CLIMB: A CubeSat mission to the Van Allen Belt

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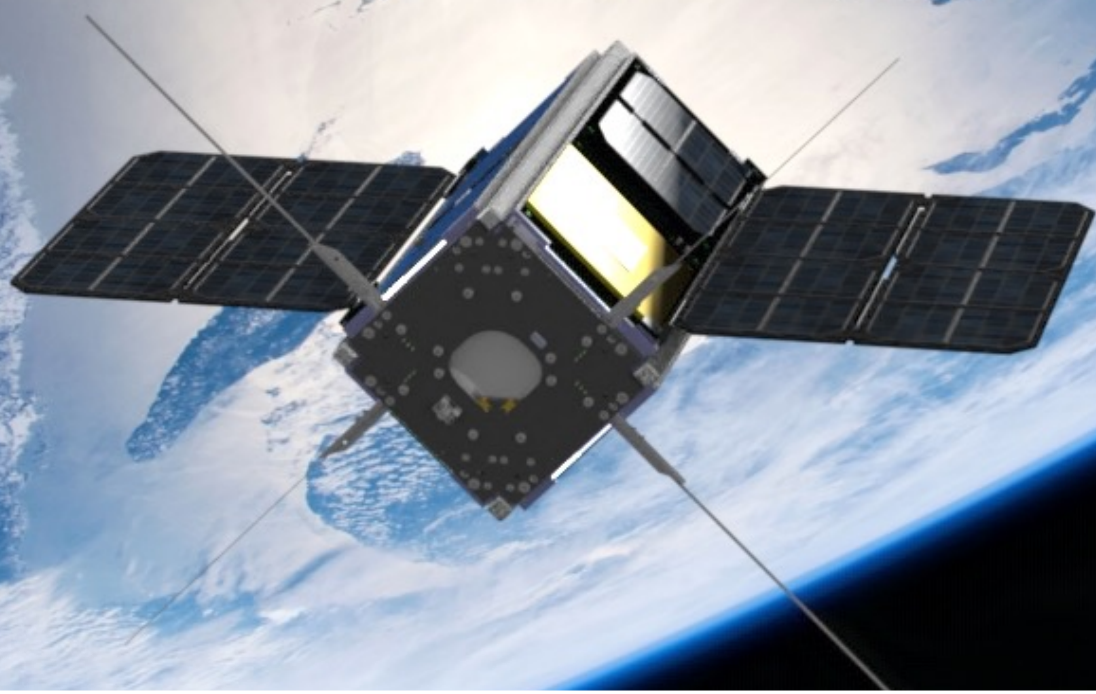
CubeSat Workshop, San Luis Obispo, 23.04.2024



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University of Applied Sciences

Aerospace Engineering at the FHWN

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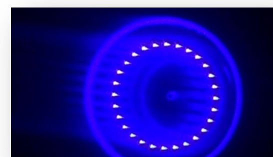
Aerospace Engineering at the FHWN….

- …. a 2 year Master‘s program
- ….is offered completely in english
- ….combines classic education (teaching) with hands-on projects



Aerospace Engineering at the FHWN

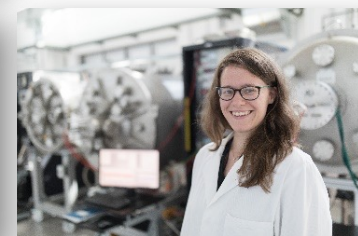
https://cubesat.fhwn.ac.at/

CubeSat development

- The FHWN has all necessary facilities to develop and qualify CubeSats:
  - ALM facilities
  - Vibration facilities
  - Shock table
  - Thermal vacuum chambers
  - Solar Simulator
  - Helmholtz cage
  - Outgassing facilities
  - etc.







https://cubesat.fhwn.ac.at/

http://spacedatacenter.at/pegasus/index.php

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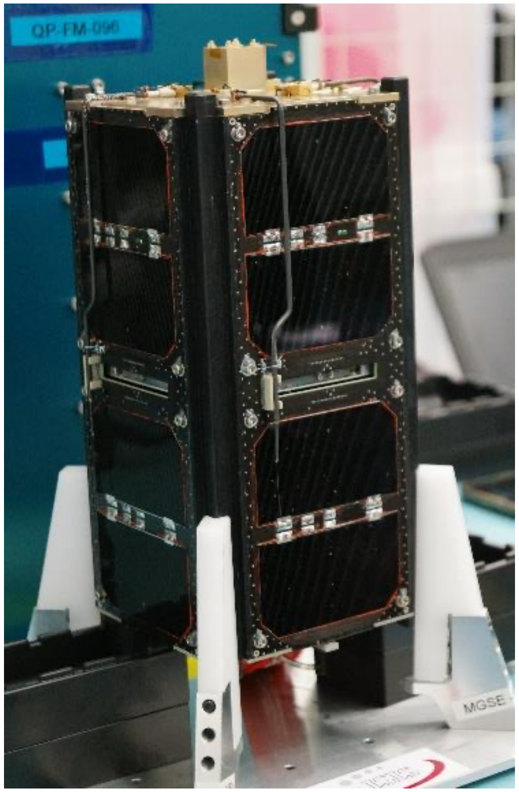
The CubeSat PEGASUS

PEGASUS was initiated as contribution to the European Commission projekt: QB50. With the exception of the GPS and the antennas all the satellite subsystems were developed by the PEGASUS team.

- PEGASUS is a 2U and weights 1960 g
- PEGASUS subsystems
  - Scientific instrument (mNLP)
  - GPS
  - On-board computer (OBC)
  - UHF transmitter and antennas
  - Power processing unit (PPU)
  - 2 re-chargeable batteries
  - 16 high efficiency solar cells
  - Experimental propulsion system
- Providing a in-orbit power between 2.5 and 3 W



From the cradle to grave

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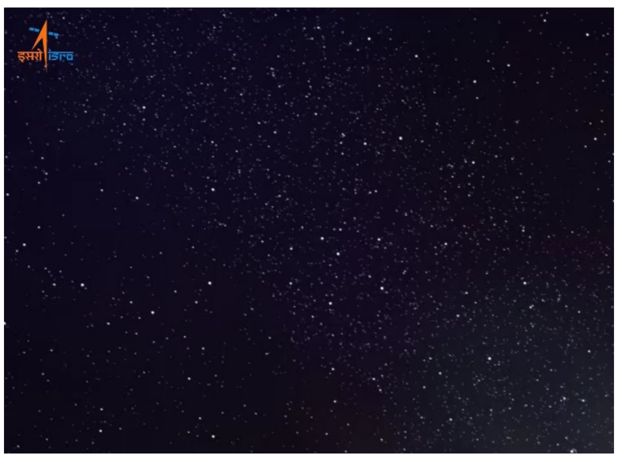
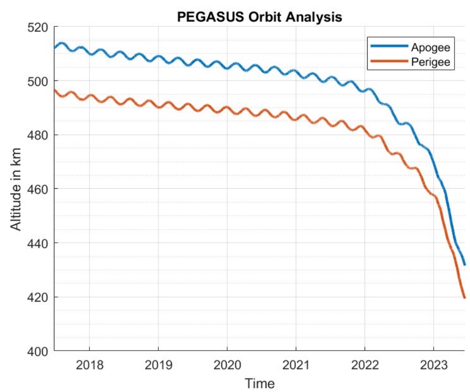
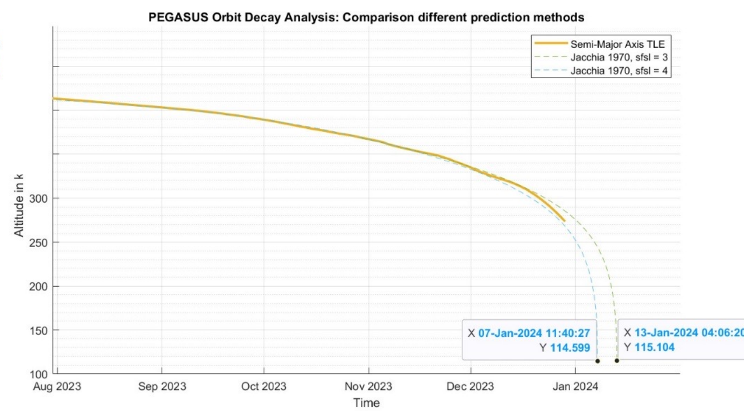
Following a launch in June, 2017, PEGASUS operated for ~6.5 years in orbit and re-entered the atmosphere on January the 8th of 2024. Communication and data download was possible unitl 1 hour prior to burn up..



Launch with a Indian PSLV, 23.06.2017



Predicted re-entry into atmosphere around Q1, 2024
→ Final re-entry on the 8th of January, 2024



CLIMB

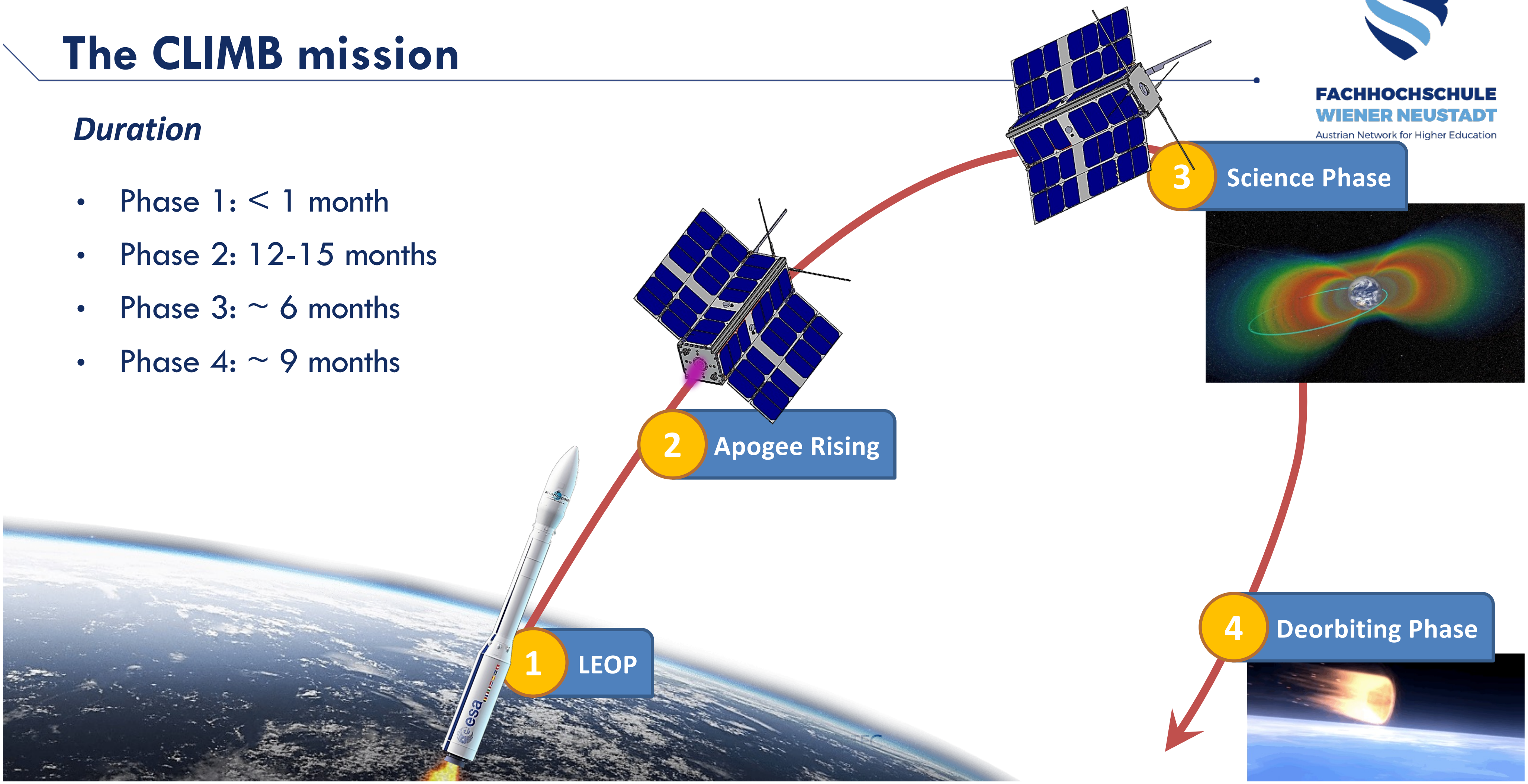
A mission to the Van Allen Belt

Overall project objective is to educate students and to develop CubeSats for future missions

The CLIMB mission

Duration

- Phase 1: < 1 month
- Phase 2: 12-15 months
- Phase 3: ~ 6 months
- Phase 4: ~ 9 months



The CLIMB mission

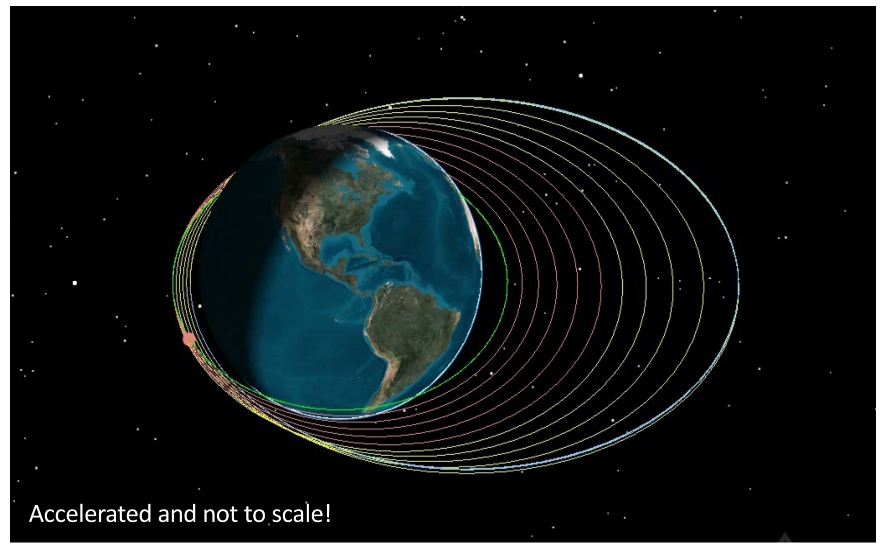
Mission objectives

- Education of students in satellite system engineering
- Using a propulsion system to reach the Van-Allen Belt (~1,000 - 1500 km)
- Using a CubeSat to measure Earth's magnetic field in high accuracy
- Monitoring the total accumulated radiation dose and its impact on subsystems

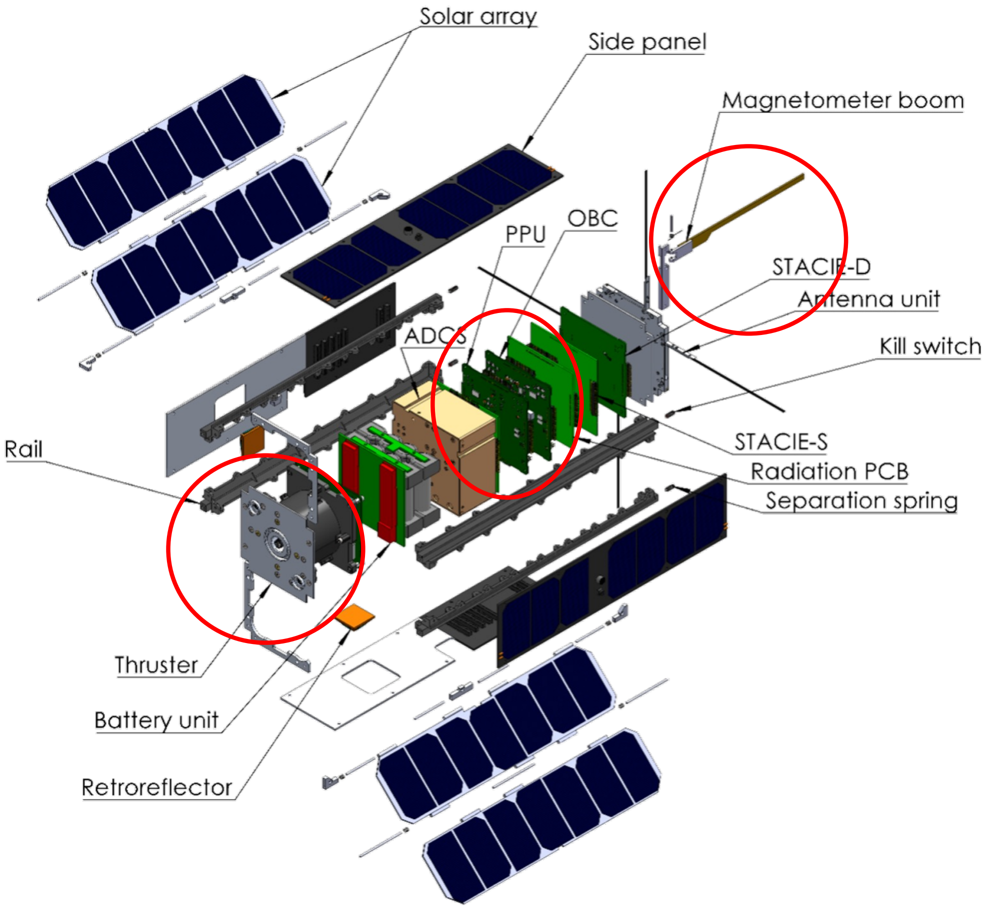
Technology and mission challenges

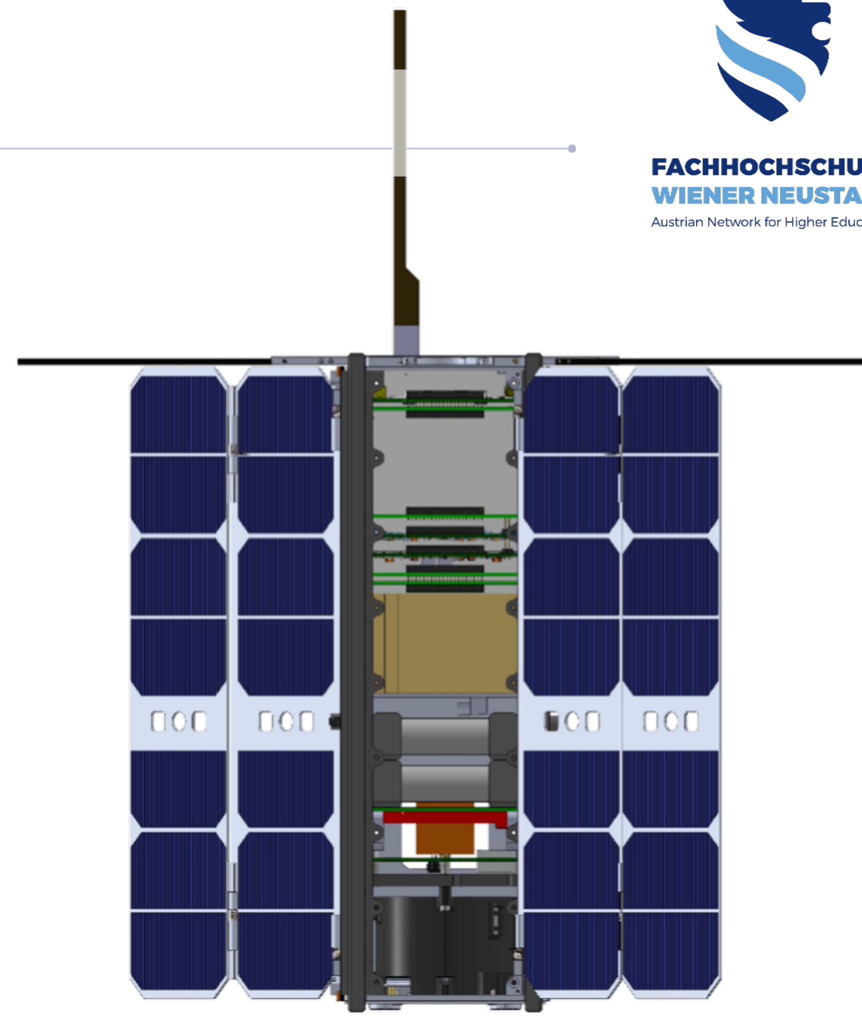
- Propulsion (power, thermal)
- Radiation (design for and mitigation of radiation effects)
- Communication (higher data rate)
- Operation (24/7, collision avoidance)

Phase 1 & 2 – LEOP and apogee increase



CLIMB Design





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Propulsion for CLIMB

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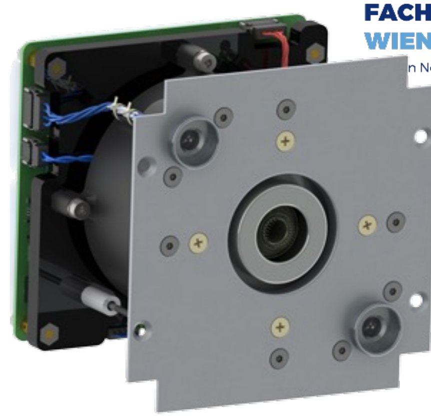
ENPULSION
SPACECRAFT TECHNOLOGY

IFM FEEP technology by ENPULSION is flight proven (~200 units in space)



Source: enpulsion.com

Propulsion on a CubeSat introduces several challenges:

- High el. power requirements
- High thermal dissipation
- Increased spacecraft alignment requirements
- Challenging operation (24/7, collision avoidance)
- Specialized testing facilities required

Source: enpulsion.com

CLIMB: the second CubeSat mission of the FHWN

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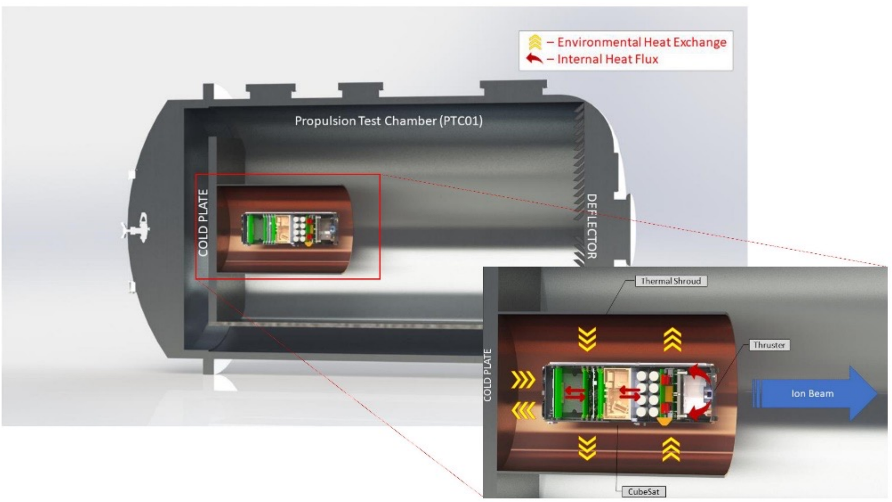
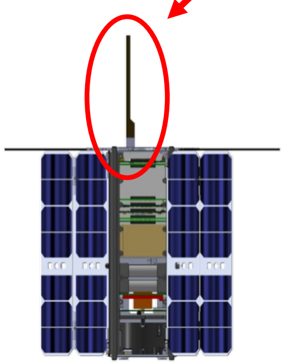
Propulsion Testing



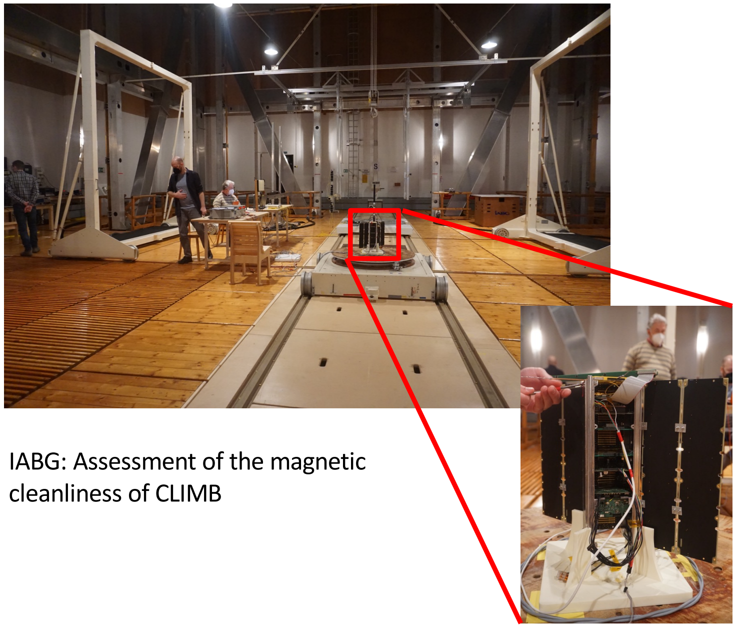
Thermal vacuum chamber: Assessment of the thermal properties with operating thruster

Magnetic field measurements

Measurement accuracy of **1-5 nT** requires to assess and control the magnetic cleanliness of the CubeSat



270 mm long MagnetoBoom with 3-axis magnetic field measurements

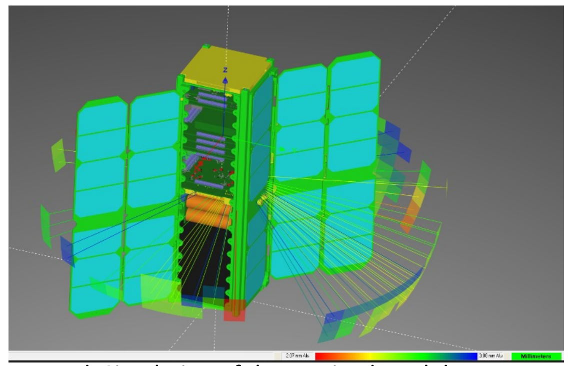


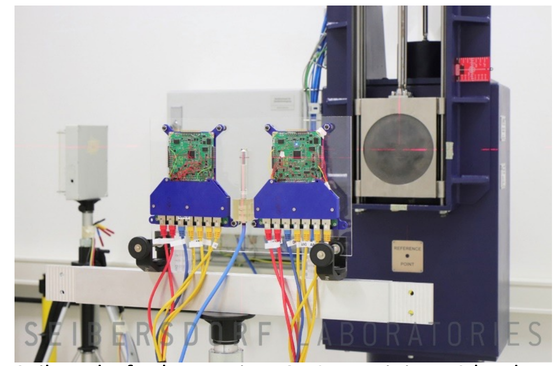
IABG: Assessment of the magnetic cleanliness of CLIMB

Radiation assessment

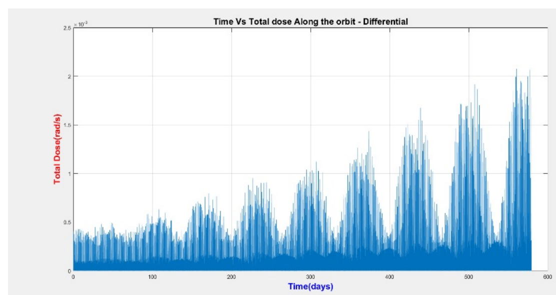
Radiation assessments

- Due to electrons as major contributor, effective shielding has to be considered and optimized
  - Complement materials at CAD model
  - Ray tracing analysis (define shielding in direction in Al thickness equivalent) calculated as worst case estimation
  - Monte Carlo calculation (based on GEANT4 implementation for interaction with matter, localize deposited dose)
- Place sensitive components on proper positions
- Find out positions, which require additional shielding
- Define dose to be taken into account at test irradiation

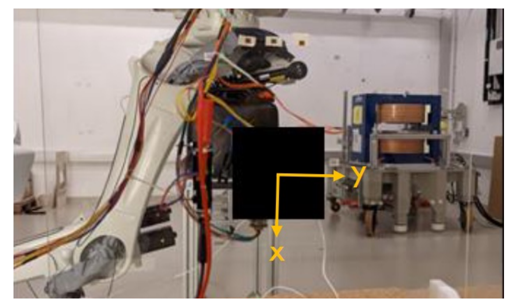

FastRad: Simulation of the received total dose



Seibersdorf Laboratories: OBC sustaining 50 krad



FastRad: Accumulated dose as a function of mission days



Medaustron: Assessment of Single Event Effects (SEE)

Radiation assessment

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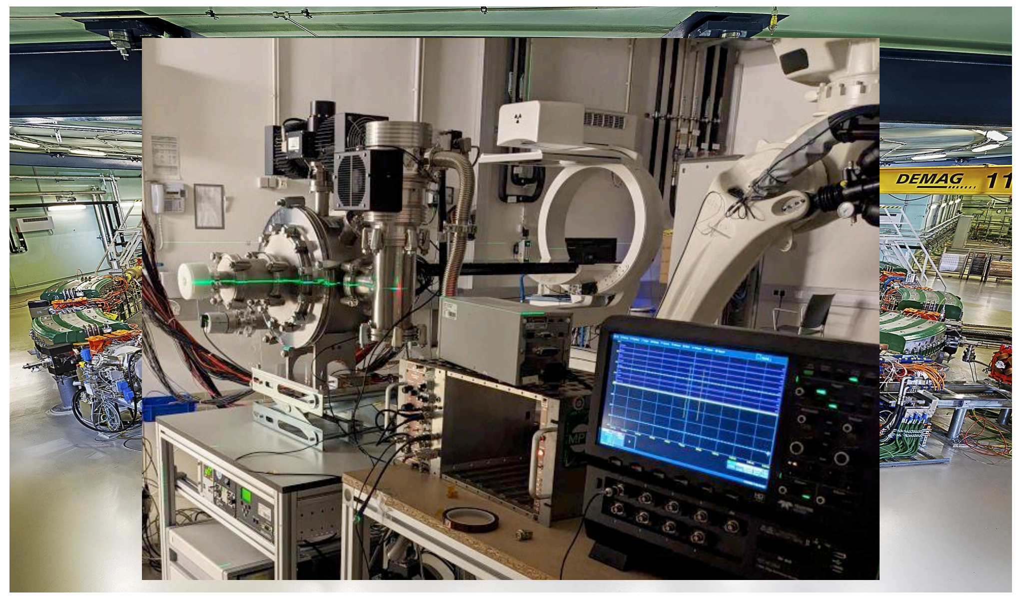
Testing for single event effects (SEE) at the MedAustron in Wiener Neustadt



Radiation assessment

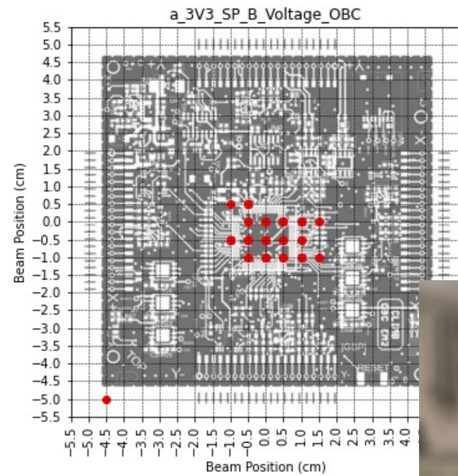
Tests on system level

- On-board computer of CLIMB
- 10 x 10 cm^2 in size to be homogenously irradiated
- Major parameter (e.g. COM interfaces, voltage supply, housekeeping) logged

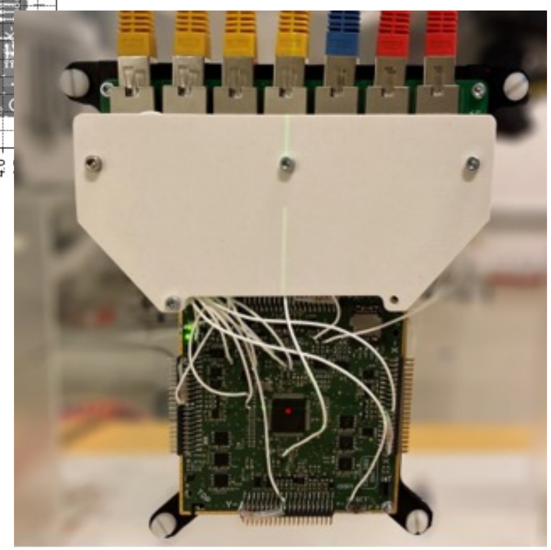
Results

- Only soft SEEs recoverable with reset
- Effects were correlated to positions
- Microcontroller and components in its vicinity affected

Parameter	Value
Treatment Machine Name	IR1HBL
Radiation Type	Proton
Nominal Beam Energy	250 MeV
Spill Length ID	5.0 (s)
Gantry Angle (deg)	90
Meterset weight (#)	10^{10}
Number of pattern dots	23 × 23 = 529
fluence	3.9×10^{10} (cm^{-2})



Irradiation plan on OBC and localization of specific single event functional interrupt (SEFI)



Radiation assessment

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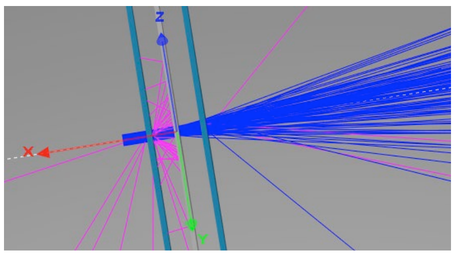
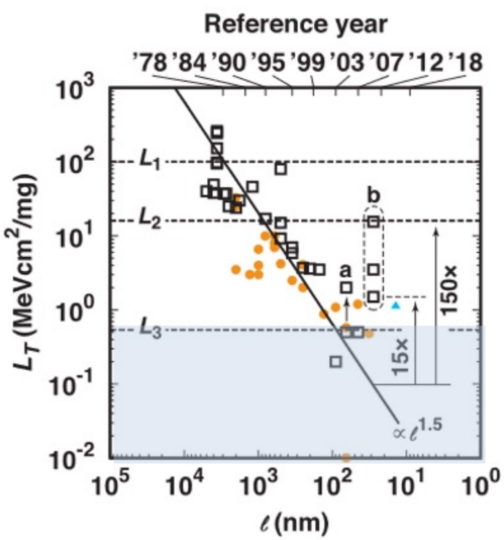
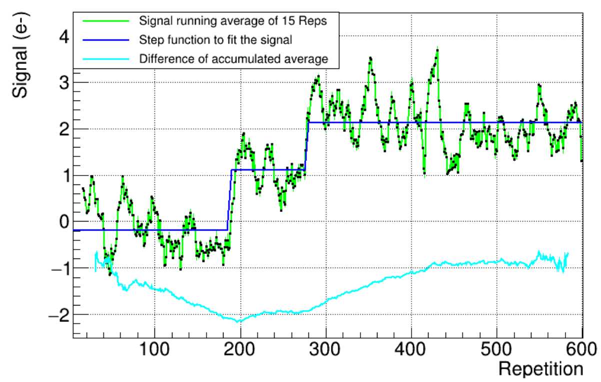


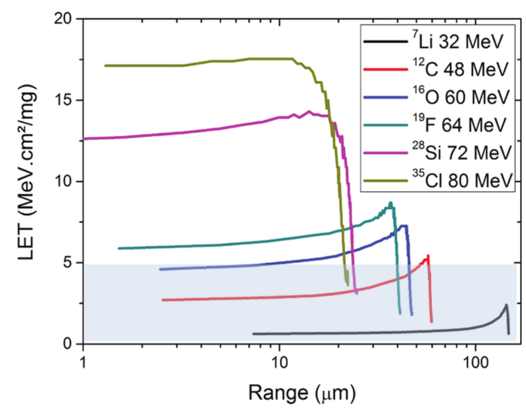
Outlook

- Irradiation studies are accompanied with beam simulations (GENAT4, FLUKA)
  - Determine position of Bragg peak
  - Control Bragg peak with degraders
- Due to reduced feature size, threshold LET continues to decrease at modern ICs

➔ Direct ionization measurements are feasible (protons and carbon)
➔ The effect of indirect and direct ionization shall be modelled for a comprehensive DuT characterization







CLIMB communication

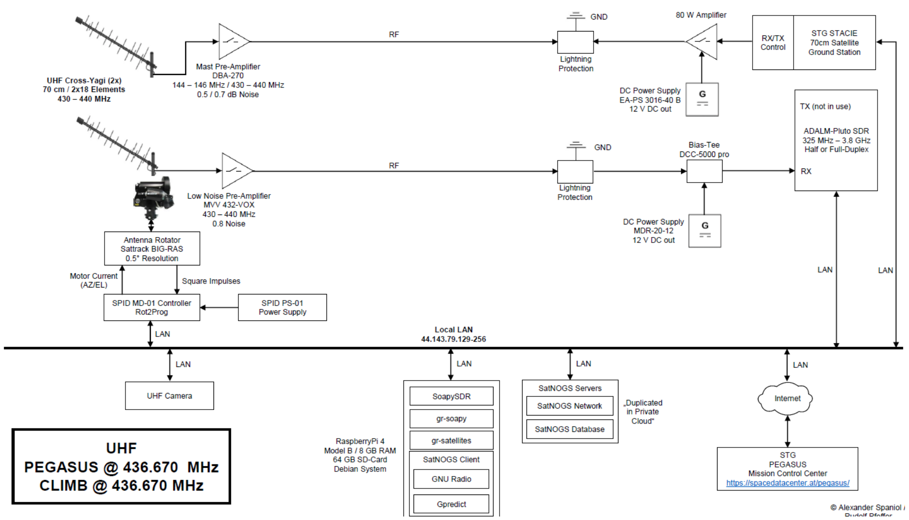
- CLIMB produces a significant amount of data which need to be sent back
- CLIMB s/c operational software shall be updated and upgraded during the mission

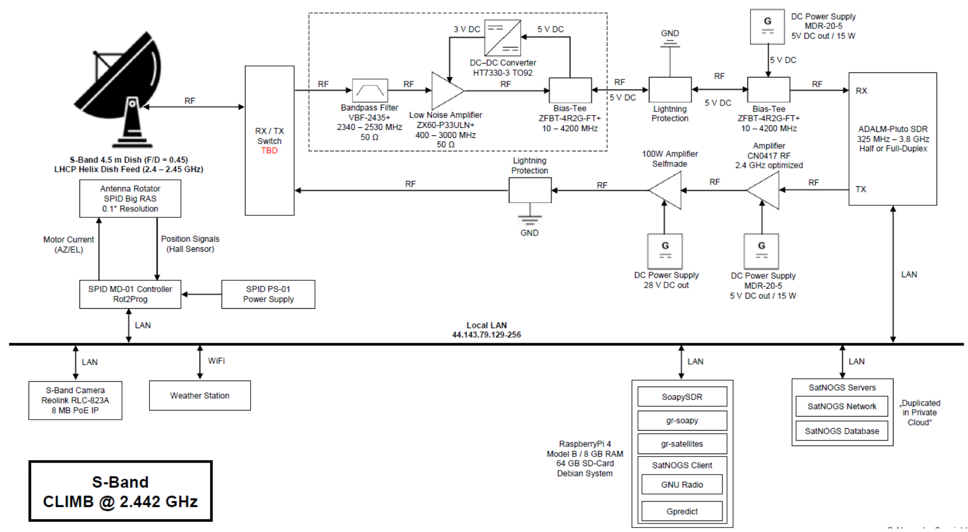
CLIMB mission

CLIMB mission

CLIMB communication

Switching from analogue to software defined radio (SDR) based ground station





Operation planning and execution

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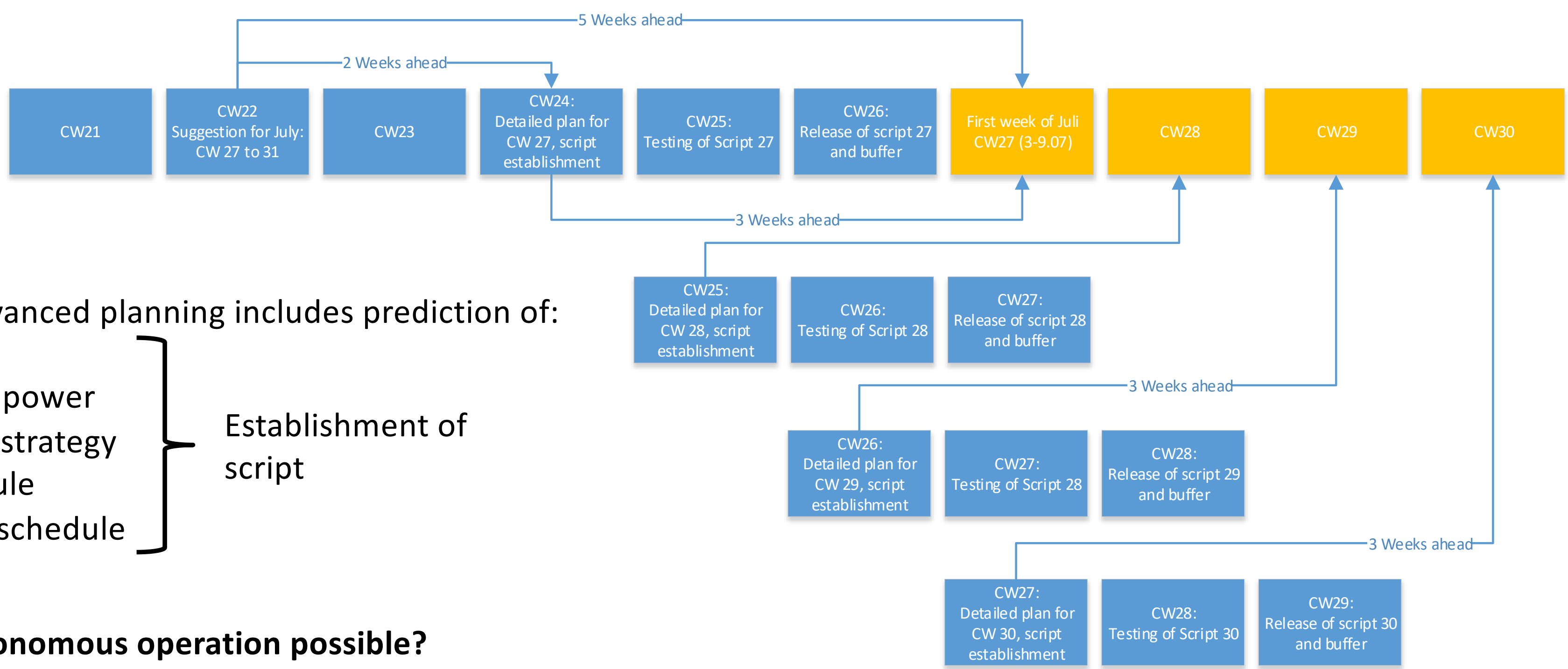
Advanced planning: Developing, testing, and uploading of scripts:



Output of advanced planning includes prediction of:

- orbits
- generated power
- alignment strategy
- link schedule
- operation schedule

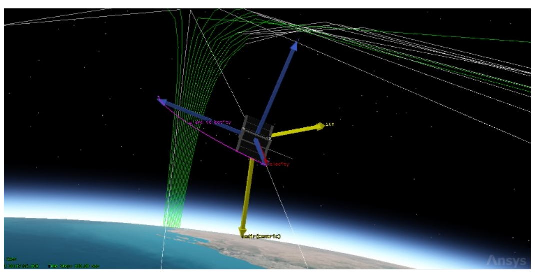
} Establishment of script

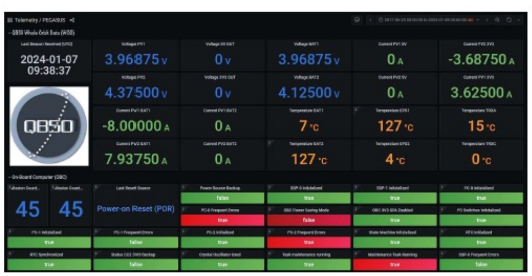
Autonomous operation possible?

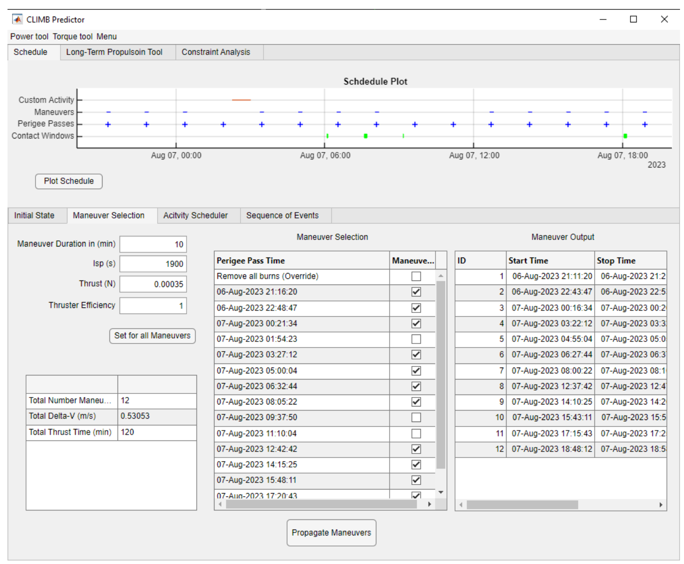
Operation planning and execution

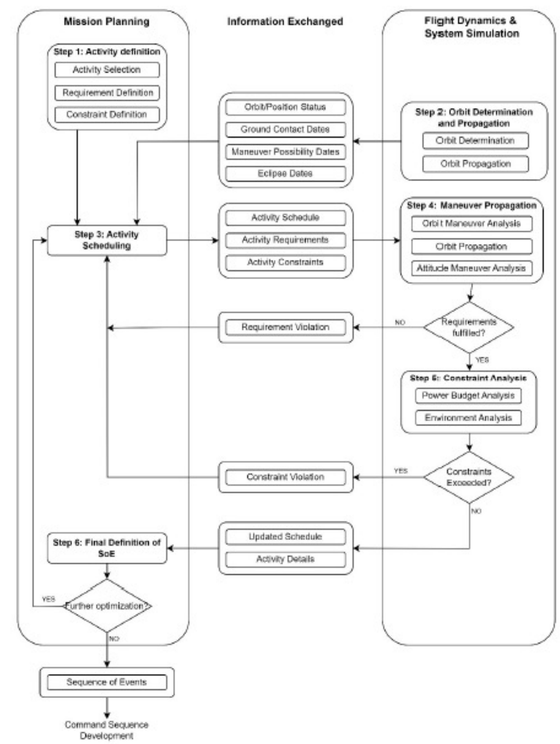
CLIMB will require a 24/7 operation due to

- Alignment requirements from:
  - Solar power
  - Propulsion
  - S-Band communication
- Collision avoidance requirements





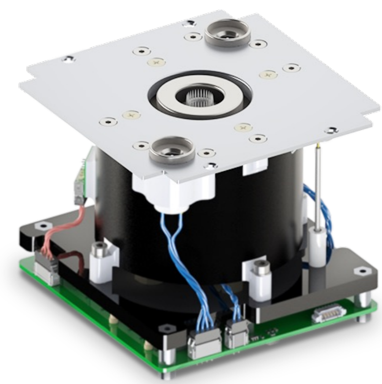


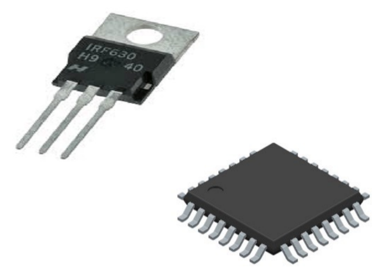


From Education

to

Business





What’s next?

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R-SPACE

We accelerate Space

- Founded in 2021
- The new way to conduct IOD/IOVs
- R-Space will ensure the launch of an IOD/IOV mission within **6 months**
- The GreenBox Service is a **one-stop shop service** using s**trategic partnerships** with launch provider and ground station networks
- The GreenBox service can **accelerate the development** (by IOD) of upstream technologies and allows the customer to generate the required data to **proof functionality in space**

What's next?

- IOD experiment ready until Q4, 2024?
- Available volume: 92 x 92 x 113 mm
- Maximum weight 1300 g

More information: www.r-space.at

Contact: info@r-space.at

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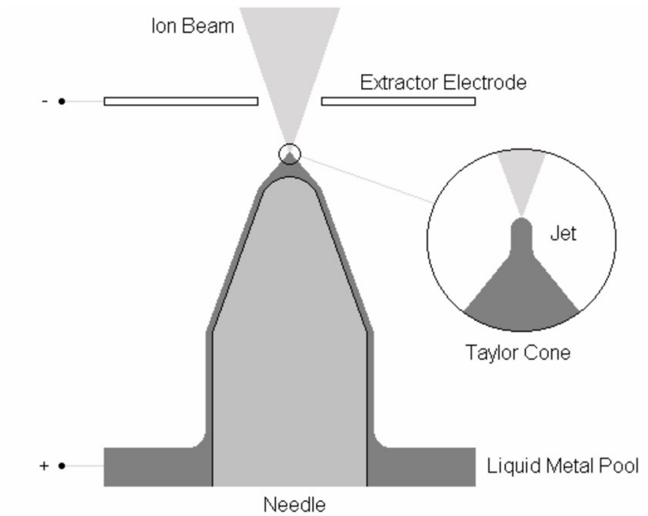
Electrostatic propulsion: FEEP

FEEP-Fundamentals



Schematic principle of operation of a FEEP thruster

Characteristics

- Field Emissions EP are based on the possibility to directly extract ions out of liquid metals by using a strong electric field (10^9 V/m)
- Such ion sources are called **Liquid Metal Ion Source (LMIS)**.
- Various FEEP technologies have been developed differing only in the fashion how the high electric field strength is produced and the type of propellant:

- Needle
- Capillary (porous)
- Slit

FOTEC Forschungsunternehmen -der FH Wiener Neustadt-

FACHHOCHSCHULE WIENER NEUSTADT Austrian Network for Higher Education

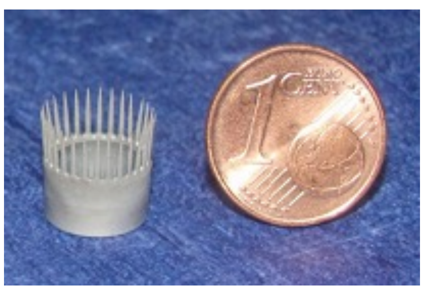
Electrostatic propulsion: FEEP

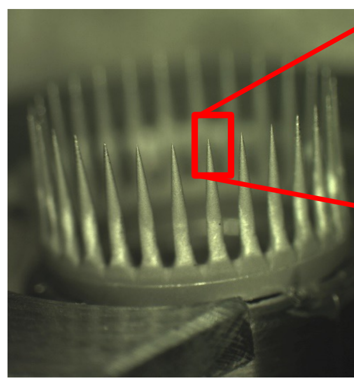
Smaller and more powerful

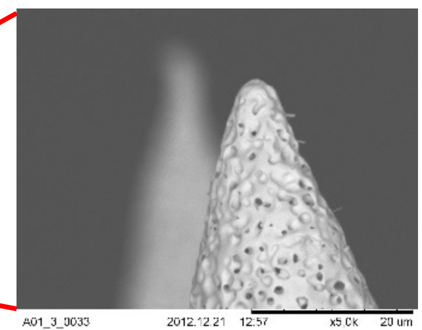
→ mN-FEEP with porous material „Crown Emitter“

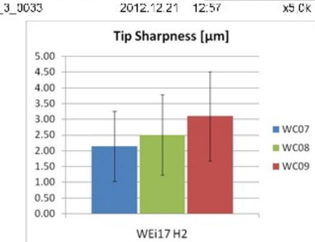
Technology:

Liquid propellant is forced through the needle using capillary forces. Combines the advantages of needle emitters (high field strenght) with the ones of a macro capillary (stability, contamination insensitivity)









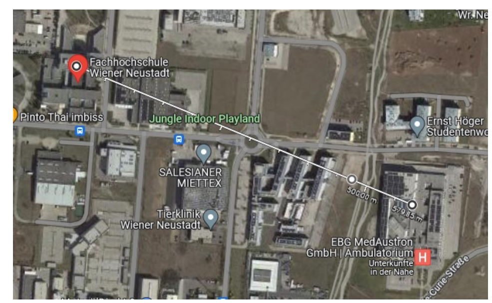
Radiation assessment

MedAustron
- Cancer Ion therapy centre
- Synchrotron accelerator
- Start of construction: 2011
- First patient treatment: 2016

Specifications
- Protons (62 to 253 MeV), Carbon (120 to 403 MeV/u) and Helium ions
- Commissioned for medical use (flux < 10^9 p/s)
- Beam pencil to scan DuT (irradiation plan)
- Intensity/Dose adaptable per position, energy adaptable per layer

- Low flux settings for non-medical use
  - flux > 2×10^3 p/s)
  - Up to 800 MeV

MedAustron facility with different irradiation rooms



MedAustron is placed 500 m apart from FHWN at Wiener Neustadt