APEX (Auroral Polarization EXplorer)

APEX is a payload designed for REXUS. REXUS is a sounding rocket provided in cooperation by the European Space Agency (ESA), the Swedish National Space Agency (SNSA), and the German Aerospace Center (DLR). It can carry multiple student-build payloads up to an altitude of 80 km, and is launched in Kiruna, Sweden. The goal of APEX is to demonstrate the measurement of the polarization of the aurora borealis, the northern lights.

Aurora Over Alaska (NASA, International Space Station, 02/19/12)

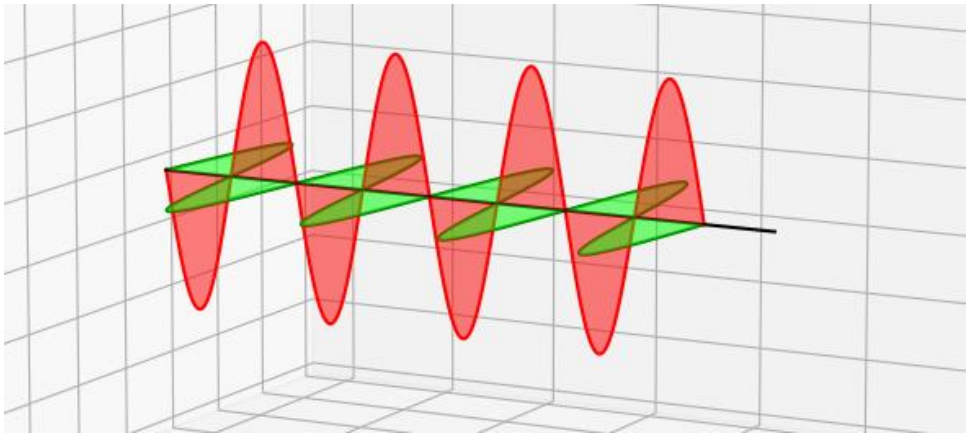
This beautiful image of the multi-colored aurora borealis over Alaska was photographed by one of the Expedition 30 crew members aboard the International Space Station. The image also shows part of the limb and airglow over Earth.

Image credit: NASA

What are northern lights?

Northern lights are caused by fast particles redirected by the Earth's magnetic field hitting the Earth's thin atmosphere at heights of over 100 km. (Yes, some air still exists up there.) The exact processes present are not fully understood yet; hence, measuring the polarization of the northern lights might give the science community another glimpse into this colorful phenomenon.

But what is polarization? To understand polarization, let's delve into the nature of light. Light is an electromagnetic wave consisting of oscillating electric and magnetic fields that propagate through space. These fields oscillate perpendicular to the direction of the wave's motion. The direction/angle of this oscillation gives the polarization of the light. In unpolarized light, all light particles are polarized in a random direction; in fully polarized light, this direction is aligned for all light particles.



The oscillating magnetic (red) and electric (green) field of an electromagnetic wave. The plane of the electric osculation defines the polarization of this wave.

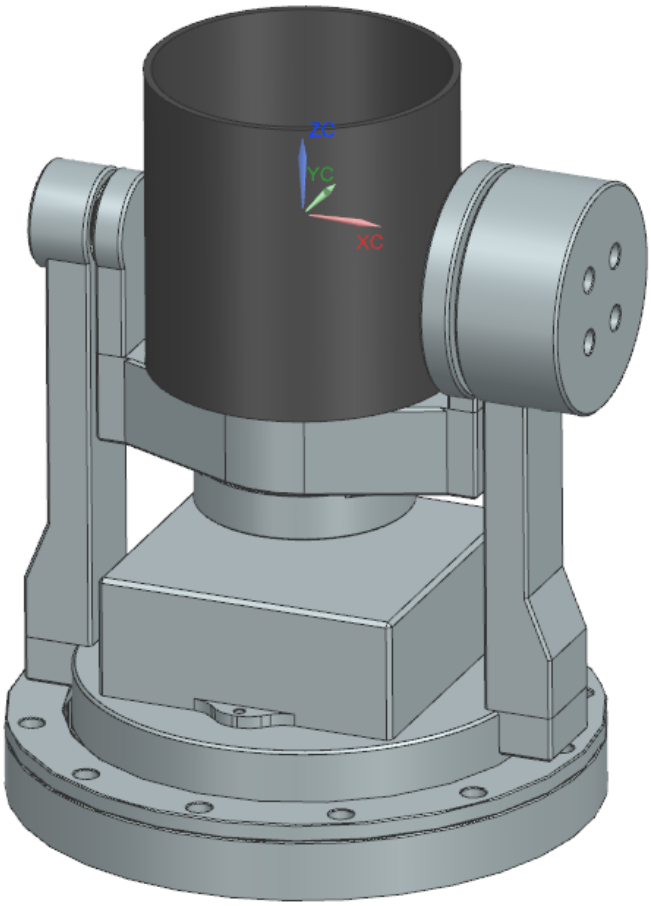
Include Playlist to APEX explanatory Videos(https://youtube.com/shorts/TAScfFPIxUw?si=blEoZuyuM-MHQUmu)

Chasing Faint Lights

To always look at the same patch of the Aurora, APEX will use a three-axis stabilized gimbal. This will allow us to compensate for the tumbling of the REXUS rocket.

The gimbal will use three motors, one per axis with added positional feedback sensors to point the two polarization cameras at our area of interest. The two cameras sit in the “camera can” on top of the gimbal, with a third camera for public outreach, recording reference videos of our flight. The special thing about our polarization cameras? They have four different linear polarization filters directly above the pixels of the sensor, allowing us to measure the full range of linear polarization of the light with one camera. As we are interested in two different spectral lines (colors) of auroral emission, we use bandpass filters and two polarization cameras, one for each spectral line.

On the rotating baseplate the electronic box will be mounted. It houses the attitude determination system with the gimbal control electronics and the camera control electronics.



Preliminary Design of the gimbal, sensors and the cameras are not modeled.

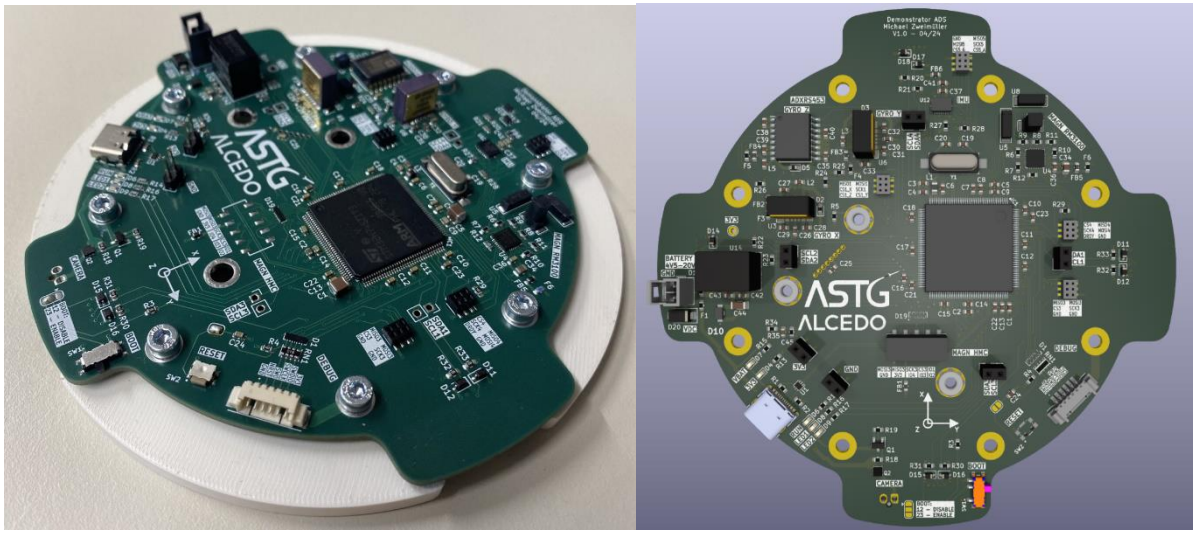
Finding Direction: The DADS Payload

The DADS Payload, or full Name Demonstrator Attitude Determination System, is a Payload developed for the Hybrid Rocket ALCEDO (Link to Alcedo) of the Aerospace Team Graz. Its goal is to demonstrate our attitude determination system (hence the name) on a 9 km altitude-sounding rocket flight.

Finding one's way high up above earth is not as easy as it sounds. Being on a ballistic trajectory means that one of the simplest ways to have an indication of direction is lost: there is no “down”. Therefore, we will use different sensors to find our way and, more importantly, the Aurora we want to look at.

The first sensor is a sun sensor. It consists of multiple photo-sensitive devices (“Position Sensitive Solar Cells”) with pinholes in front of them. The sun only illuminates a small dot through the pinhole. The position of the illuminated dot allows the system to determine the sun’s position relative to the sensor. The second group of sensors are magnetometers. Earth's magnetic field penetrates deep beyond Earth's atmosphere, shielding us from solar particles, as mentioned above. Measuring it allows one to find north, just like with a compass. With the combination of these sensors and a set of gyroscopes tracking fine

changes in orientation the attitude determination system will be able to give us a “down” up in space.



The main PCB of the DADS Payload as it was designed (right) and its flight-ready variant (left).

Unite! for REXUS/BEXUS

unite!

In February of 2024, the APEX Team applied for the SEED Fund of the Unite! network together with the SPECTRE Student team of KTH Stockholm. The Unite! network is an alliance of multiple universities throughout Europe with the goal of enhanced cooperation. The aim of their SEED Fund initiative is to allow student organizations and associations to collaborate on projects and share knowledge. The fund itself enables mainly travel between universities for shared workshops.

Our collaboration partners, the SPECTRE Student Team, are currently building their payload for the REXUS/BEXUS Cycle 33/34. It will allow the APEX Team to visit Stockholm in November 2024 to gain valuable insight into how to build and verify a Payload designed to operate at the edge of space. A second workshop will be held in May of 2025, with the SPECTRE Team visiting Graz shortly after they have (hopefully) successfully launched their payload. The second workshop will focus on launch preparations and operations.

Current Status:

- ✓ Submission of proposal (October 2023)
- ✓ APEX is shortlisted for REXUS/BEXUS (October 2023)
- ✓ Selection Workshop at ESA ESCTEC (Noordwijk, Netherlands) with a presentation to get selected for the next launch champaign (November 2023)
- ✗ Get selected for the RX 33/34 Cycle

Unfortunately, we were not selected for the REXUS Cycle 33/34. ESA reasoned that our System is too complex to be fully developed in one and a half years. But we were encouraged to further improve our concept and give it another try in the coming year.

And this is what we did. We restarted the project with a concept phase while in parallel developing demonstrator experiments for key technologies

- ✓ Concept Phase II (January-February 2024)
- ✓ Internal Concept Review (February 2024)
- ✓ Preliminary Design Phase (March – August) 2024
- ✓ Design Workshop (June 2024)
- ✓ Acceptance for the Unite! SEED fund with SPECTRE of KTH Stockholm (June 2024)
- ❑ DADS Payload (February – Oktober 2024)
- ❑ Testflight of DADS at EuRoC 2024 (Oktober 2024)
- ❑ Thermal Camera Testing (March – Oktober 2024)
- ❑ Writing of Proposal for REXUS/BEXUS RX 35/36 (August – Oktober 2024)
- ❑ !Unite Workshop with Team SPECTRE at KTH Stockholm (November 2024)

Updated Last Sept 2024