THE CARRINGTON MISSION

Mission Statement: "To provide a CME forecast system for Earth".

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Space Weather

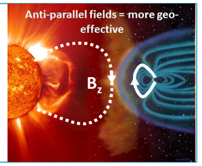
CMEs can impact

- Communications
- Navigation
- Power plants
- Flight/Astronauts
- Economy

Interplanetary Magnetic Field

Geoeffectiveness is primarily driven by the B_z component of the CME front.

We need a way to measure the magnetic field and trajectory to be able to forecast the potential impact.



Alpbach Summer School (ESA)

- 60 European students work on space-related topics
- Lectures from universities and major companies
- Four teams (15 students) **develop independant mission concepts**
- Hands-on experience in space science and engineering
- Networking and organization of intertional collaborations
- Annual ten-day event in Alpbach, Tyrol

Mission requirements

Primary

1. CME propagation trajectory and speed
2. CME 3D structure
3. CME shock front
4. CME magnetic field orientation and magnitude

Secondary

1. CME magnetic structure at the origin
2. CIR forecast

Instruments

- **Inner Coronagraph:**

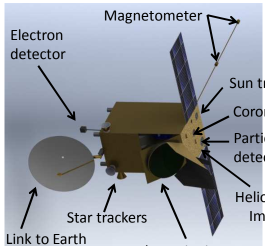
Spectropolarimetric measurement ⇨ magnetic field in the corona

- **Outer Coronagraph:**

White light imaging between 2.5 and 30 solar radii ⇨ tracking of CME path

- **Heliospheric imager:**

White light imaging between 30 and 167 solar radii ⇨ CME trajectory and plasma density



Faraday-Voigt instrument (antennas undeployed)

- **Faraday-Voigt Instrument:**

Measurement of magnetically induced birefringence using interferometry ⇨ determination of the magnetic field orientation and strength of the CME

- **Magnetometer:**

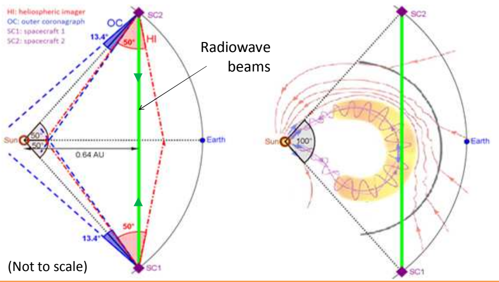
In-situ magnetic field measurement ⇨ verification and on-board calibration of the remote magnetic field measurements

- **Plasma package:**

In-situ measurement of electron and ion parameters ⇨ CIR detection

Mission configuration

Forecast time: better than 3 hours for fastest, and 19 hours for typical CMEs



(Not to scale)

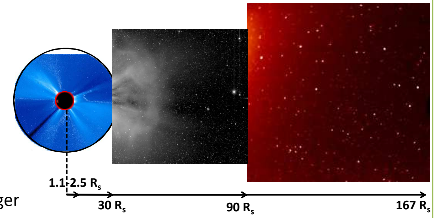
ICME speed measured at 1 AU: 290 - 1300 km/s *(Cane and Richardson, 2010)*

Coronagraphs and Imagers

Observations:

Primary: stereoscopic observation of the CME (scattered light)

Secondary: measurement of the magnetic field vector in the plane of sky at the onset of CMEs



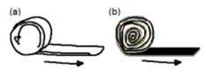
➢ 3 remote sensing instruments

- **Inner coronagraph**: spectropolarimetric imager
- **Outer coronagraph**: visible light coronagraph
- **Heliospheric imagers** (inner and outer): visible light imagers

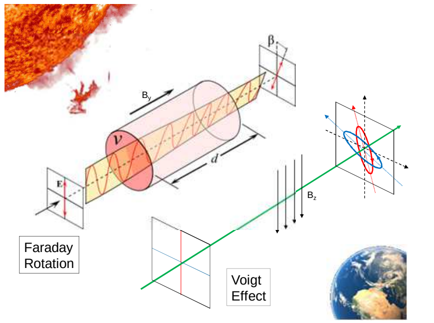
Remote magnetic field measurements – Faraday-Voigt instrument

Using a combination of the Faraday and Voigt effects we can measure the components of the magnetic field remotely. Traditionally this has to be done in-situ. As both effects are wavelength dependent, we propose continuous probing of radiowaves at two frequencies. Each satellite transmits one frequency. Two half wave dipole antennas at each satellite have to be oriented perpendicularly (i.e. two crosses). With that configuration we get 3D measurements of magnetic field strength and orientation.

λ_1	1000 m
λ_2	333 m
Transmission power	100 W each
Antenna lengths	500 m



Pre-stressed strips present a viable deployment method for large antenna geometries, as they are simple, can be coiled during transport, and have a predefined shape and orientation upon unfolding.



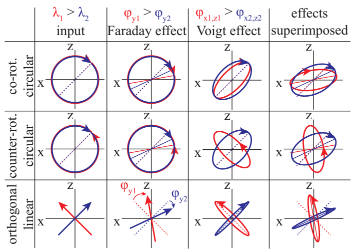
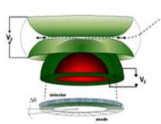


Illustration of the impact of the Faraday and Voigt effect, acting on electromagnetic waves of different frequency (red and blue), when linearly or circularly polarized.

Magnetometers and solar wind analyser



- Magnetometer: triaxial measurements, accuracy 100 pT
- Energetic particle telescope
- Electrostatic analyser versions for non-spinning platform (as on Solar Orbiter)

(MSSL for Solar Orbiter)

➢ **In-situ plasma measurements for CIR detection**

Launch & Orbit

Launcher	2 Soyuz
Separation S/C-Earth	± 50 deg @ 1AU
DeltaV needed	1,5 & 1,9 km/s
Station keeping	8 m/s per year
Dry mass margin	600 & 450 kg/sat
Propellent mass	575 & 420 kg/sat
Transfert time	13,7 months

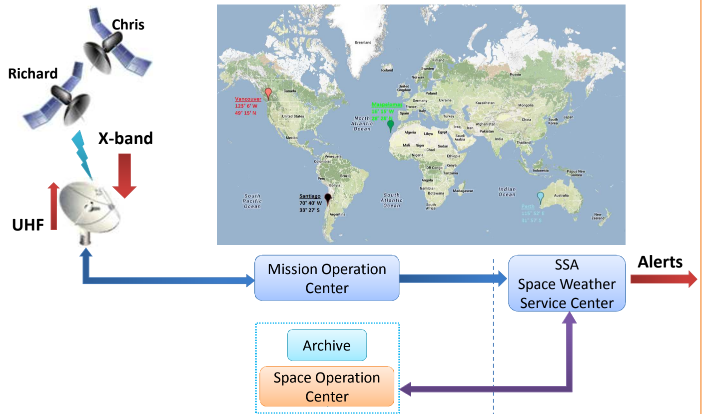
Mission time: 6 years + 6 years possible extension

50° angular separation for:

- Radiowave path as small as possible (1.5 AU)
- Meet forecast time requirement (> 3 hours)
- Stereoscopic trajectory reconstruction (100° separation in total)

Communication & Ground Operations

Building own network. Utilizing existing ESA locations where possible.



On-board Data Processing	Data Transmission	Data Handing	On-ground Data Processing	Decision Making	Information Distribution	Reaction to the event
< 10 min		35 min			15 min	> 3 h

➔ **Forecast and alert more than 3 hours before CME arrival**

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