We help
Earth benefit
from space

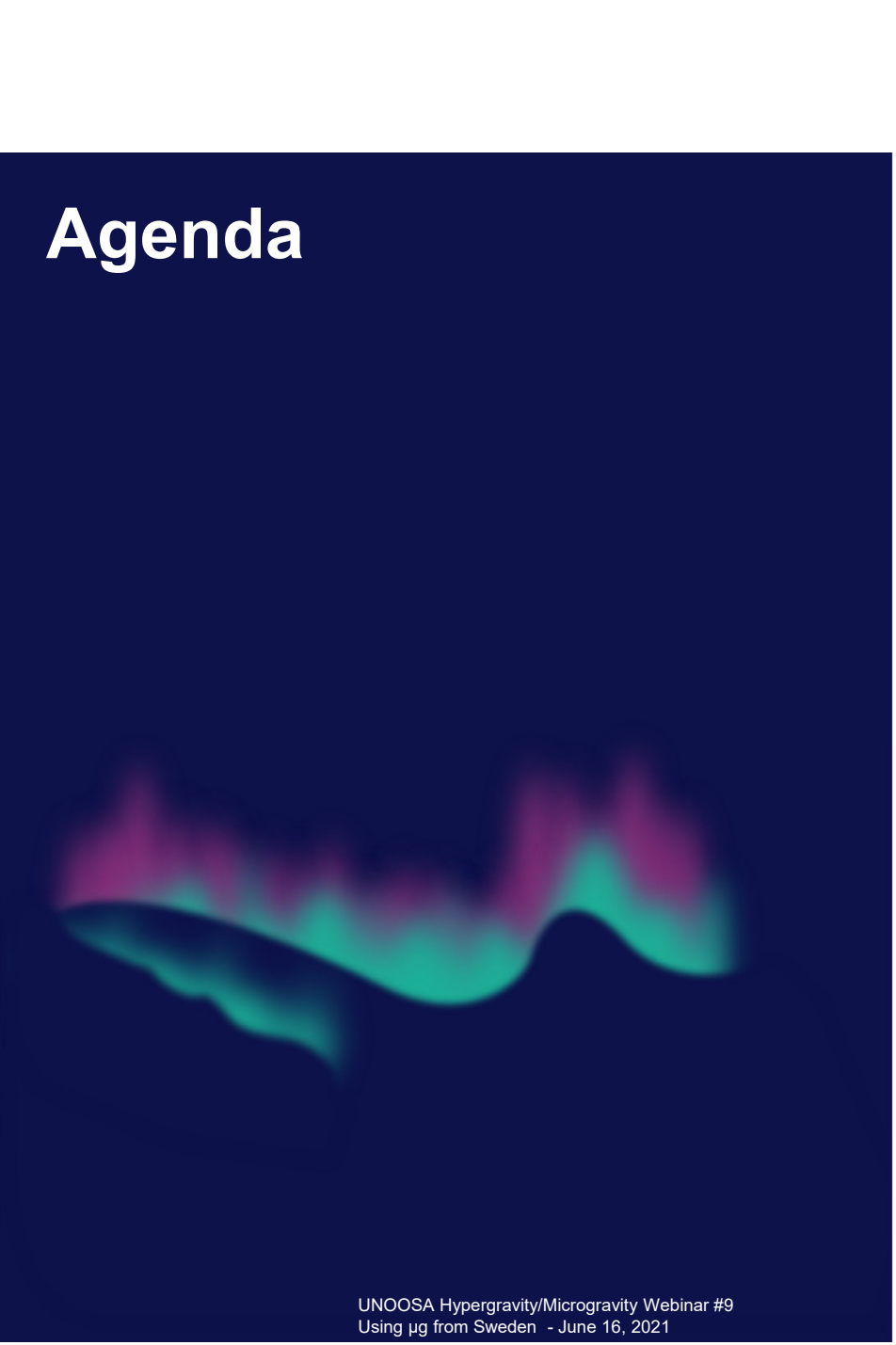
Using Microgravity from Sweden as Tool for Research

UNOOSA Hypergravity/Microgravity Webinar #9, Regional activities

Gunnar FLORIN

16 June 2021

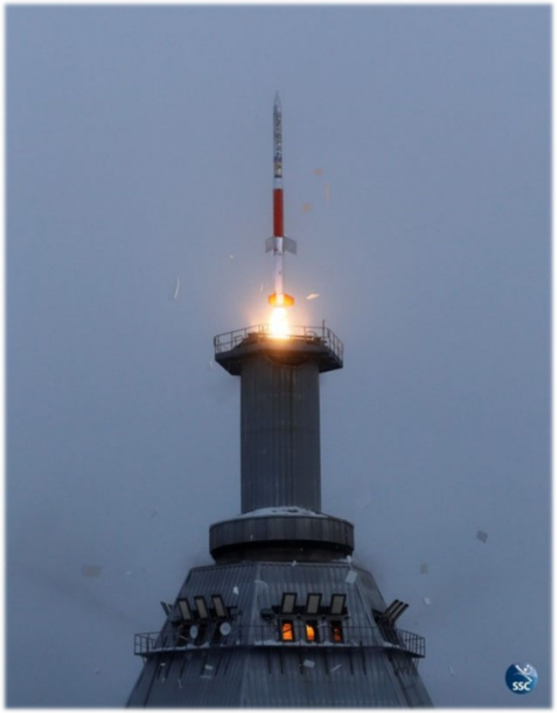
Agenda



Introduction

Gunnar FLORIN
Business Development Director, Science Services
Swedish Space Corporation (SSC)

2001-2019 Project Manager for SSC's sounding rocket microgravity missions



Legacy of SSC:

- Private company, fully owned by the Swedish Government
- SSC runs Esrange Space Center in Northern Sweden above the polar circle. Rocket impact area is vast and unpopulated, with air restrictions
- Around 600 rockets and 600 balloons launched from Esrange since 1966.
- More than 70 experiments developed for sounding rockets, the Space Shuttle and aircraft parabolic flights

ESRANGE SPACE CENTER

Basics of Weightlessness

Basics of weightlessness

When the acceleration of a body is the same as the gravitational acceleration, there is free fall – weightlessness

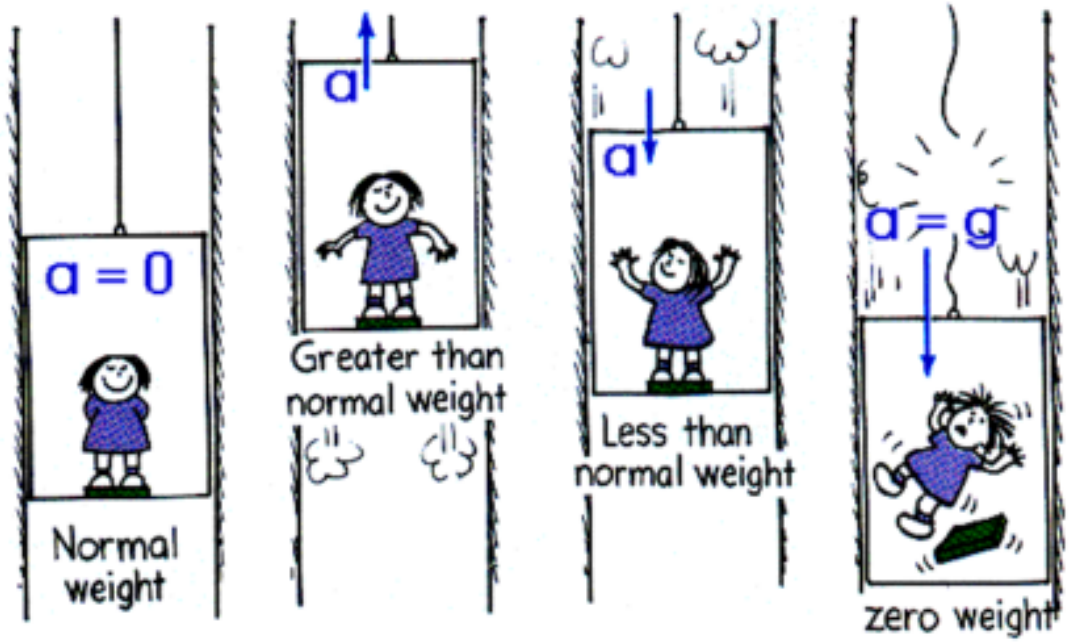


Figure: Acceleration (a) of a body in an elevator.

Gravity

On Earth:	9.8 m/s^2	1 g
On Moon:	1.6 m/s^2	0.16 g
On Mars:	3.7 m/s^2	0.38 g
Sounding Rocket		0,00001 g (1/100 000 g)

Parabolic Flights

Achieving weightlessness by means of flight parabolas

During a parabolic flight maneuver, an aircraft is weightless by flying on a trajectory which is very close to free fall conditions.

This gives 20 seconds of reduced gravity during which experiments are carried out, preceded and followed by 20 seconds of hypergravity 1.8 g.

Photo: Scientist and SSC staff in microgravity

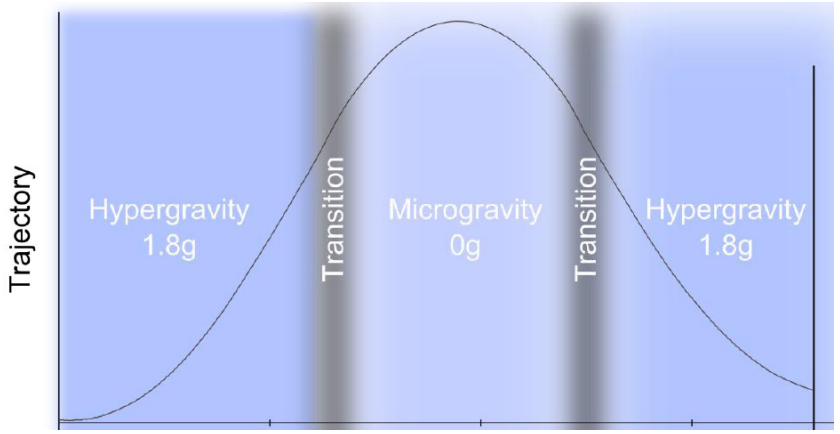


Photo and graph: Credit to Novespace

Sounding Rocket Microgravity

Achieving microgravity by means of a rocket

Sounding Rocket with experiments accelerates from Earth with up to 24 g.

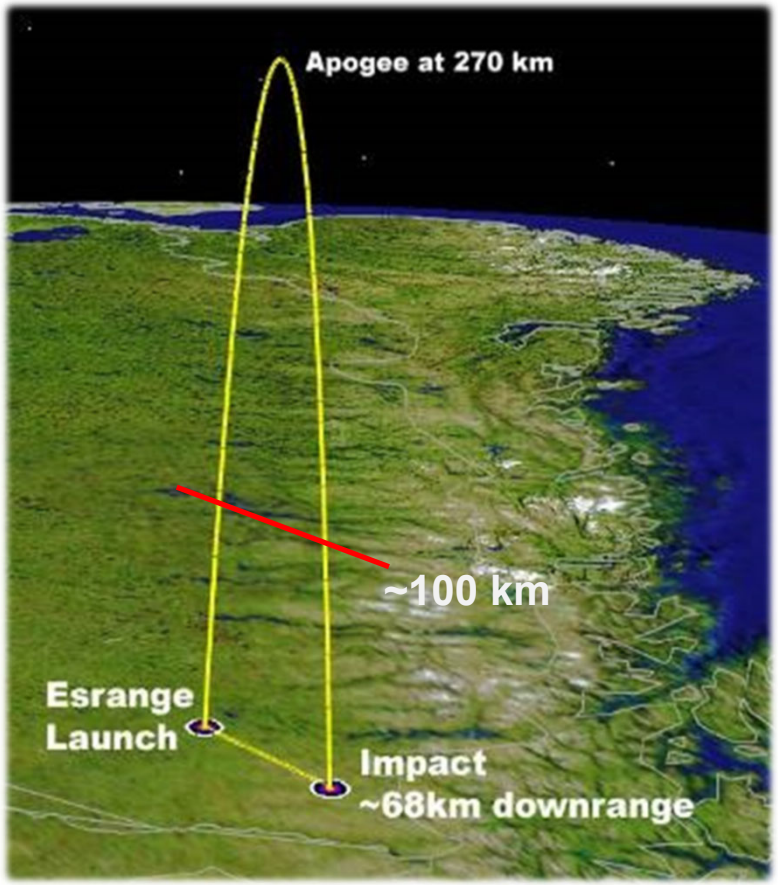
When motor has stopped burning above the atmosphere (>100 km), we have “free fall” conditions;

– **upwards**, to begin with due to the high speed of the rocket
– **then downwards** until the free fall conditions cease when the rocket re-enters into the atmosphere again.

During the free fall, there are high quality microgravity conditions during which scientific experiments are carried out, typically in a 6 minutes timeframe.

At Esrange, the experiments are retrieved within two hours after launch.

µg sounding rocket after motor burn-out



Typical flight trajectory of a microgravity rocket .

Research in Microgravity

Research in microgravity

Why using microgravity?

Many products we today take for granted results from spaceflight research – from laser eye surgery to clean cars and fighting antibiotic resistant bacteria

Microgravity is a tool or parameter used in many scientific research applications (it is not a research field in itself).

In microgravity, we remove a strong dominating force that on Earth conceals “weaker” forces and processes

- Microgravity
  - ➢ brings understanding of how the gravitational force influences different processes
  - ➢ provides better understanding of the functioning of processes, not observable on Earth

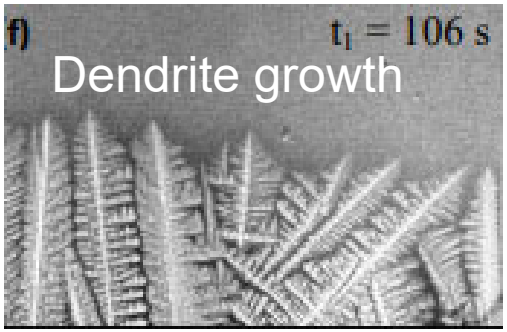
Research using microgravity

Various disciplins

- **Fundamental Physics**
  - Complex and dusty plasmas
  - Cold atoms and quantum fluids

- **Fluid and Combustion Physics**
  - Structure and dynamics of fluids and multi-phase systems
  - Combustion

- **Material Science**
  - Thermo-physical properties
  - Microstructure formation
  - Particle aggregation
  - Solidification / crystallisation
  - New materials and processes



Directional solidification of aluminium alloy

Metal foam: Turbine blades in LEAP Jet Engine

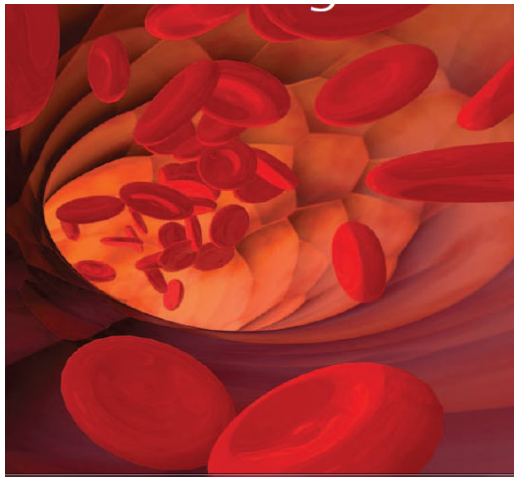
Research using microgravity

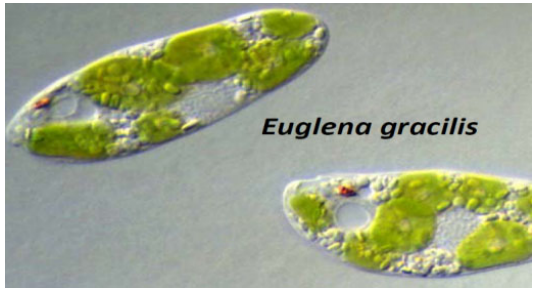
Disciplins

- **Biology**
  - Physiology
  - Plant physiology
  - Cell biology

- **Integrated Physiology**
  - Muscle and bone physiology
  - Neuroscience
  - Immunology

- **Preparation for human planetary exploration**





µg Experiments on SR flown from Sweden

More on research in microgravity on sounding rockets

Going a bit deeper…

Fluid Science

- Oil and water can be mixed into an emulsion, but gravity will quickly separate the two liquids, moving the less dense oil to the top and the water to the bottom of the container.

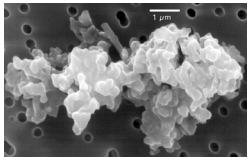
  Oil/water separation does not happen in microgravity, making it a great environment to study e.g. phenomena that cause the separation of mixtures.

Fluid experiment - investigation of chemical front propagation

Cosmology

- How are celestial bodies created? Dust particles are injected into a vacuum chamber, to observe their growth, how they interact and stick together through “Brownian motion”.

  This gives insight into how “planet embryos” evolved in the young Solar System.

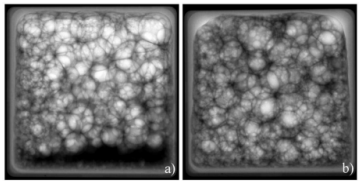


Meteorite dust particle

Liquid Evaporation

- Microgravity significantly alters the processes of evaporation and condensation.
  For some research experiments, liquids contain particles which after evaporation in microgravity will coat surfaces evenly.

  On Earth, gravity causes the deposits to spread unevenly or sediment, which is often detrimental for applications.



Foam on Earth (L) and in µg (R)

Foams

- Foams are widespread in our daily lives: they are used to produce food, detergents and plastics and light-weight metal structures.

  Foams mostly collapse in gravity, because the liquid between the bubbles is pulled downwards, bursting the bubbles.
  In microgravity foams are more stable.

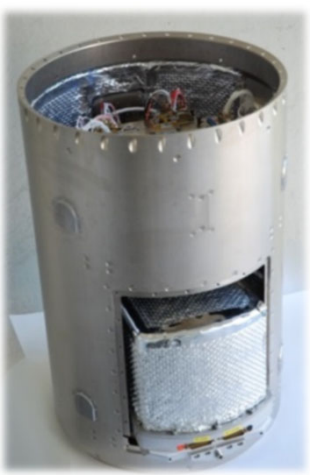
  Foam research in microgravity allows to better understand processes and create models, leading to better foam products.

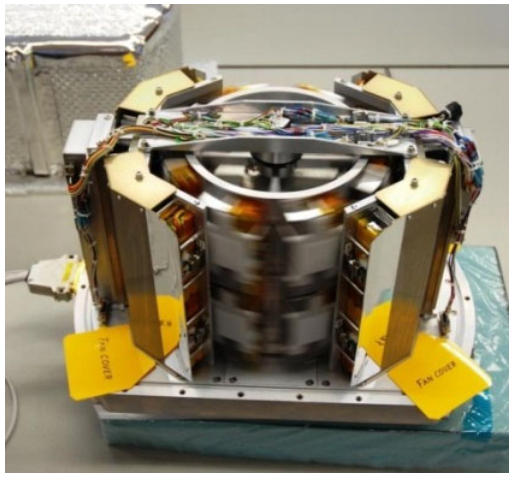
Microgravity experiment in Sweden - Biology

PLANTS IN MICROGRAVITY

GRAMAT on Microgravity mission
PI: K. Palme – Albert Ludwig University, Freiburg

- Studying isolation of mRNA to identify gravity related gene expression
- Large number of plants submitted to microgravity, and additional plants in centrifuge to provide 1 g reference during flight

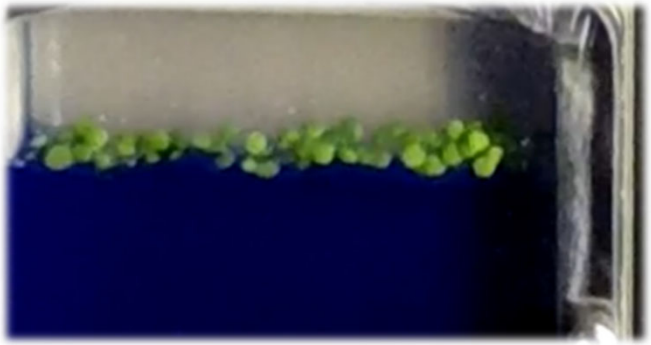




Plant biology experiment system with centrifuge

- Challenges adapting to Sounding Rocket environment:
  - Mass transfers in centrifuge
  - Seedling g vector alignment
  - Wetting of seedlings
  - Overheat & freeze protection
  - Several days of experiment preparations in lab
  - Adaption to darkness/light regime (limits launch window)

Arabidopsis Thaliana (Thale cress)



A. Thaliana in agar bed

Microgravity experiment flown in Sweden - Combustion

IRON POWDER COMBUSTION IN MICROGRAVITY

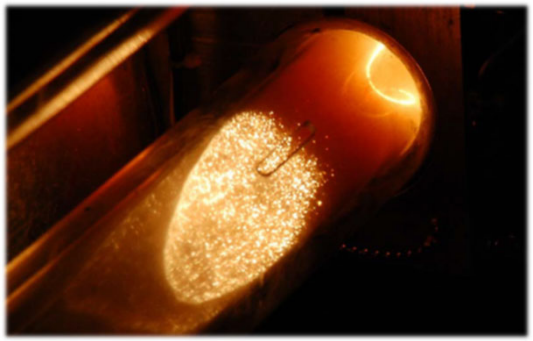
PERWAVES *"Percolating Reactive Waves in Particulate Suspensions"*

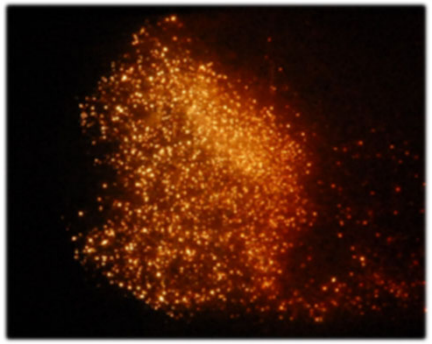
PI: A. Higgins – McGill University, Montreal

Studying combustion wave front of iron powder in microgravity (6 -12 minutes)

In weightlessness, the metal powder is evenly spaced, suspended and better studied

Application: Potential wide-spread future metal fuel. Smokeless & carbon-free process.
A first combustion facility is now installed at Swinkels Family Brewers, Netherlands





Iron powder combustion in micro gravity

PERWAVES experiment system with combustion tubes (Airbus D&S)

Photo credits: European Space Agency

Flight Opportunities

Student programmes using Esrange

Photos: Credit to REXUS/BEXUS programme

Student space programmes attract young people

REXUS:
German/Swedish programme with ESA collaboration, open for European university students performing experiments on sounding rocket flights. 2 sounding rockets yearly.

Several experiments use microgravity, e.g.
marine unicellular organisms; frog eggs; spinning fibers in µg for application on the Moon; investigation of carbon nanotubes and of gecko-materials behavior (adhesion).

SERA:
French university student rocketry within PERSEUS project. Students develop and launch supersonic rockets based on new techniques for rockets.

STERN:
German experimental university rockets student programme. Students design and launch their own rockets.

SubOrbital Express

Flight Opportunities

SubOrbital Express-1 Rideshare in June 2019

SSC runs the SubOrbital Express programme, with frequent sounding rocket flights from Esrange.

SSC offers rideshares on the microgravity flights, accessible for everyone.

Objective: affordable for all users; agencies, academia, commercial

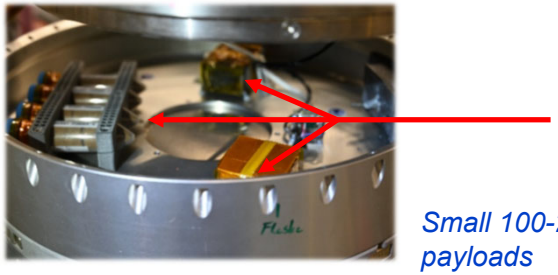
Capacity: 285 kg experiments in 17 inch diameter cylinders,
launched to 250 km, 6 minutes µg, $\leq 10^{-5}$ g

Experiment mass: from ½ kg to 60 kg, typically

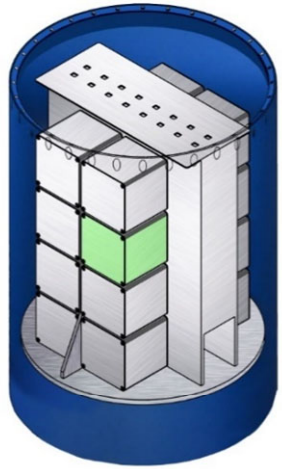
https://suborbitalexpress.com/

Flight opportunities:

June 2022: Open, 90% filled
2023: Open



Small 100-200 g payloads



Concept of resource sharing for small payloads

Suborbital Express missions

Rideshare missions, partly with ESA payloads, partly with payloads from academia, other agencies or commercial

Opportunity for µg-research using sounding rockets

SSC aims at expanding the student programme concept at Esrange to include other parts of the world, outside Europe.

Presently we are working on finding ways to cooperate with UNOOSA to include e.g. emerging space nations.

REXUS student team at Esrange Space Center

Credits and Literature List

Credits

In addition to extensive material and experience of SSC,
this presentation is based on photos and text stemming from websites

- of the European Space Agency ESA
- of the REXUS/BEXUS programme

and is also based on material from experiments on sounding rockets carried out in Sweden under ESA contracts and under Swedish National Space Agency contracts

Literature list

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