Developing a constellation of cubesats for studies of the atmosphere, ionosphere and magnetosphere

Peter Dalin

Swedish Institute of Space Physics (IRF), Kiruna, Sweden

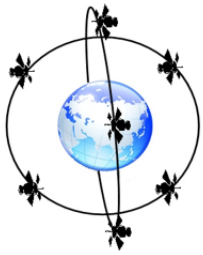
Tel: +46-(0)980-79023
E-mail: pdalin@irf.se

Scientific aims:
- Studies of various physical and dynamical processes in the atmosphere, ionosphere and magnetosphere at small and global scales during decades.

Problem:
- The basic physics and chemistry of the majority of atmospheric, ionospheric and magnetospheric phenomena is well understood at present.
- At the same time, large variability in space and time of enormous number of solar-terrestrial processes leads to complexity of those studies processes in the geospace environment (complex multi-parameter tasks).

Solution:
- This complexity can be solved from space only.
- However, a single satellite (orbiting either in a low or high orbit) cannot resolve this complexity (cannot fully observe a phenomenon) at small and large scales in time and space.
- This complexity can be solved only by applying a constellation of satellites simultaneously orbiting the Earth at fine and global scales.
- Currently, miniaturization of space technologies allows us to solve the proposed scientific aims in the geospace environment at a high scientific level.

Scientific aim: Studies of spatial and temporal evolution of atmospheric waves around the globe in the middle and upper atmosphere

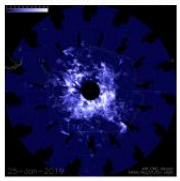


Scientific goals:
1. To study the evolution of atmospheric gravity waves (GWs) in 3D space at fine spatial scale (1 km horizontal resolution x 0.5 km vertical resolution) and at fine time scales 20-60 minutes (about 20 minutes time resolution).
2. To study the evolution GWs at medium time scales of 6 hours.
3. To study the wave dynamics at larger scales around the globe such as planetary waves, solar thermal tides and lunar gravitational tides.

Method: Utilization of a constellation of eight cubesats, carrying optical imagers to register and to 3D map layered atmospheric phenomena such as noctilucent clouds (NLCs) and airglow emission layers. This is the only way to actually observe and trace atmospheric wave disturbances in the middle and upper atmosphere around the globe and at high time and spatial resolution.

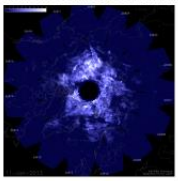
Examples of noctilucent clouds (NLCs) as observed at the nadir and at the atmospheric limb:

Nadir: Southern Hemisphere, AIM mission:



UV cameras

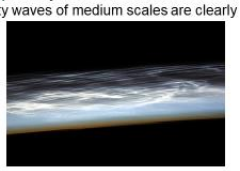
Nadir: Northern Hemisphere, AIM mission:



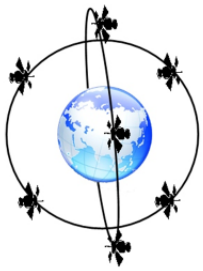
Limb: photo by cosmonaut F. Yurchikhin from ISS: Gravity waves of various scales are clearly seen.

Visible range cameras

Limb: photo by cosmonaut O. Kotov from ISS: Gravity waves of medium scales are clearly seen.



Implementation:
- Developing a constellation of cubesats deploying several cubesats in one orbit and making a constellation of similar several orbits (both low and high) orbiting the Earth during decades.
- Various packages of scientific instruments (optical cameras, measuring electrical and magnetic fields etc) can be mounted on cubesats for studies of atmospheric, ionospheric and magnetospheric processes.
- Constant replacement of cubesats at modern technological and scientific levels will maintain this mission during decades that is important from scientific (long-term changes) and social-education perspectives.



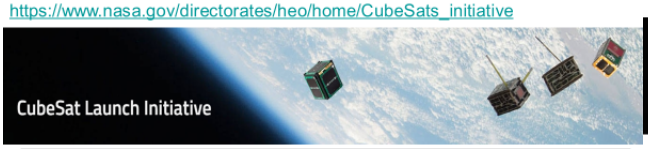
Nuvarande utvecklingsstatus:
The current technique status of the proposed project in Sweden is under the progress. For example, cubesats have already been built at LTU and KTH.

Skapar nytta för olika typer av användare i vårt samhälle:
- CubeSats can be built in Sweden by several space-oriented organizations like IRF, LTU, KTH, Stockholm University, Chalmers University.
- This mission can be realized in collaboration between universities, research institutes and the Swedish space industry.
- All these organizations can be involved into one big programme (a **national CubeSat programme**). It is of importance that this mission can unite both scientists, engineers and students during decades. Thus, space scientific aims, high level engineering tasks as well as educational and social programs can be established and conducted during decades.
- CubeSats could be launched from Esrange as part of a Swedish national cubesatellite programme.

Ungefärligt investeringsbehov för realisering: A basic 1 unit cubesat (10x10x10 cm) costs about **1 MSEK** to construct. Each scientific cubesat can be of **6-10 units**. The minimum required number of cubesats in a constellation is **eight**. Thus, a constellation of **8 scientific cubesats will cost around 80 MSEK.**

Andra deltagande aktörer och deras roller:
• Potential aktörer är scientists, engineers and students från **IRF, LTU, KTH, Stockholm University, Chalmers University**.

CubeSat Launch Initiative programme:
• NASA has selected **eight** small research satellites from seven states.
• These missions are currently planned to launch in **2023-2026**.
• The selected CubeSats were proposed by educational institutions, nonprofit organizations, and NASA centers in response to NASA's CubeSat Launch Initiative (CSLI) call for proposals issued on August 9, 2021.
• CSLI fosters innovation in the science and technology community by launching CubeSats built by diverse organizations - from middle schools to NASA Centers.These partnerships benefit NASA, commercial launch partners, and participants by providing a low-cost pathway to launch small satellites conducting scientific investigations, technology demonstrations, Earth observation and more.
https://www.nasa.gov/directorates/heo/home/CubeSats_initiative



A national Swedish CubeSat programme is needed in order to develop a constellation of minisatellites for studies of the atmosphere, ionosphere and magnetosphere during decades like it is currently realized by NASA.