate novel pumping systems in milligravity for future space applications. Preliminary results from the launch onboard a REXUS-sounding rocket in March 2024 from the Esrange Space Centre are discussed in this paper.

In space applications, mechanical moving parts are always a critical factor. Malfunctions of mechanical type in orbit should be avoided since they often mean the end of a mission. These components are susceptible to wear and tear, which limits lifetime and therefore requires regular and extensive maintenance. By using ferrofluid actuated by electromagnets, moving parts can be minimized, increasing reliability and enhancing the lifetime of components, such as reaction wheels on satellites, thus increasing the chance of mission success.

In the FerrAS project, two ferrofluid-based pumping mechanisms are tested. Ferrofluids consist of coated nanoscale iron particles suspended in a carrier fluid, primarily a type of oil. Due to the particle mobility, ferrofluids have super-paramagnetic properties.

The Displacement Pump experiment aims to develop a ferrofluid-based pumping system. The displacement body (i.e. piston) is replaced by a neodymium magnet encapsulated in a ferrofluid layer. This layer acts as a seal, bearing and guide for the displacement body, thus replacing three crucial and wear-prone components. The neodymium magnet is driven by an external coil, eliminating the necessity for a mechanical complex drive engine.

The Linear Pump experiment's application aims to be a small satellite attitude control system (ACS). For this purpose, electromagnets move a small volume of ferrofluid in a wave pattern to generate an angular momentum in the liquid circuit. The resulting pumping movement of the secondary liquid will be measured via a flowmeter. In the linear pump, the ferrofluid is the actuating medium. Without any moving solids, the linear pump is vibration-free.