SMOS for Space Weather
1st workshop

ESRIN, 14-Nov-2022

The TriHex Mission Concept

Manuel Martin-Neira (TEC-EF), Francesca Scala (PoliMi), Albert Zurita (ADS), Martin Suess (EOP-FMM), Don de Wilde (TEC-MSS)

Miguel Angel Piera (ADS), Berthyl Duesman (EOP-PES), Camilla Colombo (Polimi), Josep Closa (ADS), Erio Gandini (TEC-EFA), Raúl Díez García (EOP-GMQ)

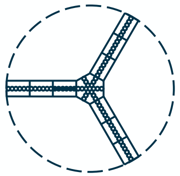
Roger Oliva (ZBT), Ignasi Corbella (UPC)

14/11/2022

Array concepts considered after SMOS

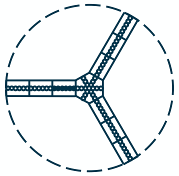
SMOS
∅ ~ 8.0 m

s=0.875 λ



2001

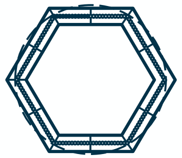
SMOS ops
(3 copies of SMOS)



2004

SMOS-H
∅ ~ 7.2 m

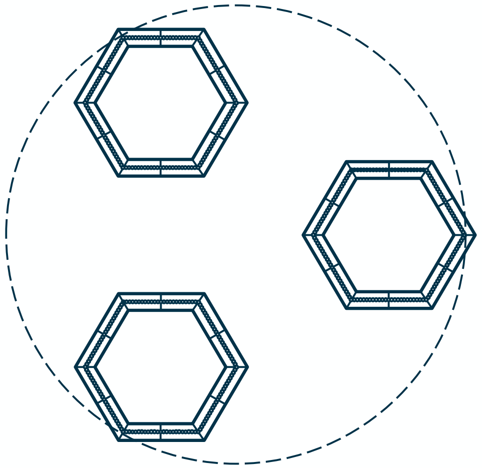
s=0.767 λ



2012

FFLAS
∅ ~ 21.6 m

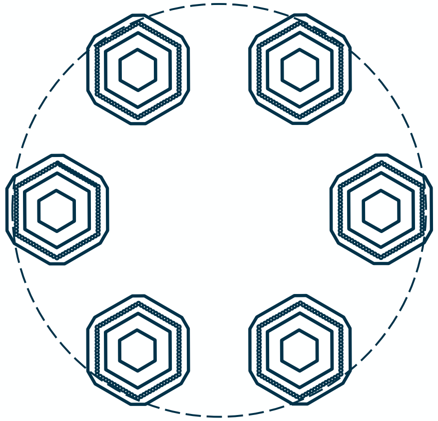
s=0.707 λ



2021

FFLAS-2
∅ ~ 17.6 m

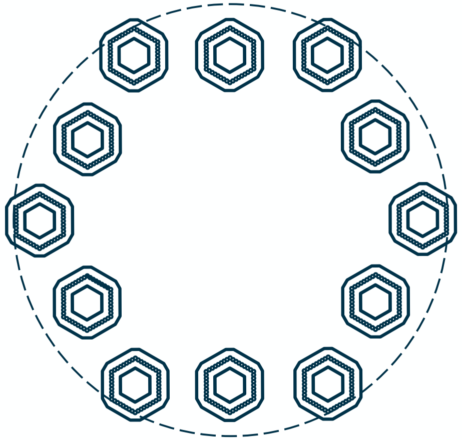
s=0.707 λ



2022

FFLAS-2 Lite-3
∅ ~ 18.7 m

s=0.707 λ



2022

FFLAS-2 Lite-5
∅ ~ 8.9 m

s=0.577 λ

2022

FFLAS-2 Lite-6
∅ ~ 11.85 m

s=0.577 λ

2022

Formation Flying: GCO Solution

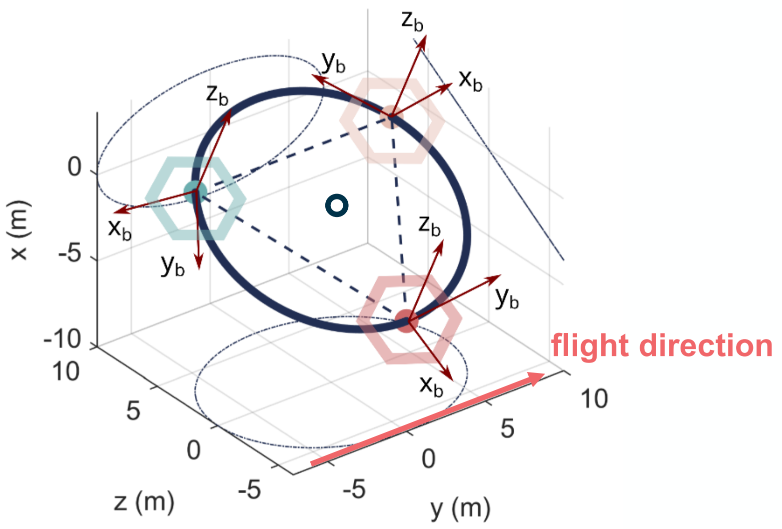
Reference orbit:

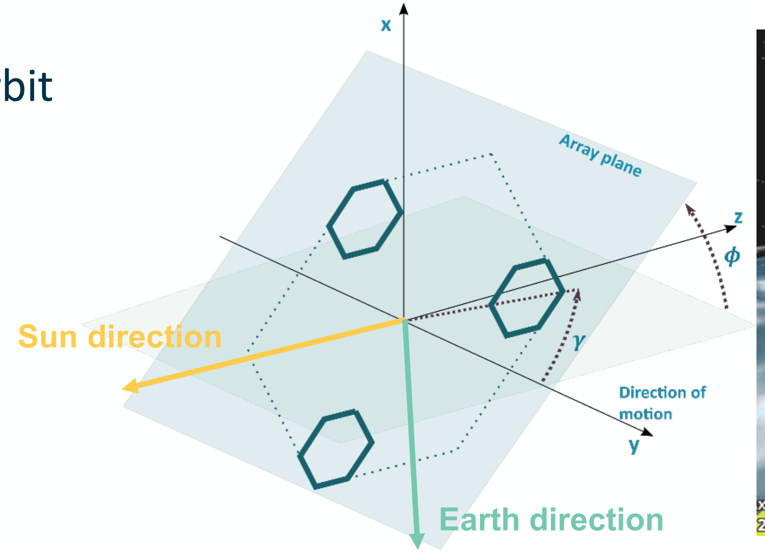
- Sun-Synchronous Orbit similar to the SMOS one
    - LTAN: 6.00 a.m., altitude around 770 km

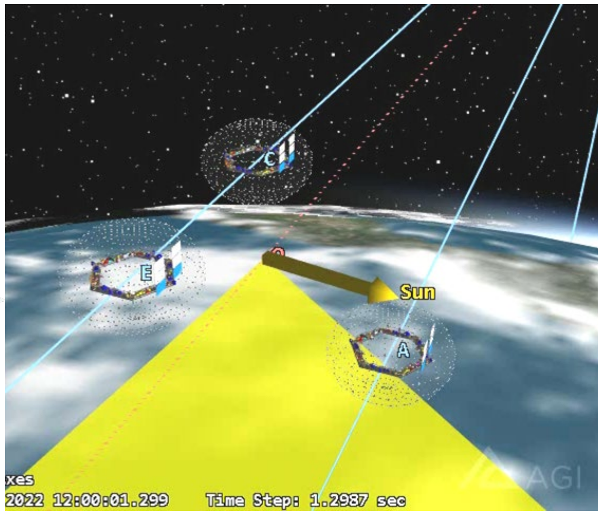
Relative motion:

- Based on natural orbits of the Hill-Clohessy-Wiltshire equations
    - General Circular Orbit (GCO) solution
    - Low thrust control for formation maintenance < 1 mN
- Formation flying made by
    - One virtual chief at the centre
    - Three identical deputies on a circular relative orbit

- **Considerations on GCO geometry**
    - Roll angle of the array plane: $\phi \sim 30$ deg
    - Array plane
        - Payload oriented in the Earth direction
        - Tilted away from the Sun direction



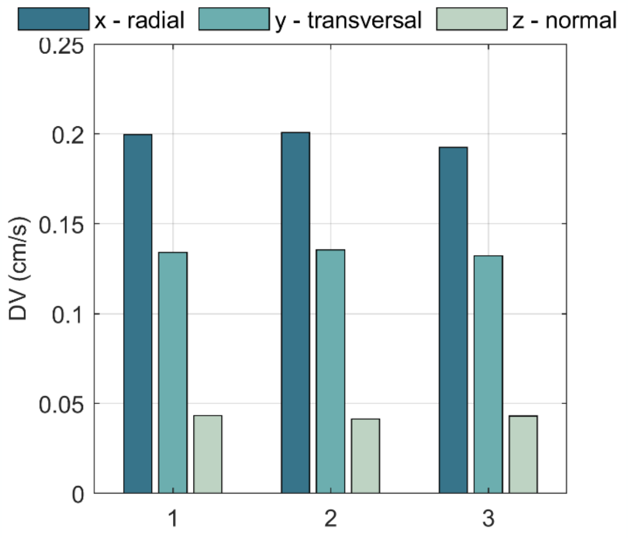


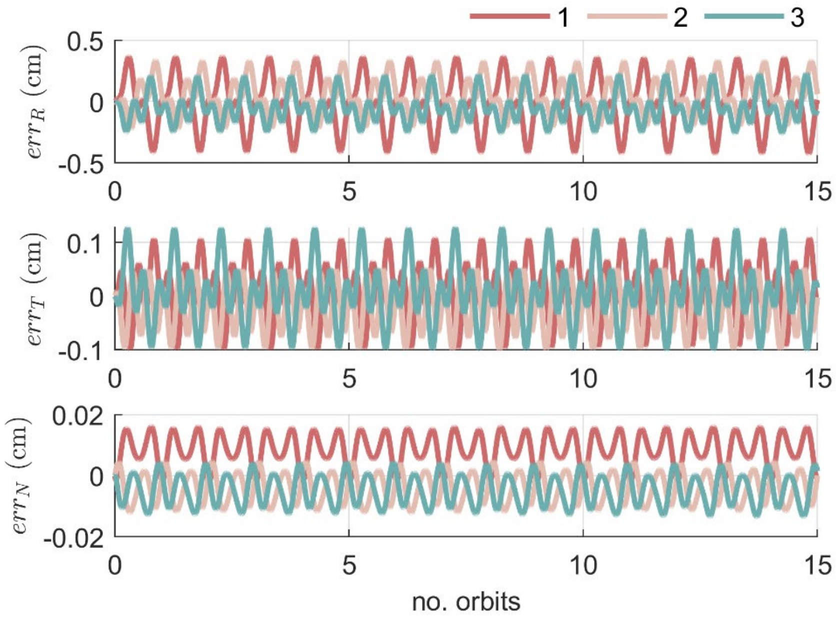


Formation Flying: GCO Solution

Control and safety consideration of the relative motion:

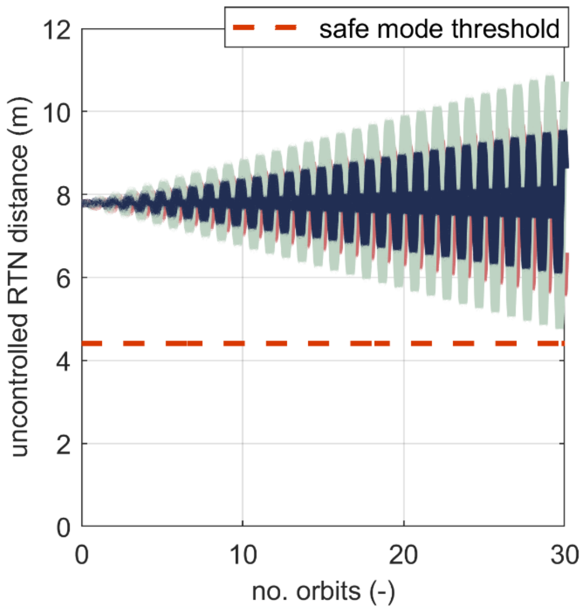
- Simulation over **15 orbital periods** (~1 day)
  - **Delta-v** budget to maintain the formation **below 1 cm/s per day**
  - **Low thrust control** in three axis (x-y-z)
  - **Accuracy in the control**:
    - The relative position is maintained with an error **smaller than 0.5 cm**



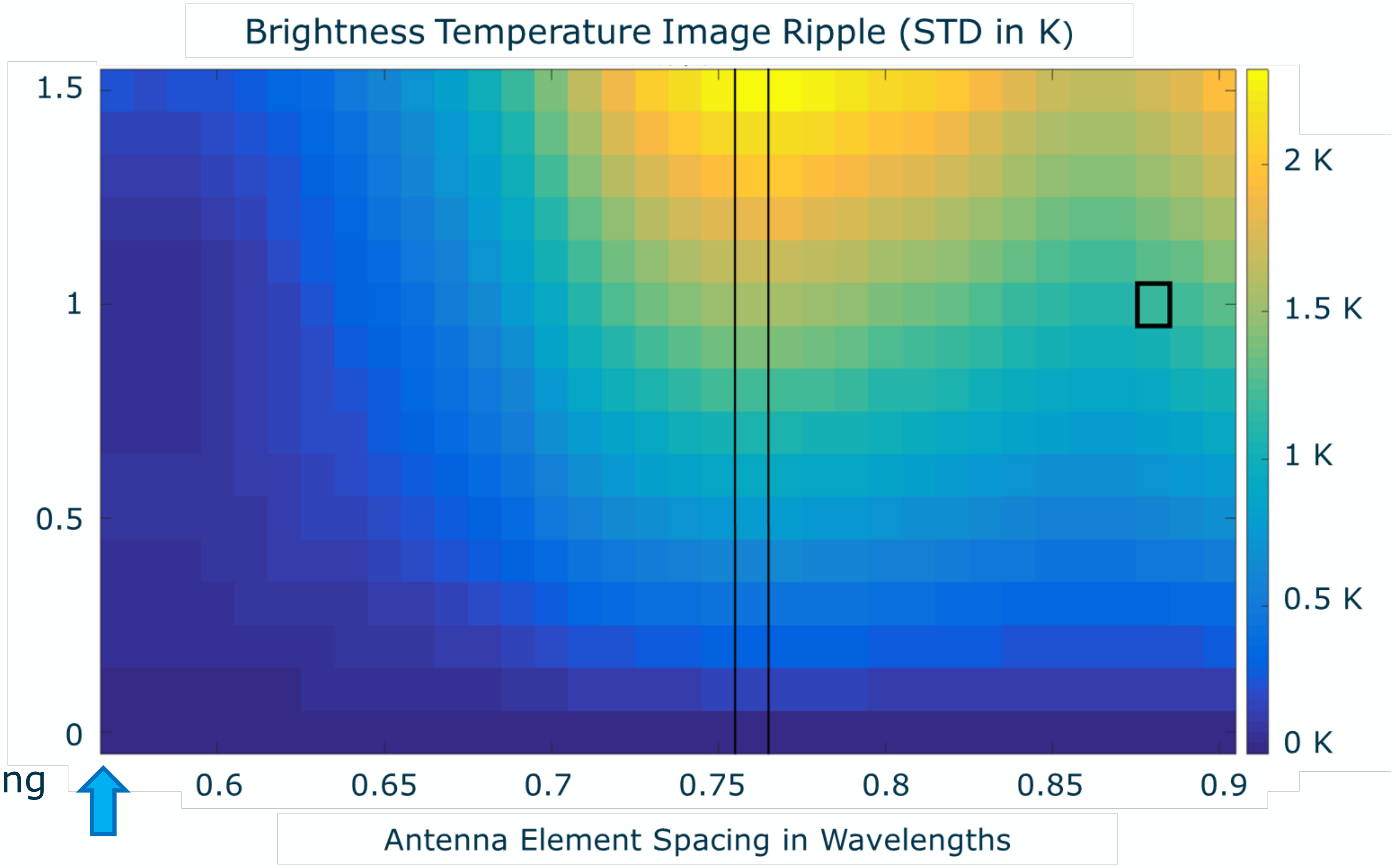


IF no control is applied to formation maintenance:

- e.g. case of **failure** of thrusters
  - The collision threshold is reached after **two days** with no control



Alias-free Spacing



Antenna Pattern Differences wrt SMOS

1 = SMOS

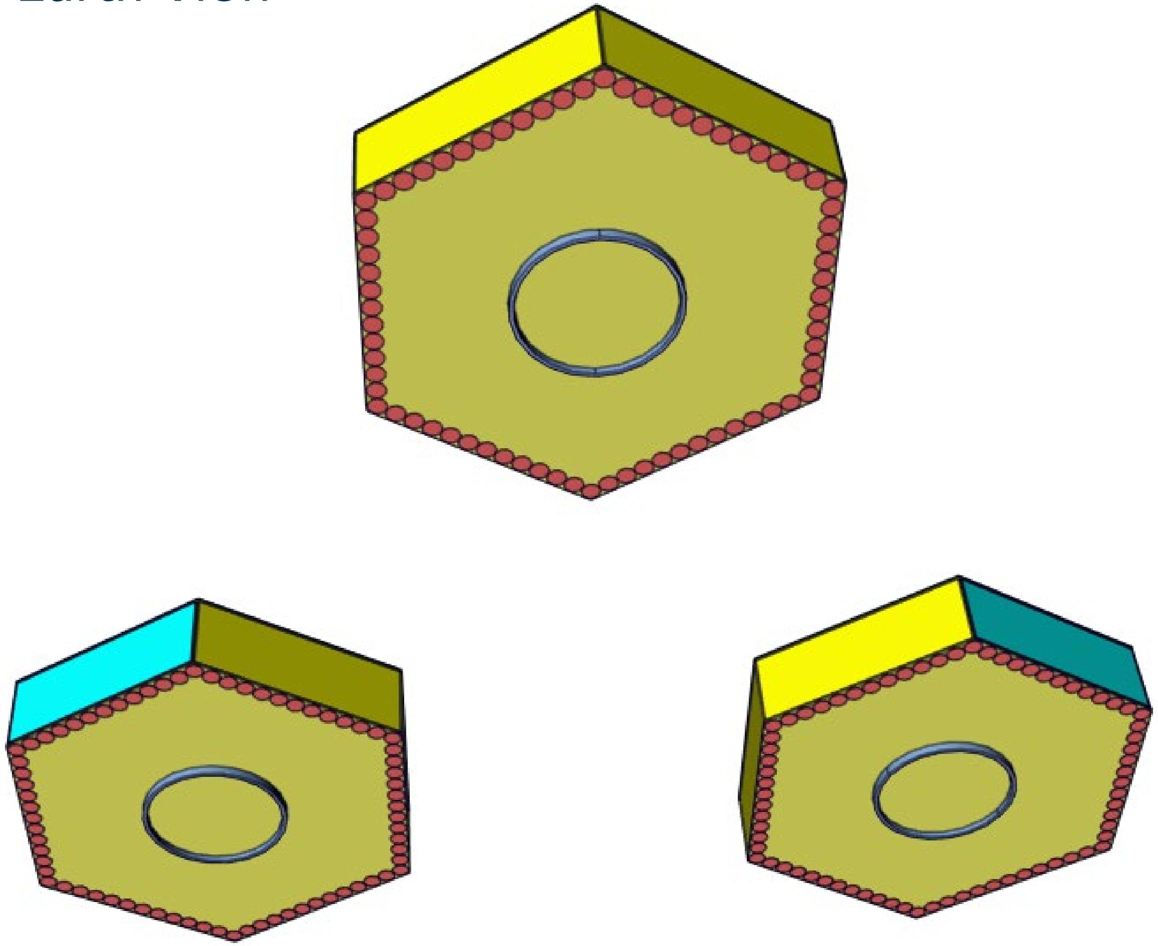
Alias-free spacing = 0.577λ

Contributions leading to TriHex

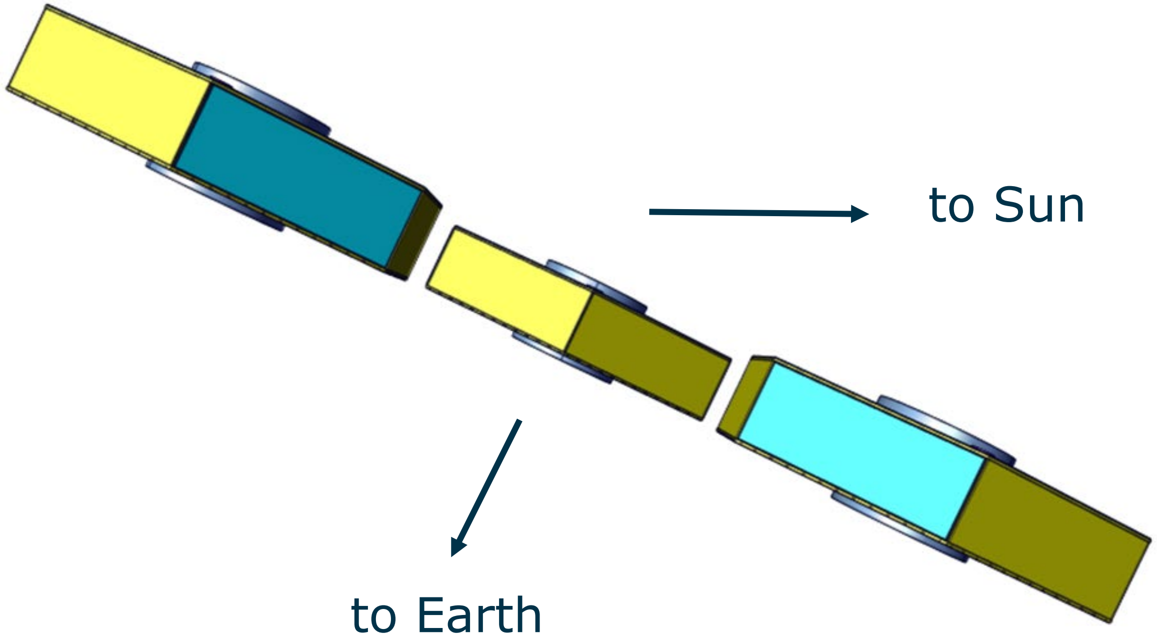
- Adding …
  - ❑ ECMWF Workshop December 2017 results (→ **better than SMOS/SMAP)**
  - ❑ Requirement Study (ESA, Kerr et al. 2016) (→ **20 km would satisfy 65% of users)**
  - ❑ **Natural General Circular Orbits**
  - ❑ **Alias-free Antenna Pre-Development**
  - ❑ **All lessons learnt from SMOS**
  - ❑ **An effort to reduce cost to possibly fit within the Earth Explorer cost cap**
- … yields the **TriHex** mission concept

TriHex: Earth and Velocity views of the formation

Earth View

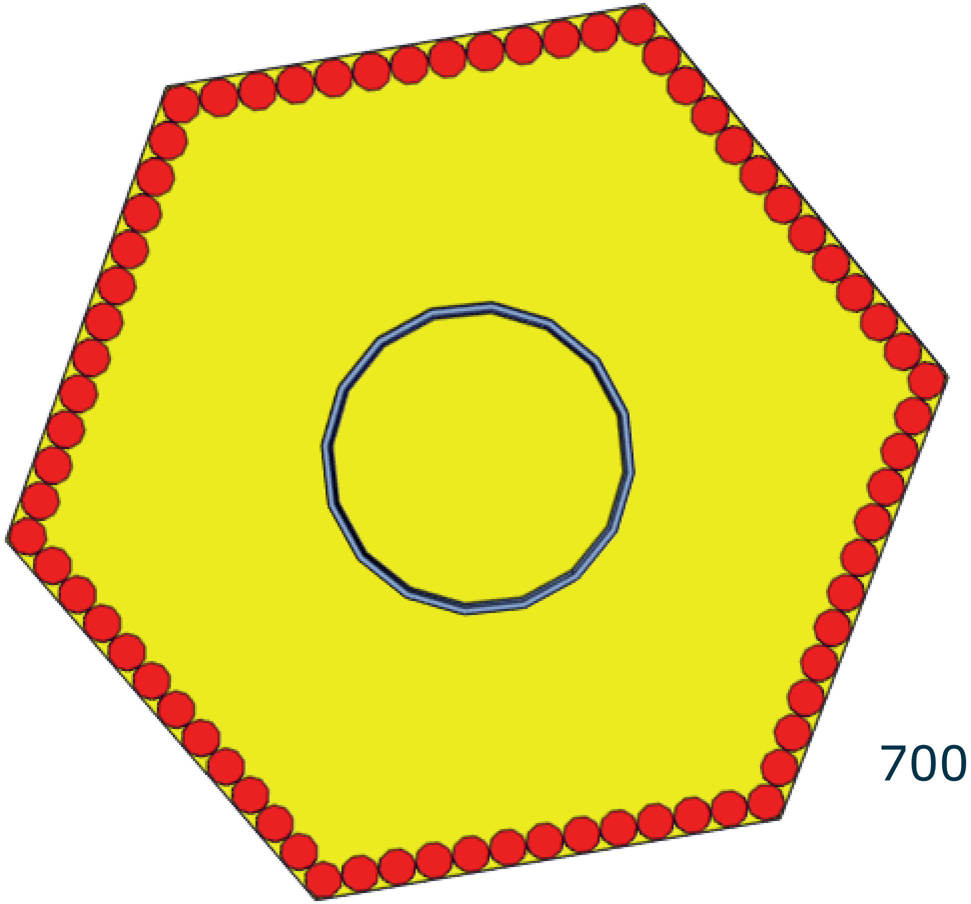


Velocity View



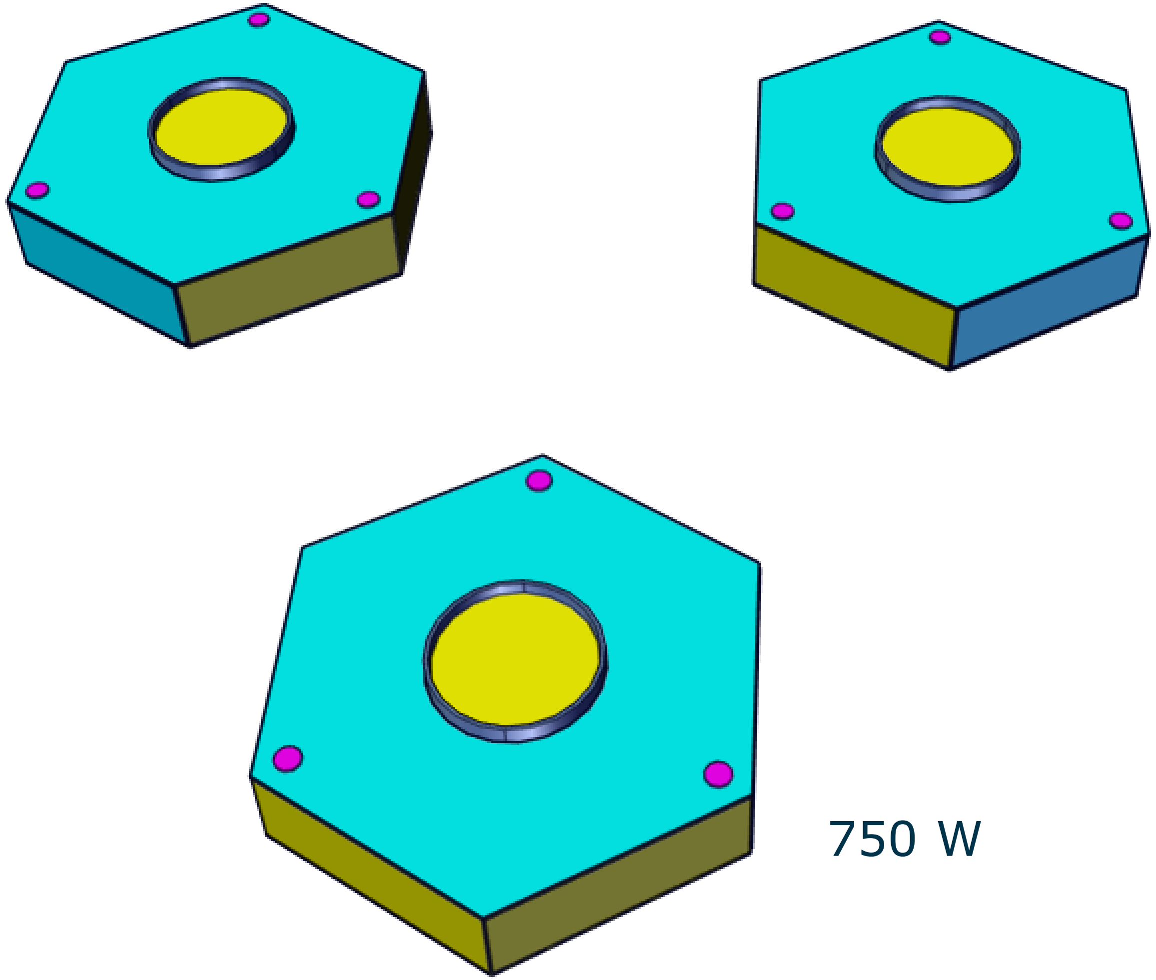
TriHex: single spacecraft and Sun view

Single Spacecraft
(3 m diameter, 0.8 m height)



700 kg

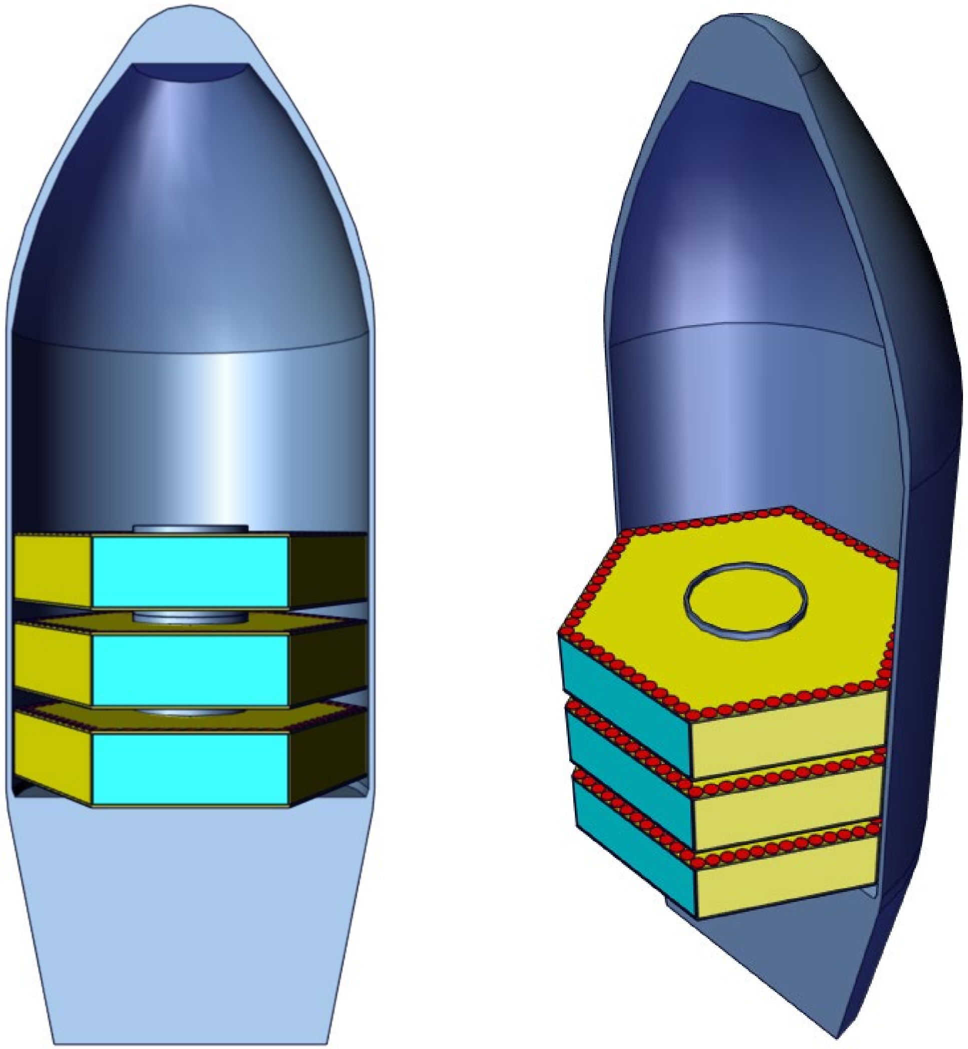
Sun View



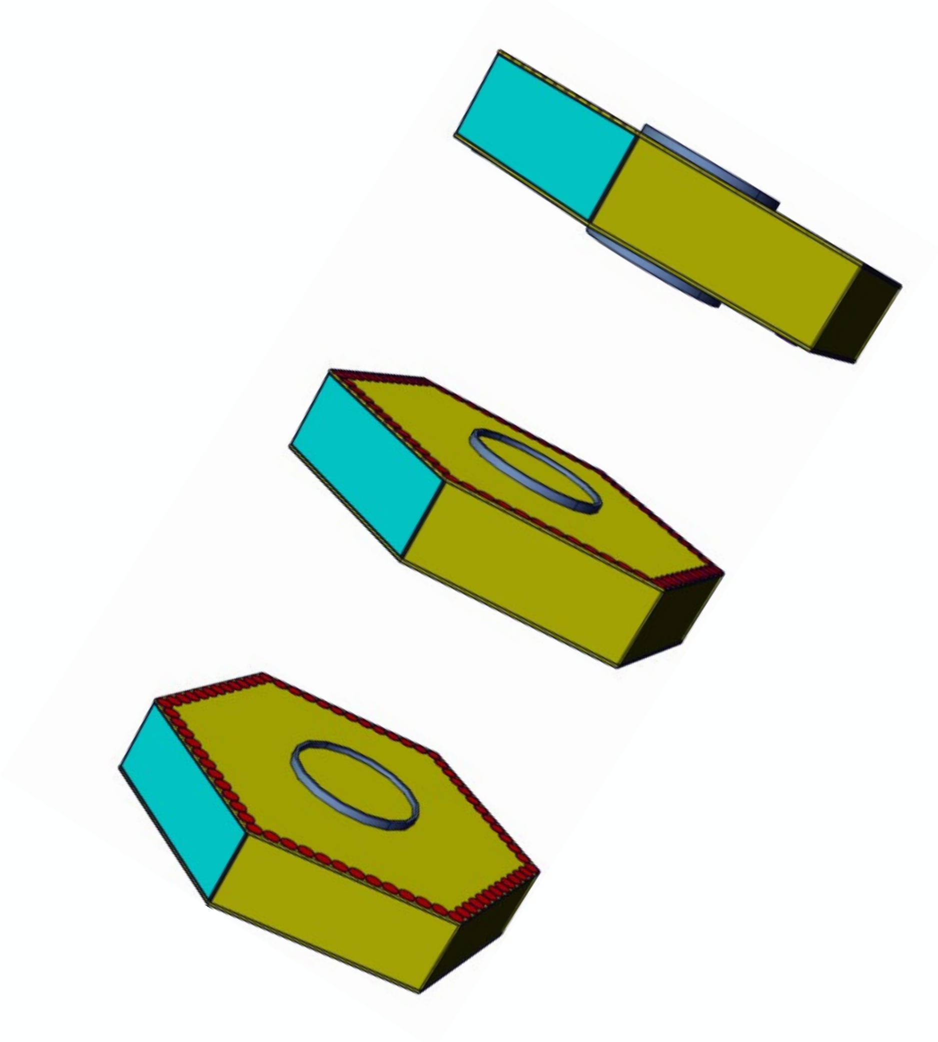
750 W

TriHex: stowed in VEGA and released

TriHex in VEGA launcher



TriHex as released from launcher

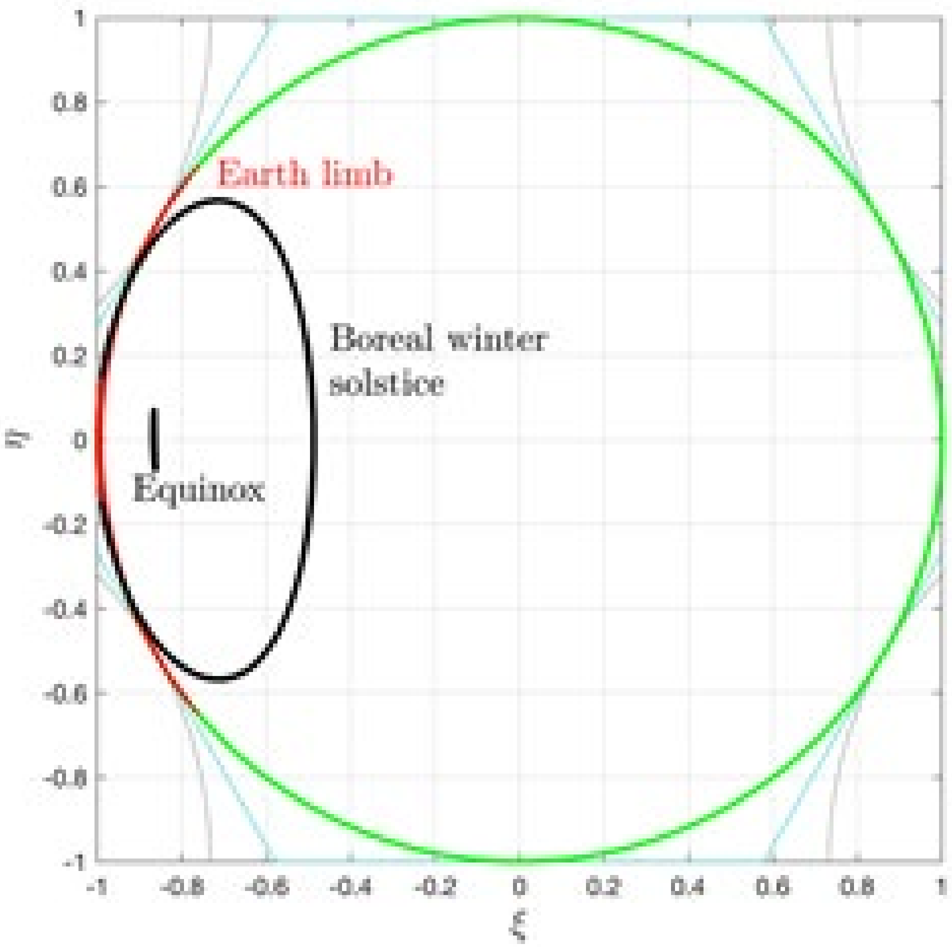


Some TriHex features

- Natural orbits reduce drastically fuel consumption and allow for long reaction time to failures
- Spacecraft fit in one single piece in VEGA and have body mounted solar cells
- Spacecraft do not need any deployments and have no moving solar wings
- Hexagonal geometry allows building on SMOS level-1 processor for image processing
    - ❑ Spacecraft rotation can be accounted for in the processor (as Earth rotation too)
- Complete coverage of both poles (one of them at very high incidence angle)

TriHex features specifically related to Sun and TEC

- Satellites look away from the Sun:
  - ❑ The Sun is no longer in the FoV of the instrument: it is always behind (roll angle is 30 deg)
  - ❑ No Sun in the image
  - ❑ No Sun side lobes in the image
  - ❑ No eclipse effects in Hovmoller plots
  - ❑ Receivers, not illuminated by the Sun, can work at colder temperature improving sensitivity
- Sun Tb might still be possible through the backlobes
- TEC estimations through the Faraday Rotation Angle



Unit Circle of the Rear Hemisphere