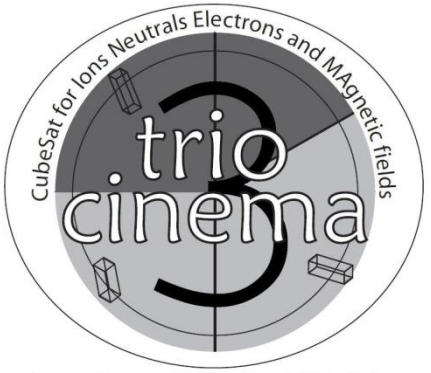
CINEMA/TRIO

A three-spacecraft space weather CubeSat mission



Space Sciences Laboratory, UC Berkeley
Kyung Hee University of South Korea
Imperial College London

Imperial College London

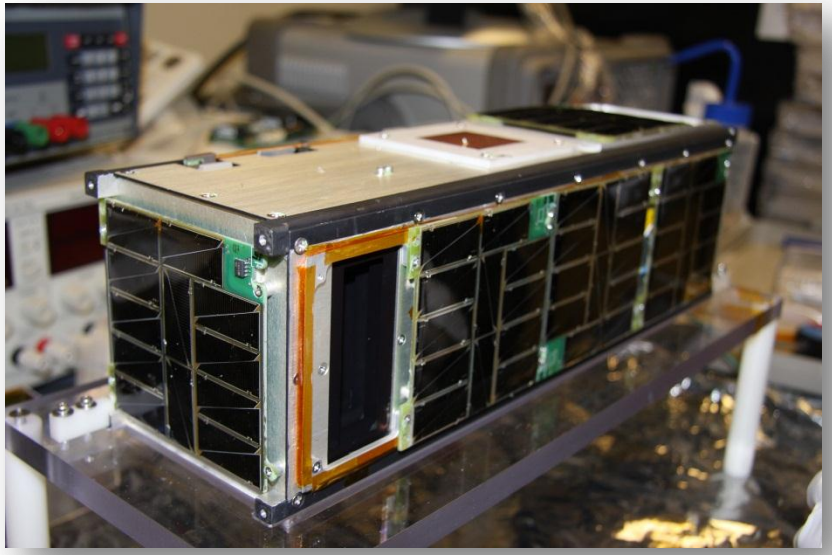
T. S. Horbury, P. Brown, J. P. Eastwood, M. Archer
Imperial College London, UK

R. P. Lin, T. Immel, D. Glaser
Space Science Lab,
University of California, Berkeley, CA, USA

D.-H. Lee, J. Seon, H. Jin
School of Space Research,
Kyung Hee University, Yongin, Republic of Korea

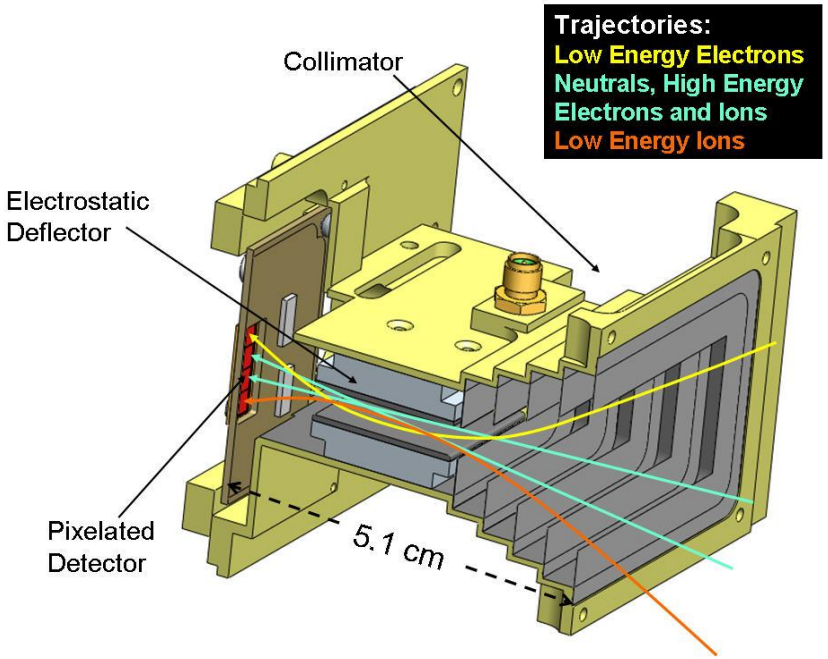
CINEMA

- 3U CubeSat form factor
  - 30cm long, 3kg
  - 1m stacer boom
- Spin-stabilised, 1rpm
  - First ever spinning CubeSat
  - Magnetotorquers for attitude control
- S-band communications
  - 1Mbps downlink
- Two science instruments
  - STEIN, MAGIC
- Spacecraft designed and built at UC Berkeley, Space Sciences Lab
- Delivered January 2012, launch August
  - Low latitude, high inclination orbit



STEIN

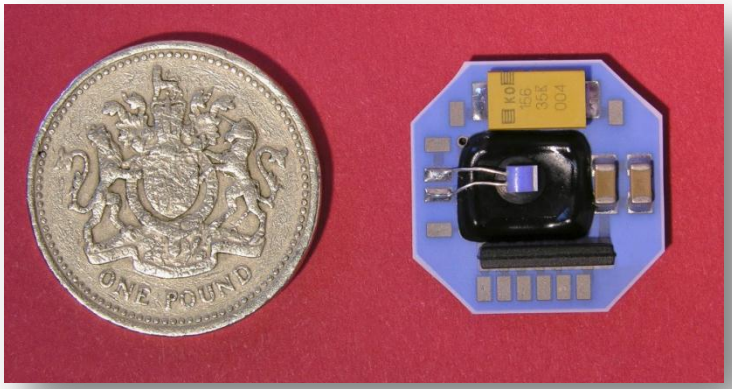
- Passively cooled, thin window silicon semiconductor detectors (SSDs)
- Electrostatic deflection
  - Detects energetic neutrals, ions and electrons with single instrument
- 2keV-300keV range, 2keV resolution
- Nearly full-sky view over each spin



- Radiation belt imaging using energetic neutral atoms
  - Local time asymmetry, ~1 minute resolution
- Electron microbursts
- Auroral precipitation

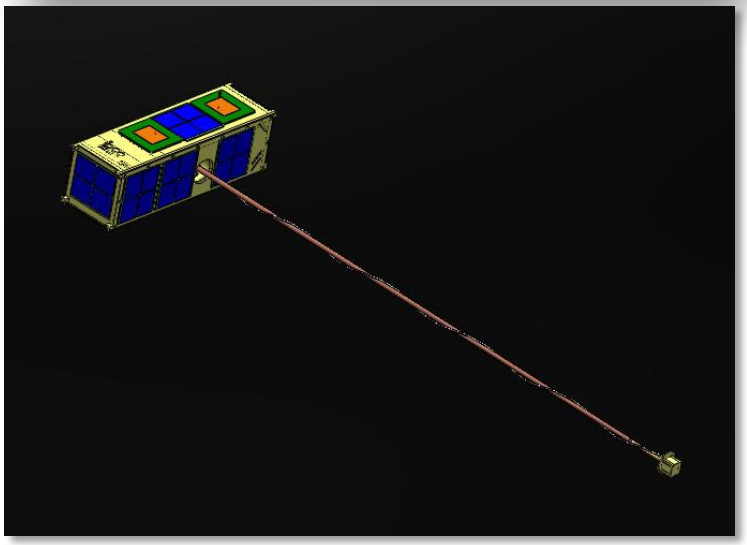
Imperial College MAGIC sensor

- Novel magnetoresistive design
- Less than 500mW power
- 15g sensor head, 150g electronics board
- Outboard sensor on 90cm boom



- Science mode
  - <0.25nT resolution, 10 vectors per second

- Magnetometer role
  - Measurements of waves and structures
  - Local magnetic field for particle data
  - Attitude information for spacecraft control

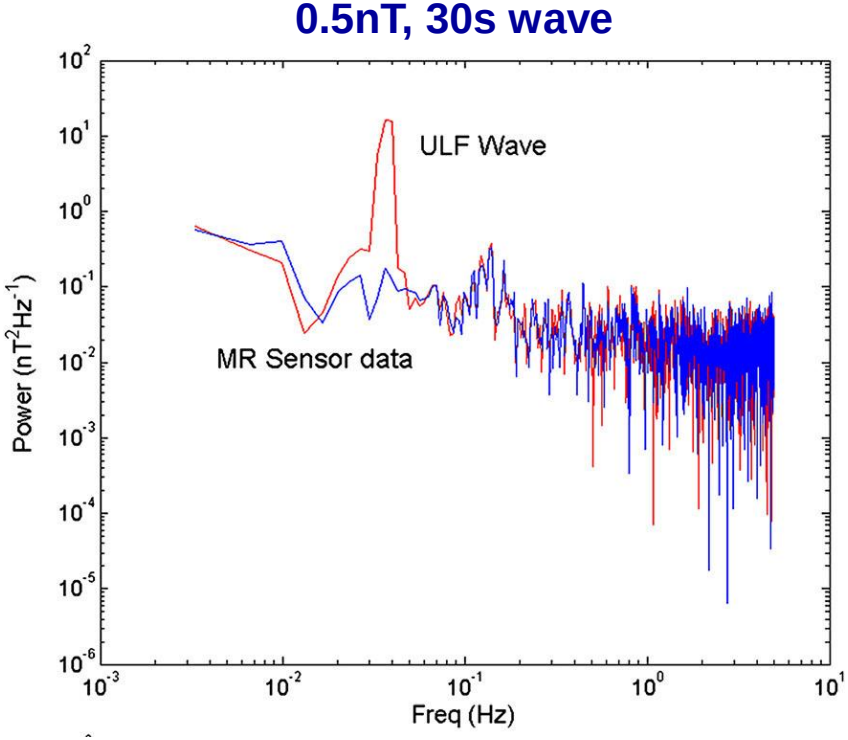


MAGIC: challenges

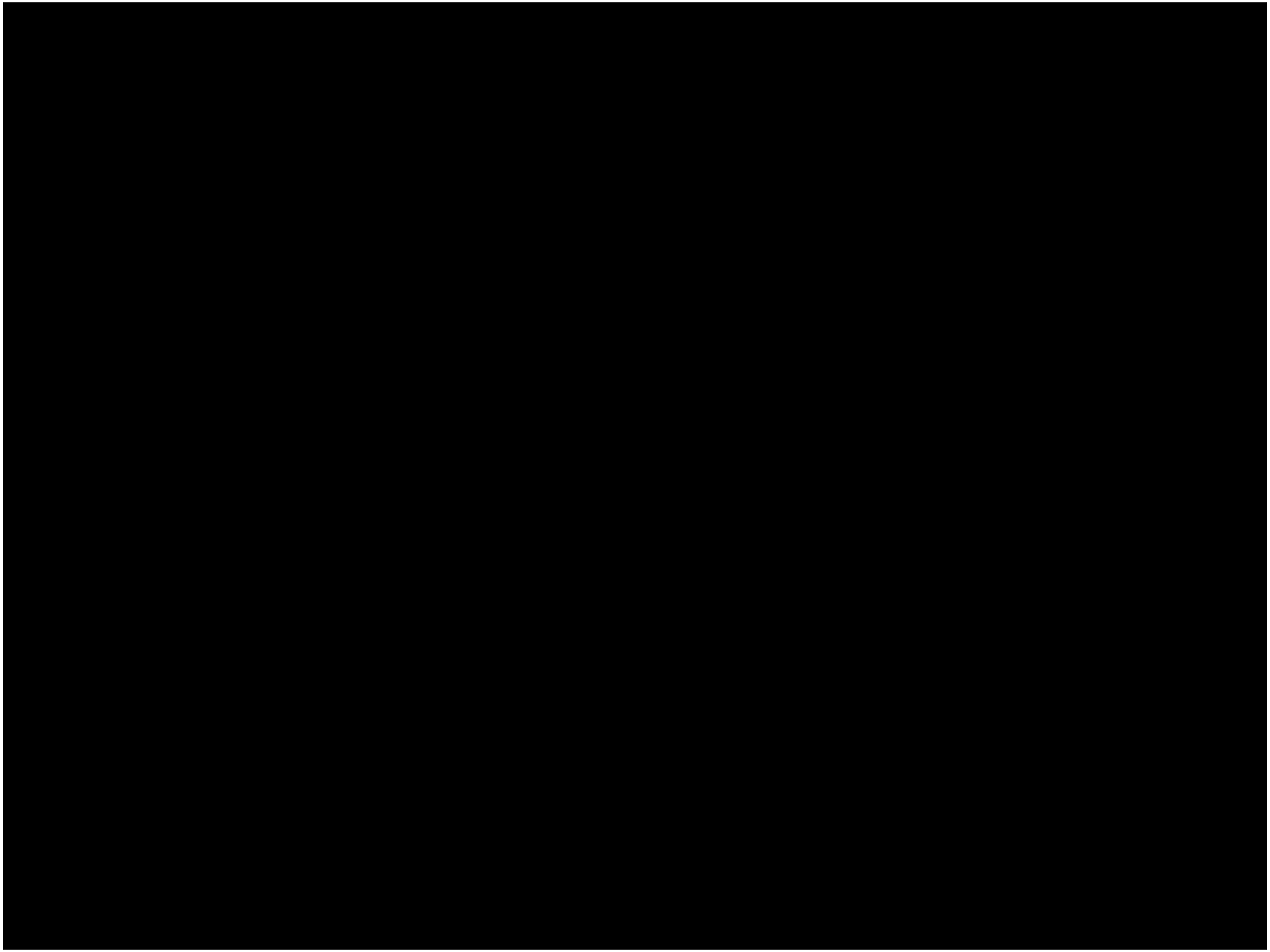
- Thermal and spacecraft environment is expected to be very variable
- Offsets are likely to drift along the orbit

➢ MAGIC goal is **not** precisely to measure absolute magnetic field

➢ MAGIC **will** accurately measure transients and structures



P. Brown et al., *Meas. Sci. Tech.,* v.23, 25902, 2012

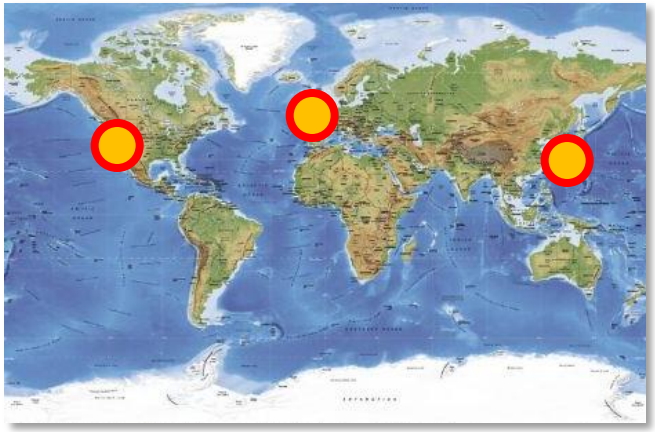


TRIO-CINEMA

A constellation of 3 identical spacecraft

Space Sciences Laboratory, U. California Berkeley

- Design and build of one spacecraft
- Design and build of one STEIN sensor
- Design and build of 3 booms



Kyung Hee University, Seoul

- Build of two TRIO spacecraft
- Build of two STEIN detectors

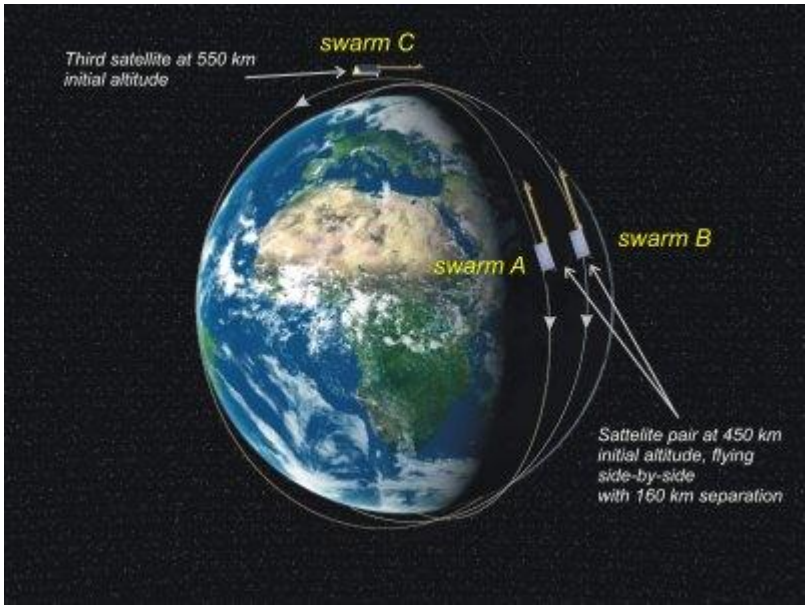
Imperial College London

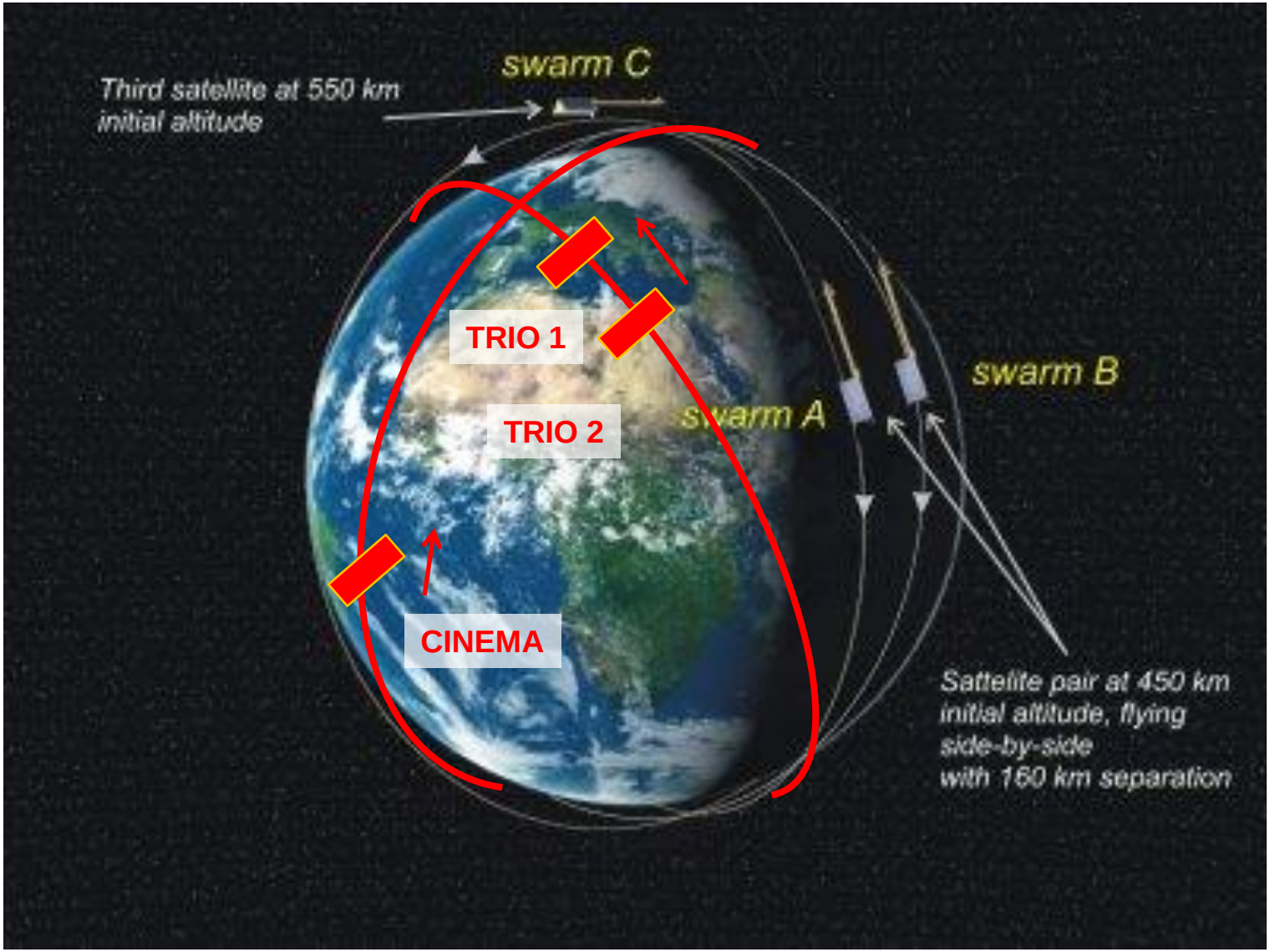
- Design and build of 3 MAGIC magnetometers

- Two Korean spacecraft will launch together, after CINEMA

SWARM and geomagnetic variations

- Geomagnetic disturbances are a key issue for SWARM
- Vital to measure and quantify their spatial and temporal variations
- SWARM constellation is optimised given available resources, but still grossly under-samples the inner magnetosphere
- Additional information is required:
  - Variation of the ring current in time and space
  - Global disturbances and local time variations




swarm C
Third satellite at 550 km
initial altitude
TRIO 1
TRIO 2
CINEMA
swarm A
swarm B
Sattelite pair at 450 km
initial altitude, flying
side-by-side
with 160 km separation

Relation to SWARM

- SWARM is a unique opportunity to bring together diverse inner magnetospheric measurements
  - Cluster
  - RBSP (launch August 2012)
  - Ground-based magnetometers and radars

- CINEMA/TRIO provide unique additional information to this constellation
  - Local time variations in radiation belts
  - Widely spread measurements of magnetospheric transients
  - Re-sampling of SWARM measurement locations

- CINEMA/TRIO will help SWARM to achieve its measurement objectives

Summary: TRIO-CINEMA

CINEMA

- Launch August 2012
- Two miniature instruments: STEIN and MAGIC

TRIO-CINEMA

- 3-nation collaboration
- Multi-point magnetospheric data
- 2 spacecraft launch together end 2012

- Provide space weather inputs to SWARM

- All data will be free – please get involved