

A large, stylized graphic for the SWARM 10 Year Anniversary Science Conference. It features the word "SWARM" in a bold, teal font above the number "10" in a very large, outlined teal font. The "0" contains a small globe and a satellite icon. Below the "10" is the text "YEAR ANNIVERSARY" and "SCIENCE CONFERENCE" in a smaller teal font. The graphic is set against a background of blue and teal wavy lines and a satellite in orbit.

SWARM

10

YEAR ANNIVERSARY  
SCIENCE CONFERENCE

Swarm - Past Present Future

*Anja Strømme*  
ESA

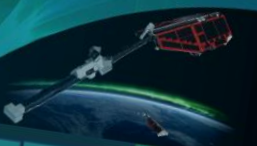
Swarm 10 Year Anniversary & Science Conference 2024





# Swarm Mission status and future perspectives

Anja Strømme and Enkelejda Qamili  
On behalf of the whole Swarm team





### Swarm Mission Status


The three satellite Swarm constellation is on a mission to unravel our planet's invisible shield - the Earth's magnetic field, and Swarm is, after 10 years in orbit, still in excellent shape and is still contributing to a wide range of scientific studies from the core of our planet via the mantle, the lithosphere and out to the ionosphere and the interaction with the Solar wind.

**Excellent performance overall!**

- Platforms, instruments and ground segments nominal and in overall good health
- Full mission processing and TTD of new Swarm data completed
- New "Fast" data chain deployment, and TTD performed in Nov. 2023
- Improved data access and discoverability
- No major concerns regarding life-limited items (including fuel resources on all three satellites - both in the 2025 (end 2025) timeframe)

**Swarm Mission Lifetime**

The Swarm mission has been extended several times in the past through a scientific assessment performed by ESAC followed by PE-ED approval. A new procedure ESAC/PE-ED/202404 is in place to align the mission extension through the current solar cycle and overlap during next solar minimum (~2030) to allow lithospheric measurements close to Earth while the Sun is quiet.

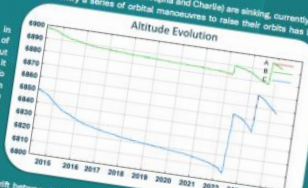


### Swarm Mission Objectives

- Capturing and understanding the Earth's core dynamics
- Mapping and understanding the near-Earth environment response to the solar cycle
- Disentangling spatial and temporal variation in the near-Earth environment
- Mapping ocean tides and the electrical conductivity of the mantle
- Seismic opportunities at the cutting edge of Earth and space physics and the understanding of physical coupling between terrestrial and space
- Lithospheric Programs: Fields

### Swarm Orbit Evolution

Due to the very active phase of the Solar cycle the lower pair (Swarm Alpha and Charlie) are sinking, currently with a rate of 2 km/month. To prevent an early re-entry a series of orbital manoeuvres to raise their orbits has been performed.



This orbital raise is carried out in few steps, i.e., raising the altitude of Swarm Alpha and Charlie by about 40 km in May 2022 and raising it again by 29 km in April 2023. To ensure the vertical separation between Swarm Bravo and the lower pair, the altitude of Swarm Bravo was raised by ~19 km in September 2023.

In addition, we stopped the relative drift between Swarm Alpha and Charlie at 1.4° early fall, to be decreased to ~1.2° toward the end of the mission

### Swarm Product Portfolio

**L1B AND L2 Data**

- Multi-scale Magnetic Field reconstruction from the core to the ionosphere
- Production of L1B MAGNETIC data: MAGNETIC
- Production of L2 data: improved, growing portfolio of ~60 products
- Completed (new) L1B baseline, reprocessing & TTD deployed in end Q3-2024

**LEVEL 2 DATA**

- synergy with other satellite missions and enhance the scientific return of Swarm
- On-going: Collaboration platform: SWARM, SWARM-Q2 and Copernicus
- On-going: MIS-1, CO2 and E-Field processing, completed
- On-going: L2 data processing of multiple L1B Swarm data products

**LEVEL 3 DATA**


- Fast-track processing of reprocessed L1B and L2 data for Science Workshop applications
- Top priority during Swarm Mission extension phase
- Completed (re)processing of multiple L1B Swarm data products
- On-going: L2 DISC products for Science Workshop applications
- On-going: L2 data processing of multiple L1B and L2 Swarm data products and indices

### Swarm DISC

**What is the Swarm DISC?**  
The Swarm Data and Innovation Science Cluster (DISC) is an international consortium created to enhance the scientific return of the Swarm mission.

**Main Tasks:**  
Process & disseminate Swarm data, communication, identify, select and run New Swarm Products and Services.

**Swarm DISC Consortium:**  
The Swarm DISC Consortium currently consist of 20 partners from 19 countries in Europe and North America



### Status of Swarm L1B OPER and FAST data

Overall status of Swarm OPER L1B data is Nominal. Evolutions to be implemented in Swarm L1B Operational data production chain (Q4/Q3/24), i.e., SWI parameter counter product: new product containing the Night energy proton flux (1000 MeV) measured by the Camera Head Units by counting the halos.


Improved SWI Sun correction for ASM data to count for Sun eclipses

new compensation for electron density and improved flagging for artificial spikes

Status of Swarm FAST L1B data is Nominal

A downlink optimization strategy to reduce the bandwidth of Swarm FAST data acquired over 2024.

Some SWI resolutions planned for the OPER data production chain will be implemented on FAST as well.



### Swarm Data Access

All Swarm Level 1b (OPER & FAST) and Level 2 (OPER) data are freely accessible to all users:

- <http://swarm-dias.eo.esa.int>
- <http://swarm-dias.eo.esa.int>
- Interactive data manipulation tool & retrieval for Swarm: <https://vires.services>
- Web-based interactive environment based on JupyterLab: <https://virescent.readthedocs.io/>

### Upcoming events

You are invited to attend the Swarm Data Quality Workshop 2024 (DQW24)

When: 7 to 11 October 2024  
Where: Bucharest, Romania

# Swarm – the past



We have this morning heard how Swarm came to be – and if it should be summarized:

# Swarm – the past



We have this morning heard how Swarm came to be – and if it should be summarized:

“Never ever give up” if you have a good idea

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”It takes a village”

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“Never ever give up” if you have a good idea

”It takes a village”

”Keep moving forward ”

# Swarm – current



How does this compare to the current situation for Swarm?



# Swarm – current



How does this compare to the current situation for Swarm?

“Never ever give up” if you have a good idea





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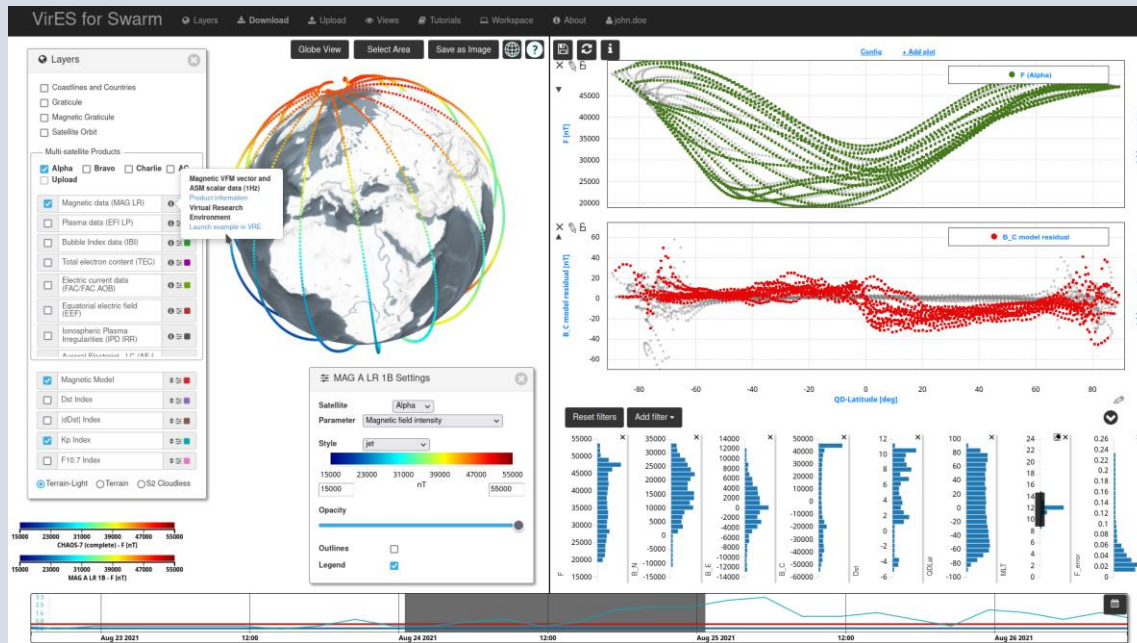
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Process & disseminate Swarm data, communication, identify, select and run New Swarm Products and Services.

## Swarm DISC Consortium

The Swarm DISC Consortium currently consist of 35 partners from 19 countries in Europe and North America





## VirES for (not only) Swarm

<https://vires.services>

### ecosystem of services:

- highly interactive web for quick data exploration
- Jupyter-based Virtual Research Environment
- VirES Python client for API access to data
- Heliophysics API



### offered data:

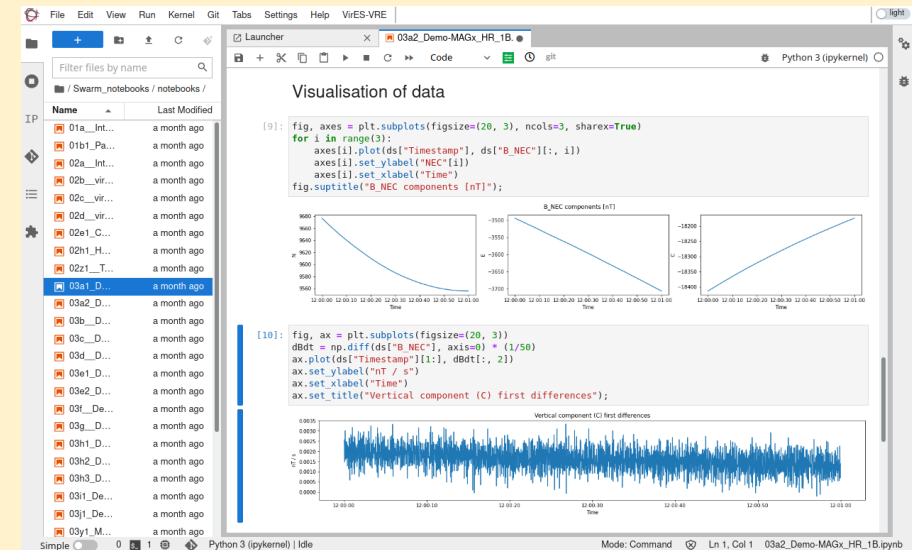
- Swarm products (L1B MAG and EFI, L2)
- rich collection geomagnetic models (L2 SHA, CHAOS, IGRF, ...)
- calibrated measurements from CryoSat-2, GRACE-1,2 and GRACE-FO platform magnetometers.
- INTERMAGNET ground observatory data

## Virtual Research Environment

- ready-to-use cloud execution environment
  - access to VirES datasets
  - curated set of pre-installed libraries
  - collection of example recipes
- allows for custom data-processing and visualization

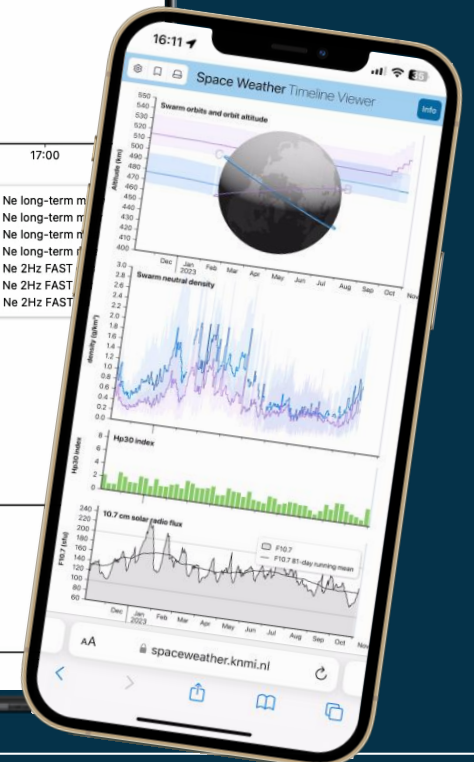
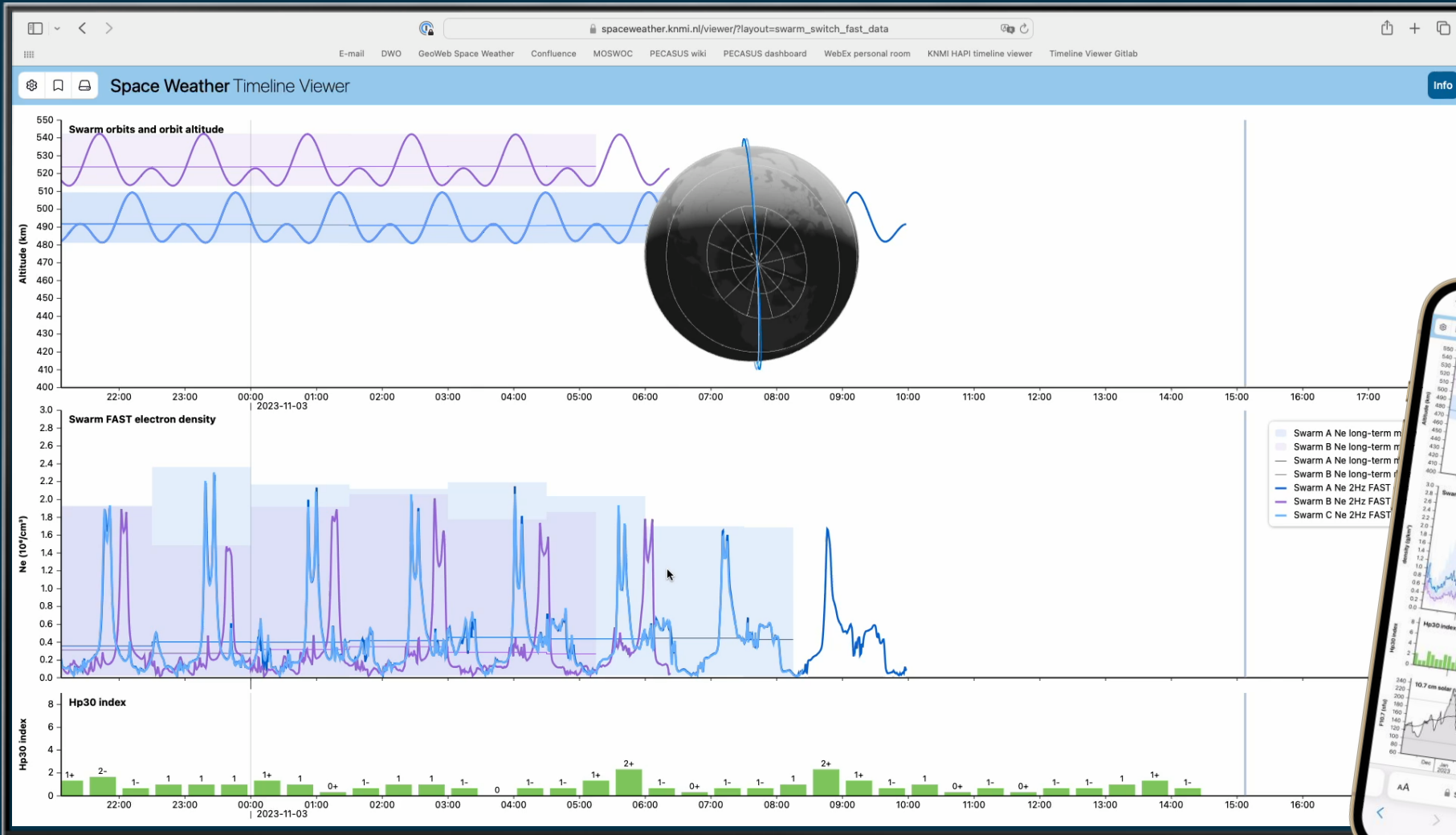
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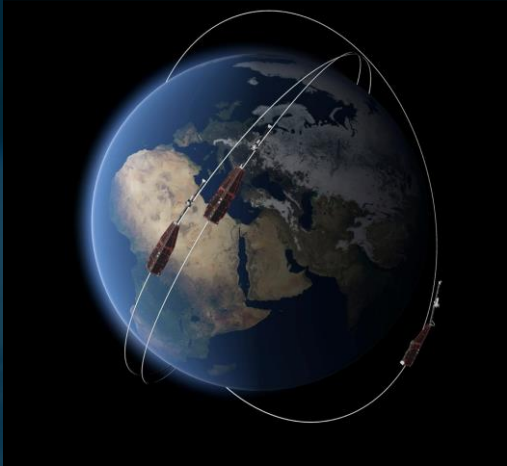


# Swarm observations together with a large number of other sources in the KNMI Space Weather Timeline Viewer

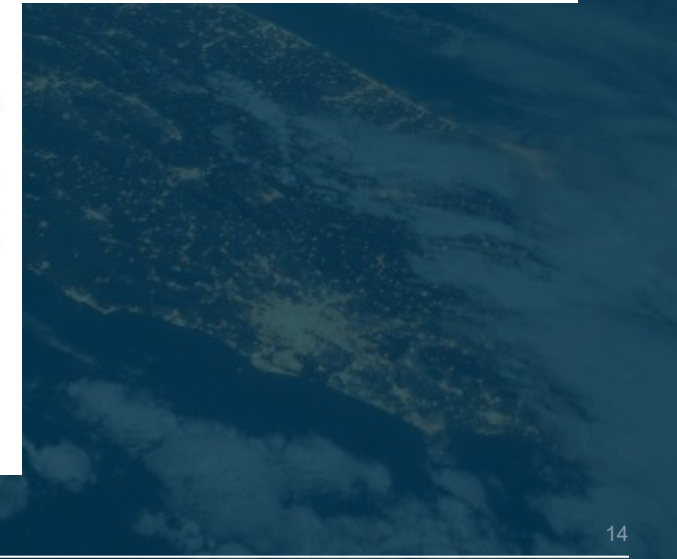
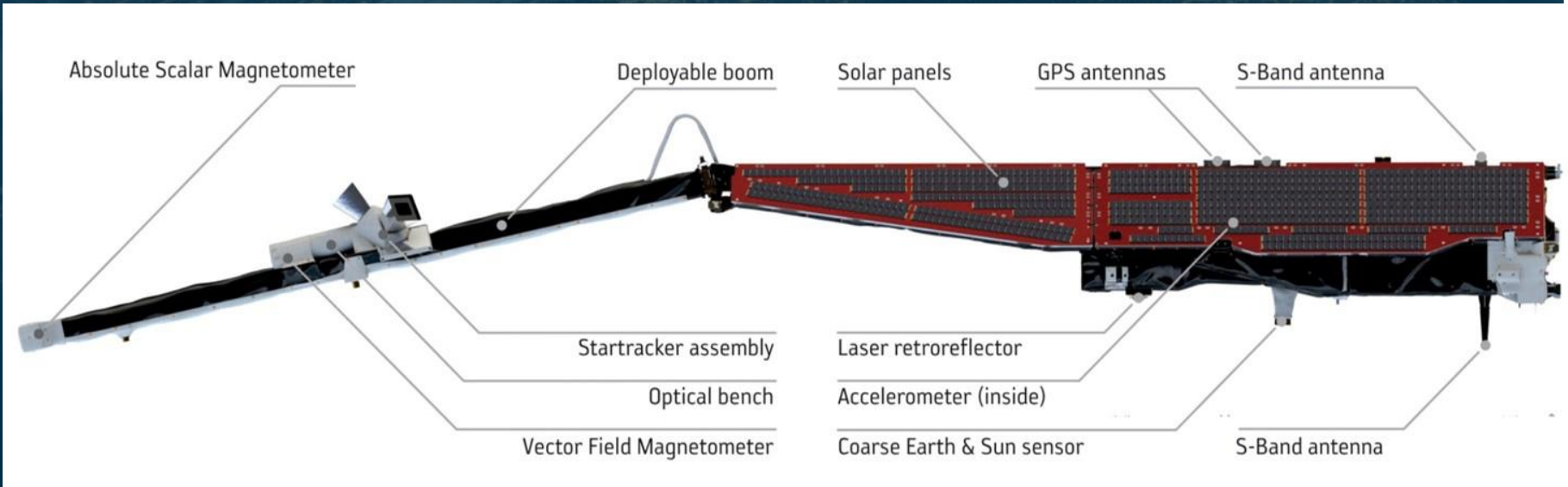
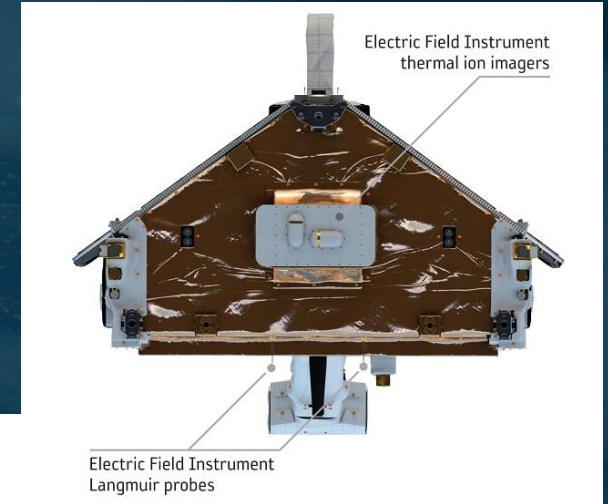




# The Swarm Satellite and Instrumentation

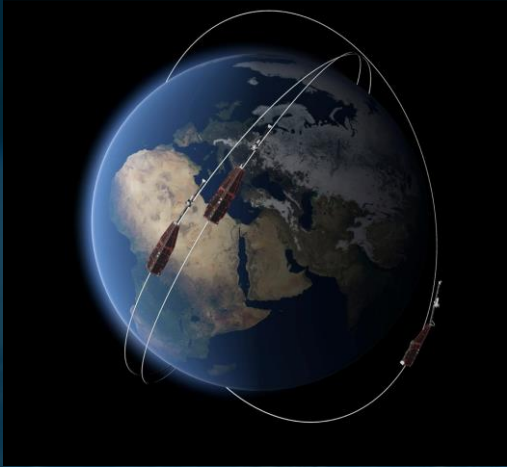


- Swarm is a constellation of 3 identical satellites
- Lower pair (Alpha and Charlie) “side by side” nominally 150 km separation at the equator and 4-10 s along-track separation to avoid collision at the poles
  - Upper satellite (Bravo) in nominally different local time orbit

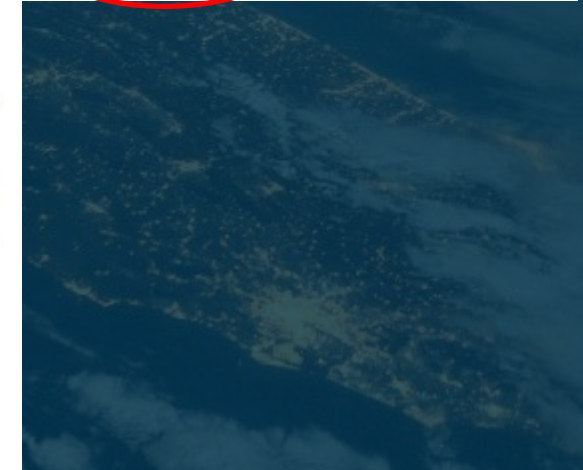
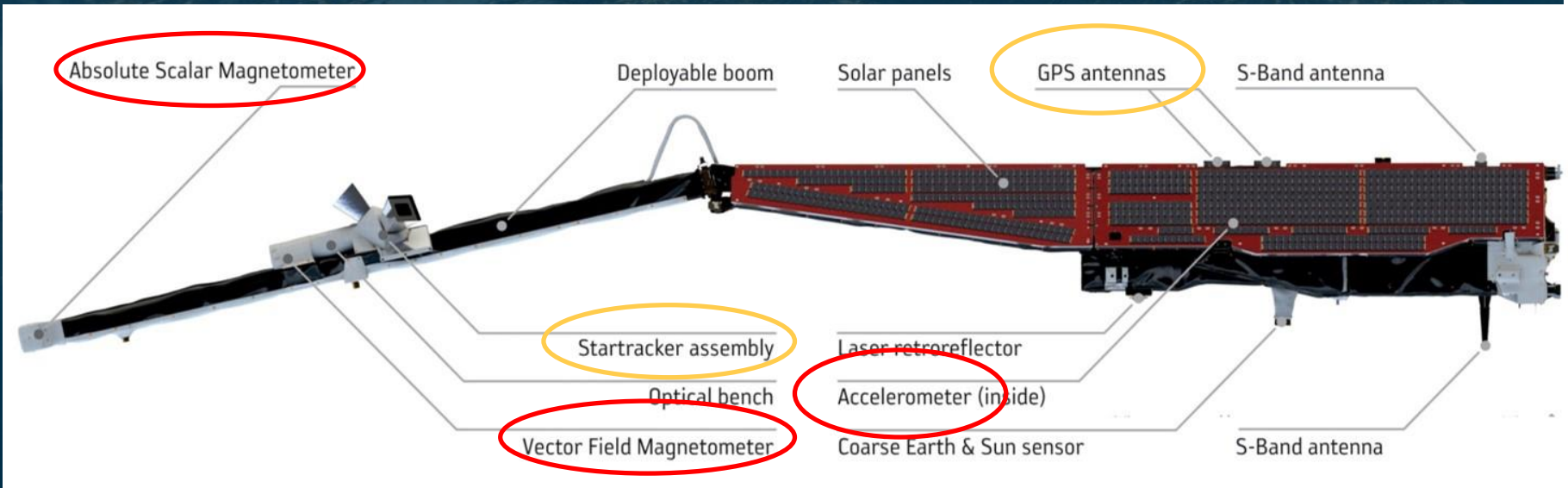




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“Even a (almost) perfect mission can get better”



earth online  
visuals

MISSIONS DATA APPLICATIONS

esa

< See all Missions

## Swarm

Magnetic Field Mission

ABOUT THE MISSION

SCIENTIFIC INSTRUMENTS

- + ACC
- + ASM
- + LP
- + TII
- + GPSR
- + LRR
- + STR
- + VFM

Related Data Applications

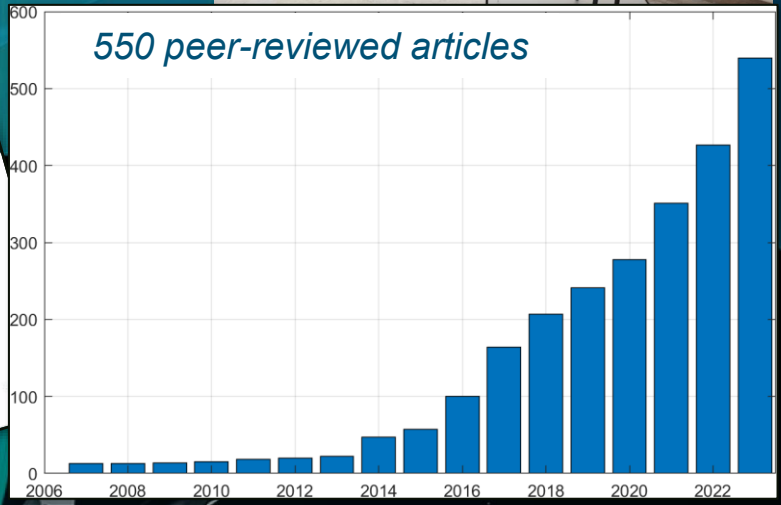
European Space Agency Earth Online Cookie Notice Terms & Conditions





# Swarm 10 years in orbit!

- ✓ 56,204 orbits for Swarm Alpha
- ✓ 56,200 orbits for Swarm Charlie
- ✓ 55,508 orbits for Swarm Bravo
- ✓ 102 Level-2 data products



STORY APPLICATIONS

There's a jet stream in our core  
19/12/2016 31631 VIEWS  
READ

When Swarm met Steve  
21/04/2017 38141 VIEWS 281 LIKES  
READ

Unravelling Earth's magnetic field  
14/05/2020 15744 VIEWS  
READ

Magnetic north and the elongating blob  
14/05/2020 15744 VIEWS  
READ

Energy from solar wind favours the north  
12/01/2021 5717 VIEWS 123 LIKES  
READ

Swarm helps Earth's magnetic field  
01/05/2019 13015 VIEWS 245 LIKES  
READ

Swarm reveals why satellites lose track  
28/10/2016 16395 VIEWS 223 LIKES  
READ

Swarm turns to whistlers and storms  
13/04/2018 4324 VIEWS 83 LIKES  
READ

Tug-of-war between magnetic north and south  
15/05/2019 13360 VIEWS 195 LIKES  
READ

Swarm yields new insight into animal migration  
09/07/2021 7775 VIEWS 118 LIKES  
READ

Swarm reveals weaker magnetic field  
20/05/2021  
READ



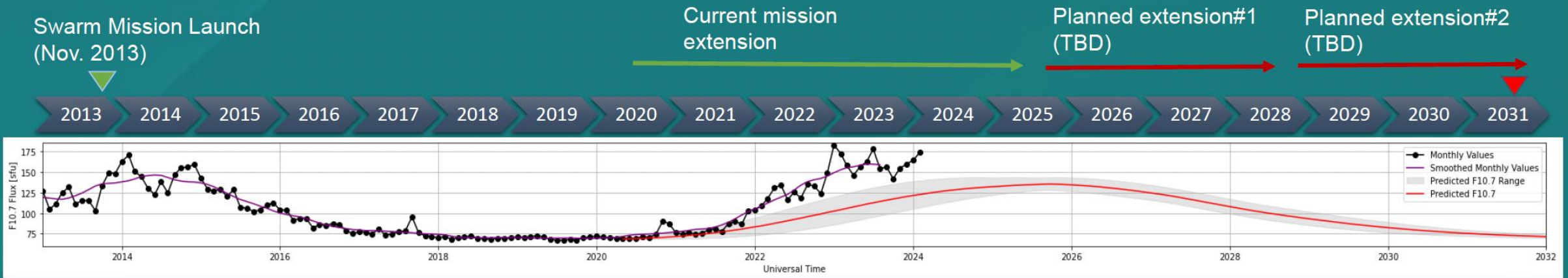




# Swarm Mission Lifetime

The Swarm mission has been extended several times in the past through a scientific assessment performed by ACEO (ESAC) followed by PB-EO approval. A new procedure ESA/PB-EO(2020)40 is in place to align the mission extension with the 3 year cycle of the FutureEO program in time for the Ministerial Conferences.

Swarm is currently extended through 2025, and if onboard recourses and funding allows, the plan is to fly the mission through the current solar cycle and deorbit during next solar minimum (~2030) to allow lithospheric measurements close to Earth while the Sun is quiet.



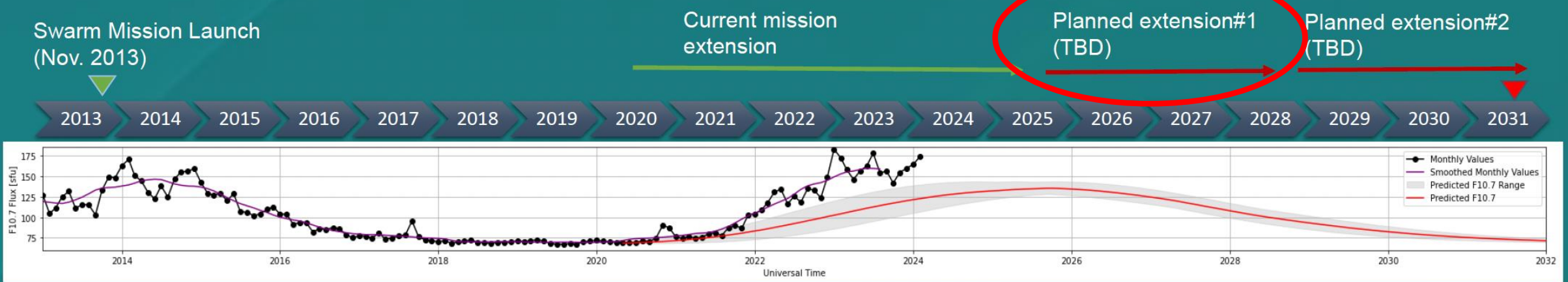




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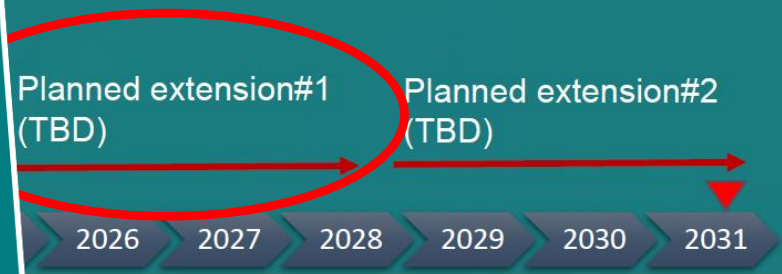
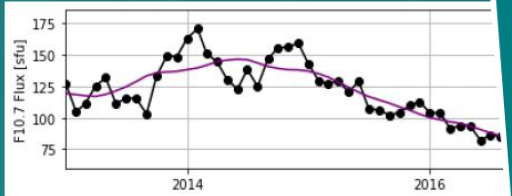
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Swarm is currently extended through the current solar cycle close to Earth while the

Shortly after this meeting we will start working on the mission extension report to be presents for ACEO\* first week of November 2024

\* The Advisory Committee for Earth Observation

Swarm Mission Launch (Nov. 2013)



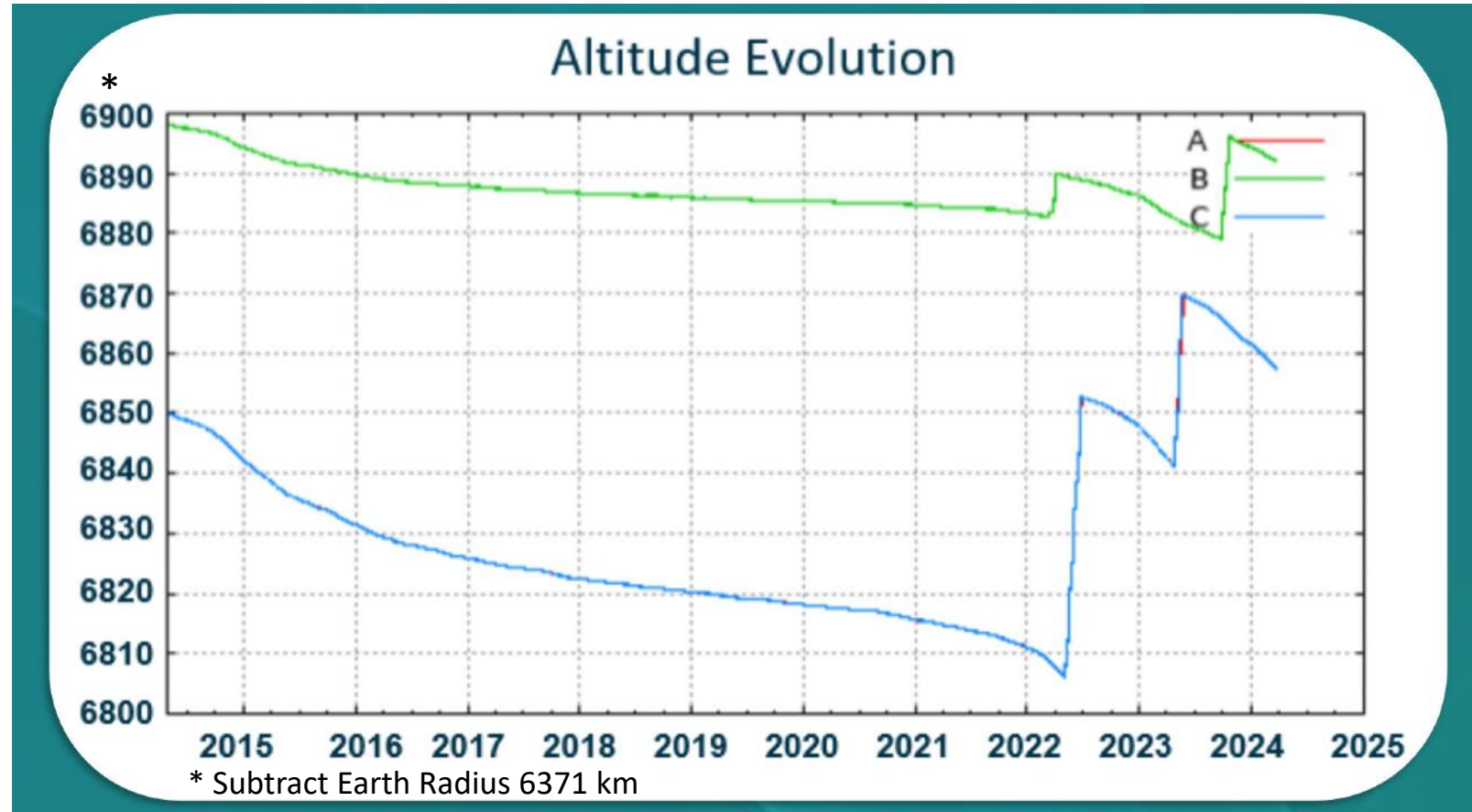




The Swarm lower pair has been raised twice the past two years and will now slowly (!) decay until reentry ~2031-2032 timeframe

Swarm Bravo completed a delta orbit raise to maintain proper separation with the lower pair while staying away from dense Starlink orbits.

Lower pair separation at the equator stopped at 1.4 deg, same as before 2019.



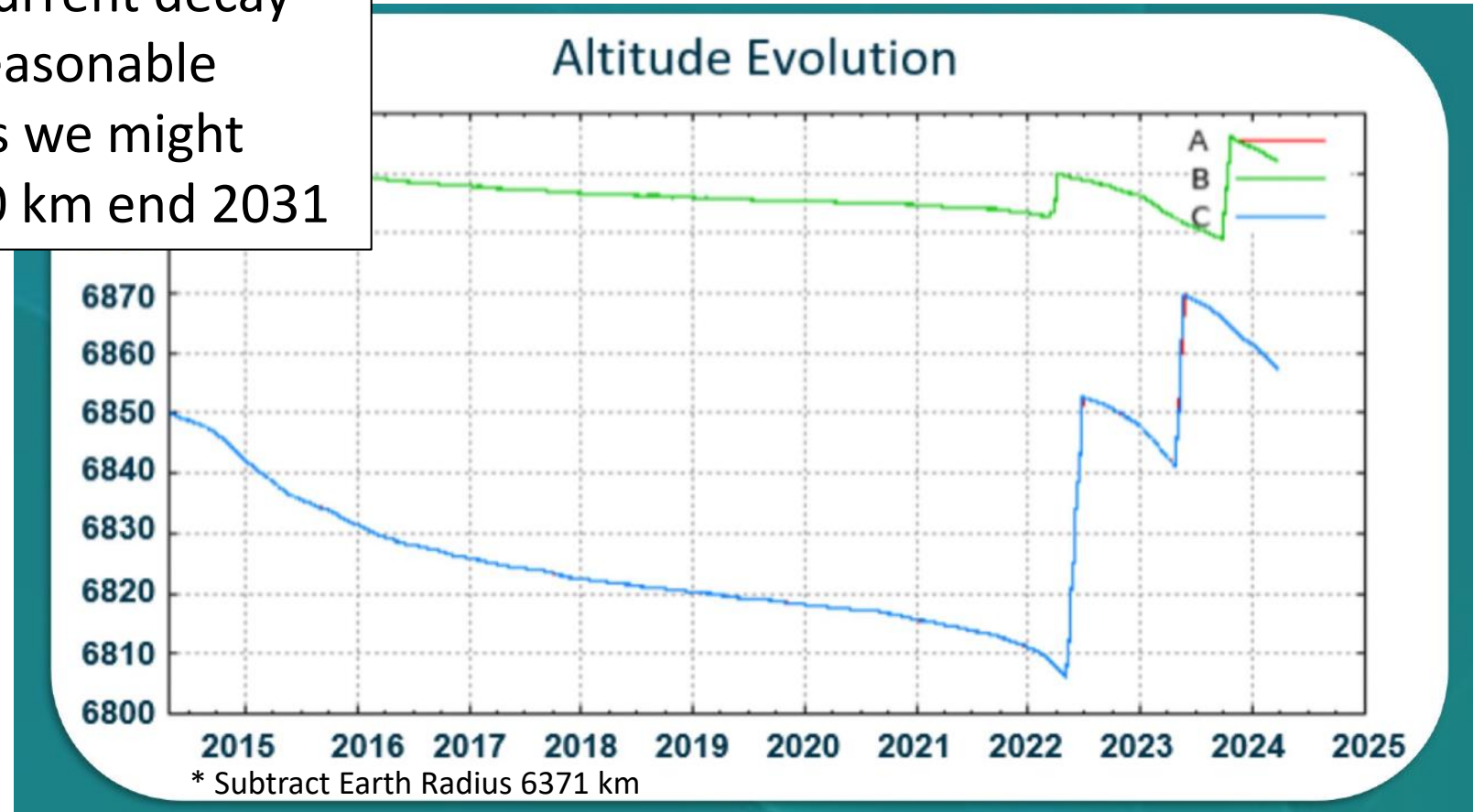


The Swarm lower pair has decayed twice the past two years and is slowly (!) decaying until reaching the 2032 timeframe

With the current decay rate and reasonable predictions we might reach ~380 km end 2031

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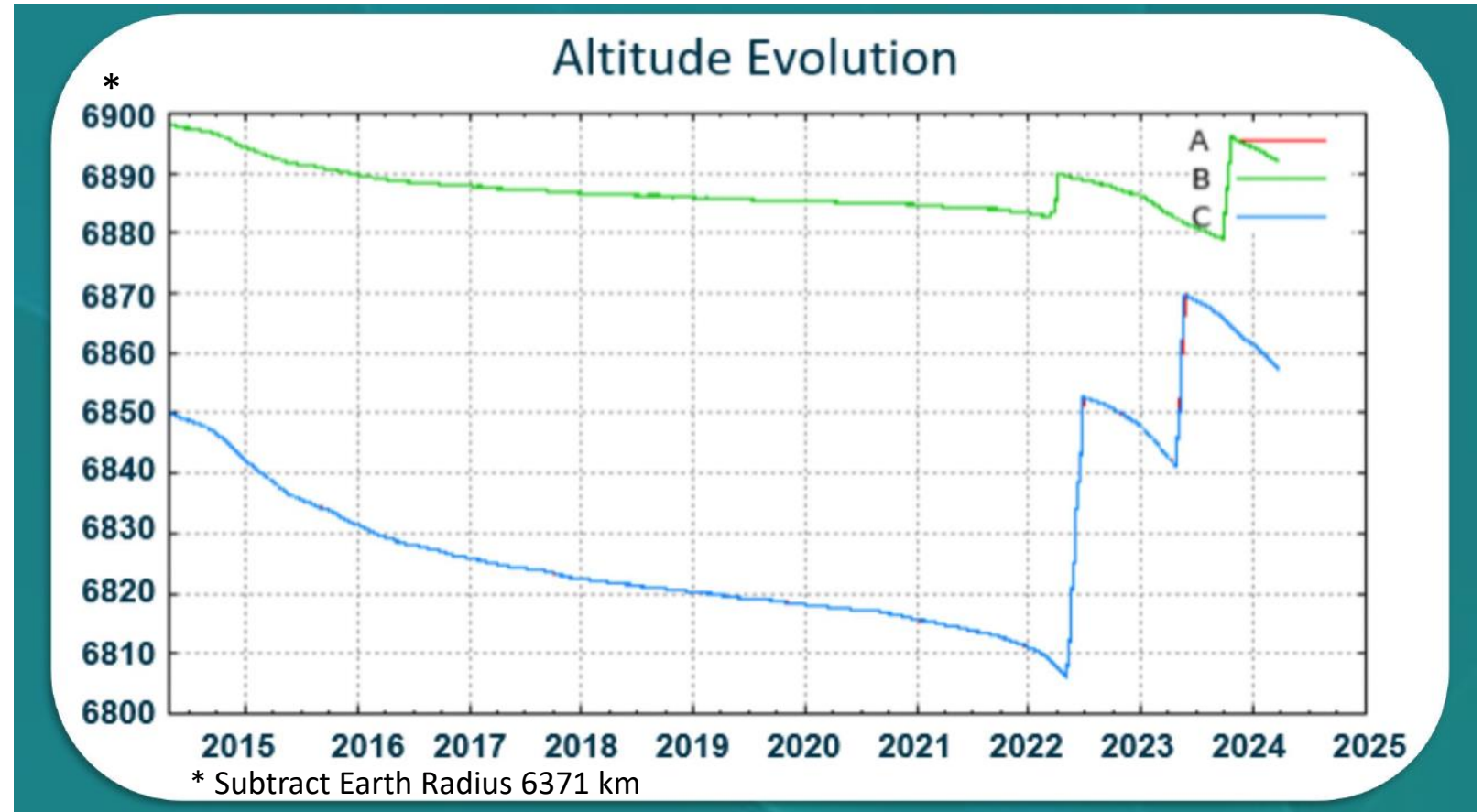




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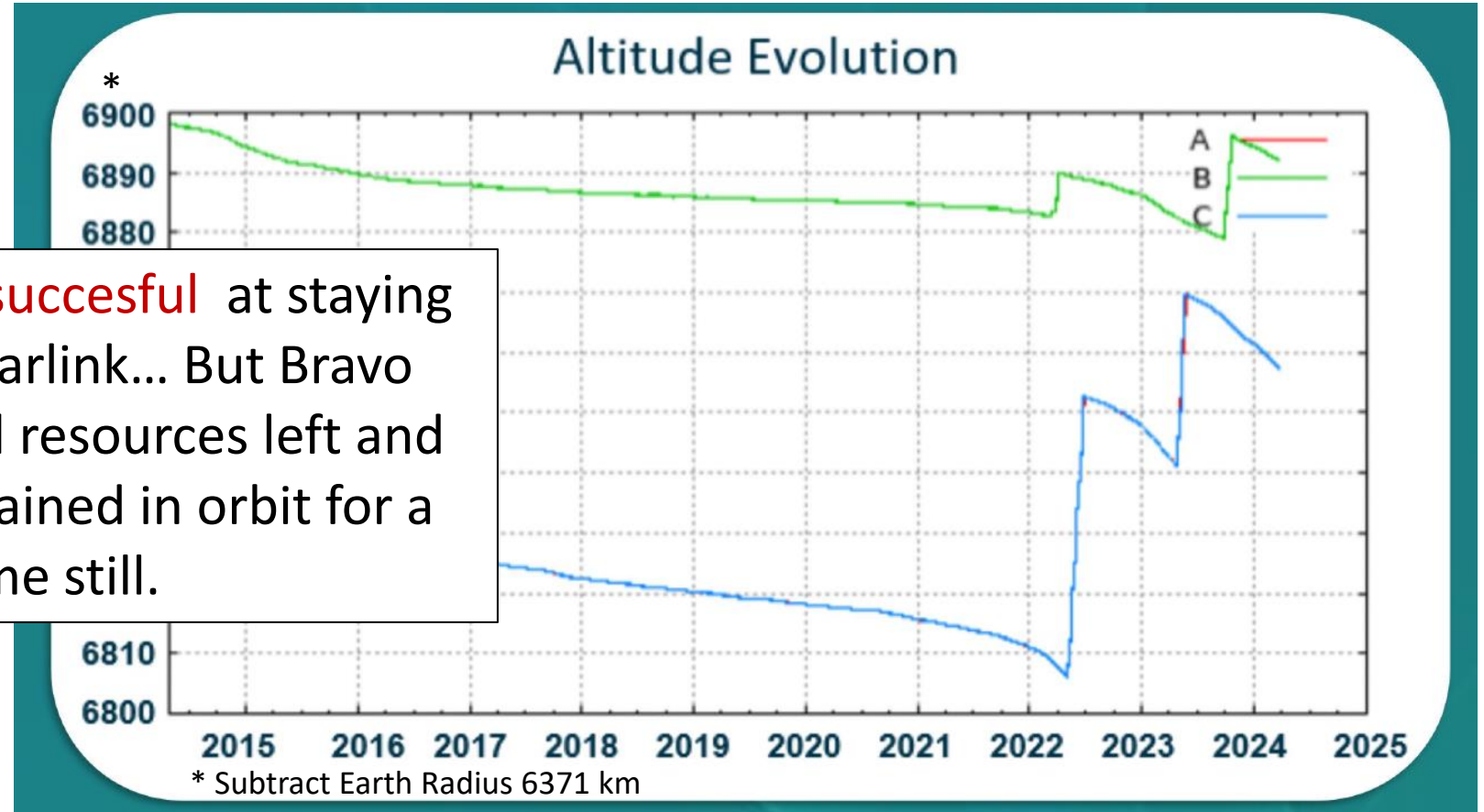


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Swarm Bravo complete raise to maintain proper separation from the lower pair while staying clear of dense Starlink orbits.

**Not entirely successful** at staying away from Starlink... But Bravo has good fuel resources left and can be maintained in orbit for a significant time still.

Lower pair separation at the equator stopped at 1.4 deg, same as before 2019.

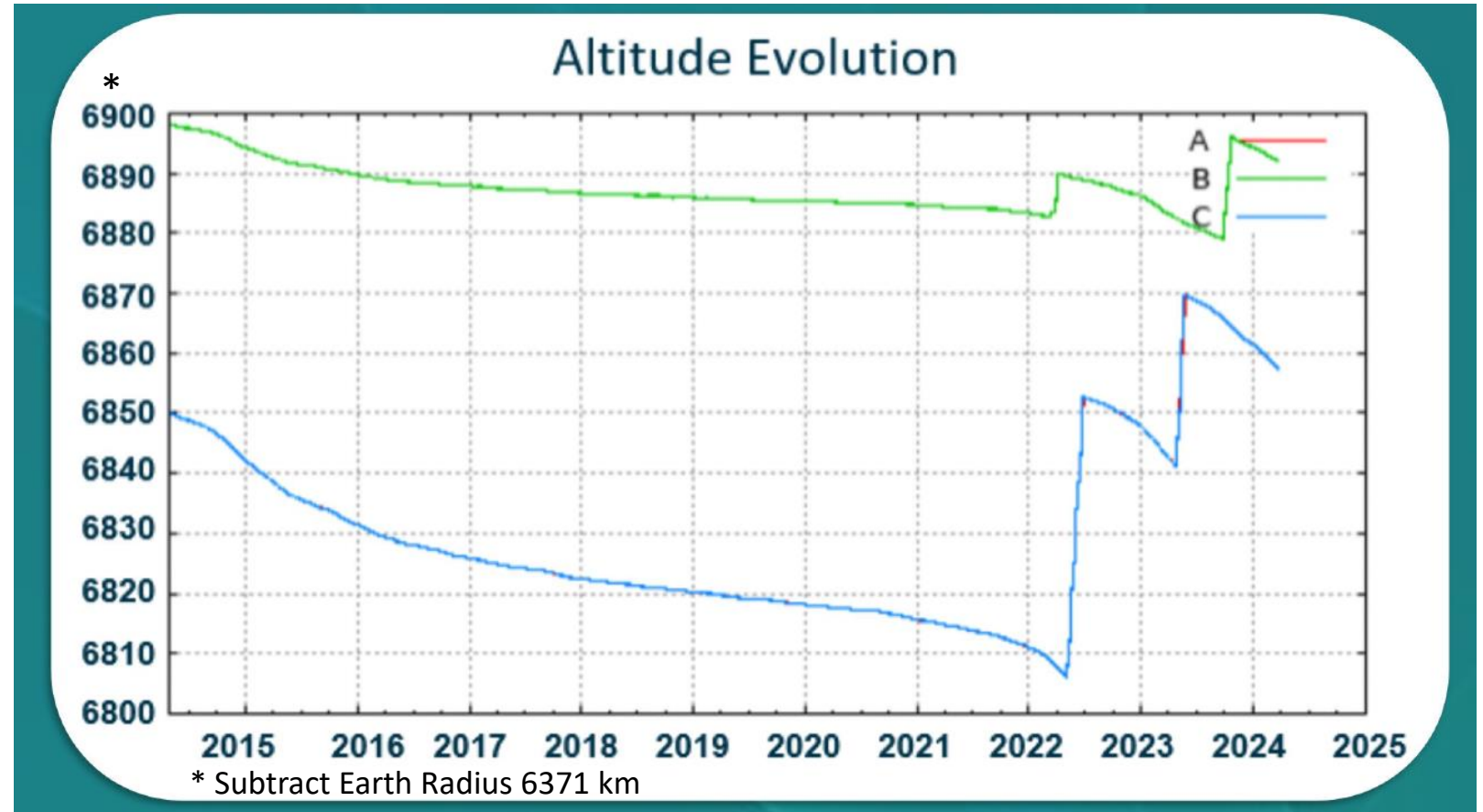




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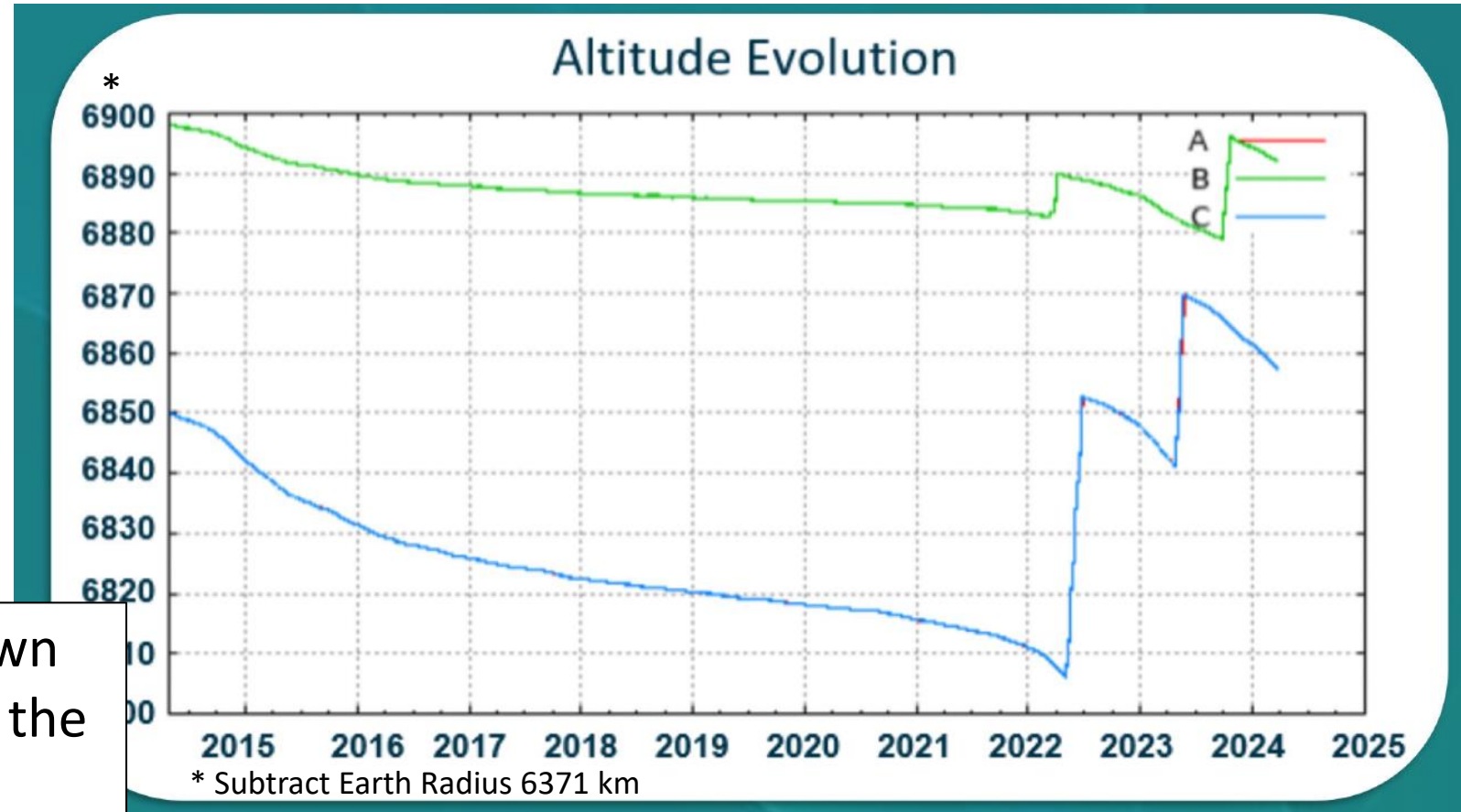


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Lower pair se  
stopped at 1.4  
2019.

Plans to reduce down to ~1.2 deg toward the end of the mission while closer to Earth





**Swarm-E/CASSIOPE e-POP**

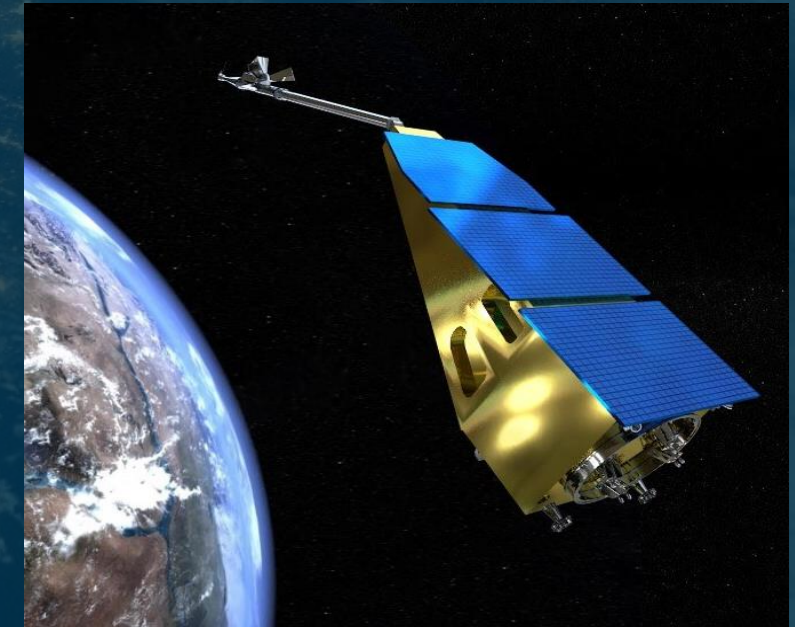
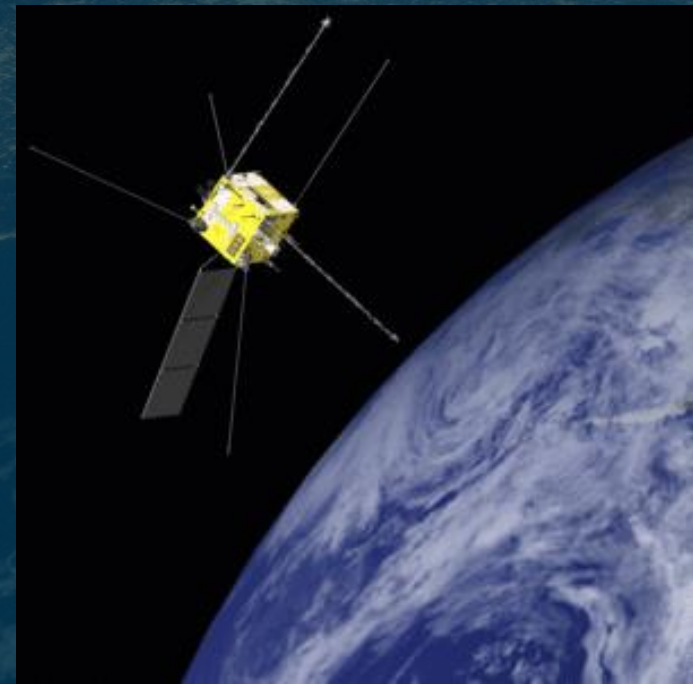
Although the routine Swarm-E operation has come to an end, e-POP is still going strong. Phase F activities and new opportunities

**CSES**

Some CSES data made available in “Swarm-like” data format to encourage joint analysis of Swarm and CSES magnetic data

**MSS-1: First Macau Science Satellite**

Launched on 21 May 2023  
 Commissioned end of 2023  
 Swarm - MSS collaboration on CalVal activities





## NanoMagsat Constellation - New ESA Scout

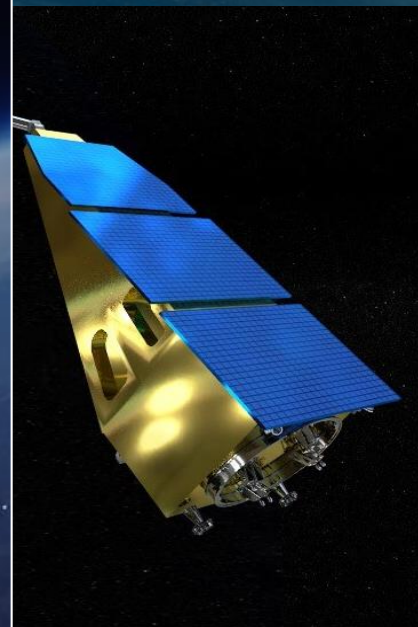
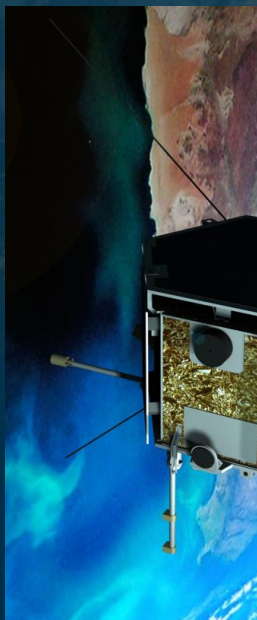
- 3 cubesats (16u) at 575 km initial altitude
- Two satellites at 60° inclination, one near-polar
- Vector and scalar magnetometers, star tracker plasma instrument (Langmuir probe)

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## First Macau Science Satellite

on 21 May 2023  
 ended end of 2023  
 MSS collaboration on CalVal activities



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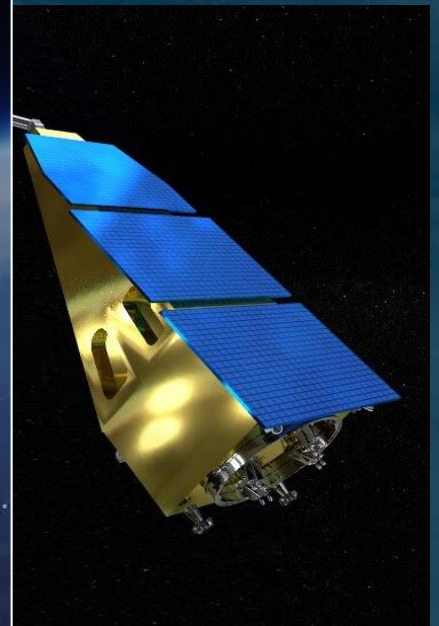
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From all we have learned today, can we identify the one key factor to success for Swarm?





Swarm 10 Year A





Swarm 10 Year A

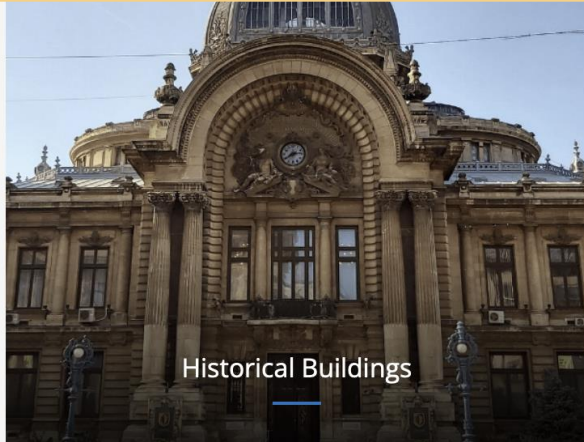


# READY TO EXPLORE?

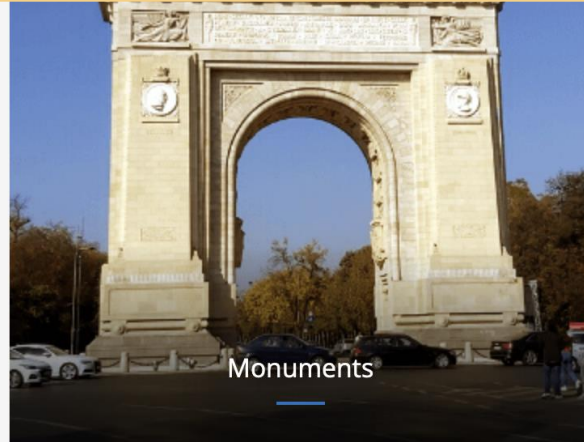
We are welcoming you all to Bucharest, Romania for the 14th Swarm Data Quality Workshop 7 – 11 October 2024



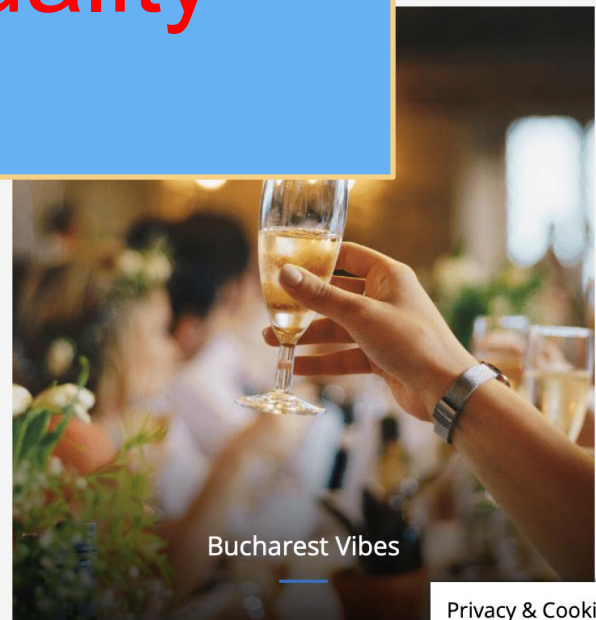
Museums



Historical Buildings



Monuments



Bucharest Vibes



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Swarm 10 Year Anniversary & Science Conference 2024







