



# Recent Developments in Space Weather Research and Services in Germany

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Presented at the Space Weather Working Team meeting, 29 June 2006, ESA HQ, Paris, France. The authors do not claim to completely cover all activities in Germany.

## 2nd National Workshop on Space Weather

held on 26-27 September 2005 in Neustrelitz, Germany (ca. 60 participants)

Organized at DLR - Institute of Communications and Navigation by:

Dr. Norbert Jakowski, DLR (Main Organizer)

Dr. Volker Bothmer, Universität Göttingen

Dr. Frank Jansen, Universität Greifswald

Prof. Hermann Lühr, GFZ Potsdam

Prof. Rainer Schwenn MPS, Katlenburg-Lindau



- Scientific investigations on the impact of space weather on communication systems and navigation (GPS, Galileo)
- Concept studies for small satellite systems dedicated to explore the solar effects on geospace, with special emphasis on the impact on communication/navigation systems (GPS, Galileo)
- Establishment of a National Space Weather Competence Center to provide scientific input and forecast capabilities

- ✚ **Research on Space Weather effects on GNSS-based navigation/positioning.** Focus: GNSS reference network performance/integrity. (DLR: N.Jakowski, S.M.Stankov, Allsat: J. Rueffer)
- ✚ **Research on Space Weather effects on satellite electronic systems.** Started as a joint collaboration between the University of Göttingen and EADS-Astrium. Goal: Investigate the correlation between bit memory errors (in LEO satellites) and solar events. Based on LEO/GRACE data. (J. Dobschinski, V. Bothmer, W. Keil, etc.)
- ✚ **Space Weather research** as members of the LYRA (Lyman- $\alpha$  Radiometer) / SWAP (Sun Watcher using APS and Image Processing) science consortium for ESA's Proba 2 mission in conjunction with SoHO, STEREO and Solar-B. LYRA: Solar UV irradiance monitoring for studying the effects on the Earth's ionosphere and atmosphere. SWAP: High resolution (1 min) imaging of the lower corona - ideal measurements for studying the onset/development of solar eruptions - flares and CMEs. (V. Bothmer)
- ✚ **Space Weather Services** via the DLR project SWACI (Space Weather Applications Center – Ionosphere). Specific products, based on GNSS and space weather observations, are being generated and distributed to industrial users to help them mitigating space weather effects. (N.Jakowski, S. M. Stankov, D. Klaehn, J. Rueffer)
- ✚ Participation in space weather related **satellite missions:**  
STEREO (Uni Göttingen, Uni Kiel, MPS, MPI), SWARM (GFZ, EADS-Astrium).

- **National Space Weather Satellite** with international partnership (NASA/GSFC, NRL, Hanscom AFB, etc.). Goals: Space weather effects - analysis and prediction. Status: User requirements, scientific payload studies in progress. (V. Bothmer, N. Jakowski).
- EU/ESA/INTAS project 03-51-6206 (2004-2007): Solar and interplanetary disturbances causing severe geomagnetic storms). Czech Republic; Belgium, Russia. (V. Bothmer)
- **Strong cooperation with industry** - provision of support/advise on technical issues: design of a suitable platform, use of launch capabilities, set-up of ground segments, and logistics. (EADS-Astrium, W. Keil)
- Establishment of a **SID (Sudden Ionospheric Disturbance) / Space Weather Monitoring System** in Germany for scientific and educational purposes (as defined by the Stanford Solar Center). A collaborative effort for the UN IHY-2007 between University Göttingen, EADS-Astrium, Stanford University, NASA, DLR-Neustrelitz, Felix-Klein Gymnasium, Planetarium Hamburg. (V. Bothmer, W. Keil, N. Jakowski, T. Kraupe)
- Establishment of a **German National Competence Center**. Feasibility studies started at Hamburg (Planetarium/Science Center) in connection to the ongoing data archiving preparations to accommodate NASA STEREO-Mission data (launch mid-2006). National partners: University Göttingen, Planetarium Hamburg, DLR, EADS Astrium, GFZ, etc. International partners: NASA/GSFC, NRL, ESA. (V. Bothmer, T. Kraupe, N. Jakowski)



# Space Weather Application Center - Ionosphere SWACI

The Space Weather Application Center - Ionosphere (SWACI) is a joint project of the German Aerospace Center (DLR) and the German Remote Sensing Data Center (DFD). The project is supported by the German State Government of Mecklenburg-Vorpommern under grant V230-630-08-TIFA-334. SWACI is a research project for developing the fundamentals of a space weather center whose services are focused mainly on ionospheric conditions/effects. The future DLR-Neustrelitz Ionosphere Center (NIC) shall serve the users by providing warning, nowcast and forecast, as well as historical data related to the ionosphere state and the space weather in general.

**BACKGROUND:** 2003-2005: SWIPPA - Space Weather Impact on Precise Positioning Applications



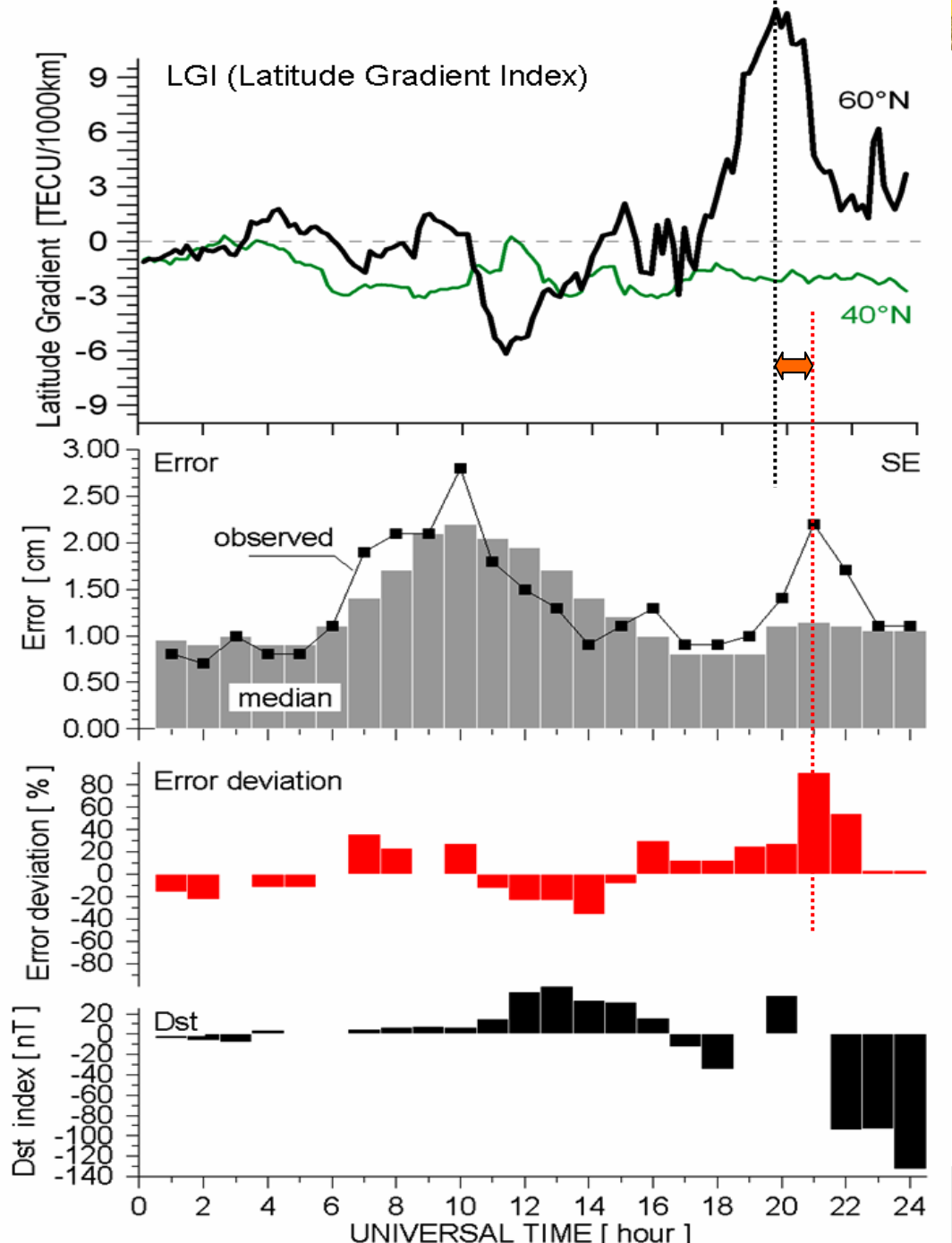
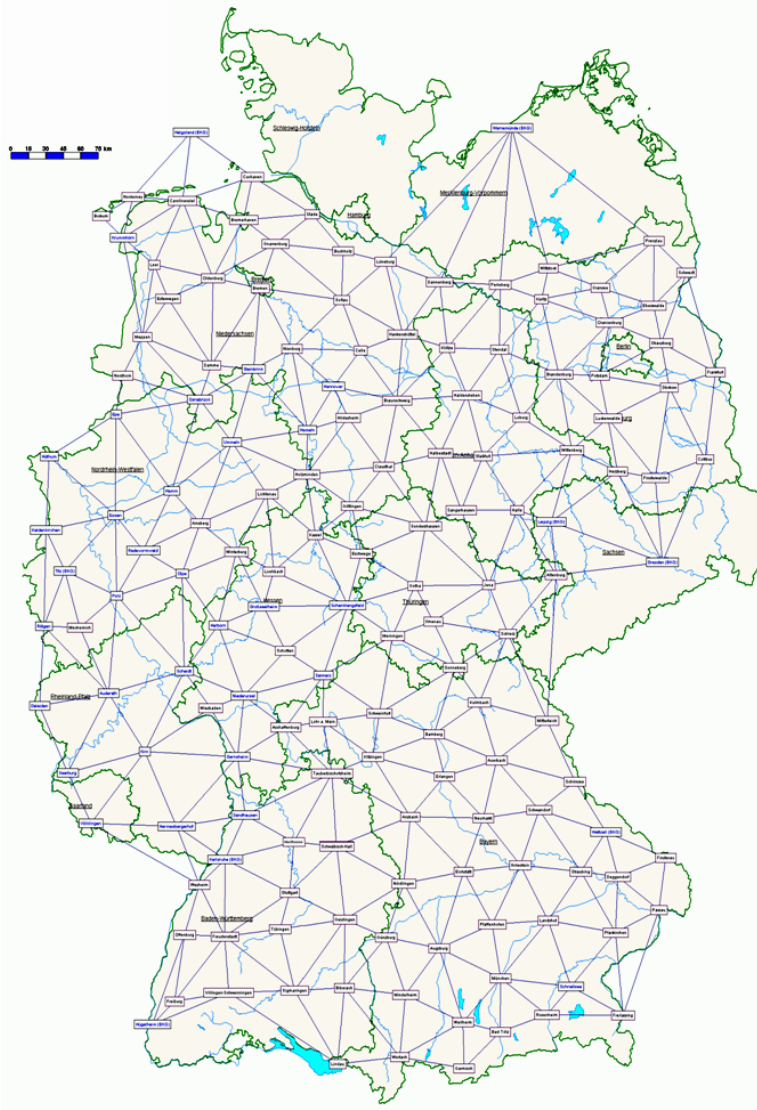
**SWIPPA was a pilot project, jointly supported by the German Aerospace Centre (DLR) and the European Space Agency (ESA) via contract ESTEC-16952/02/NL/LvH.**

The space weather can induce adverse effects on GNSS-based communication, navigation, and positioning applications. Permanent **ionosphere/space weather monitoring service should be established** and specific products, based on GNSS and space weather observations, are being generated and distributed to GNSS reference network operators in order to help them **deliver more reliable, precise and secure positioning services** and to eventually reduce the operation, production, and other business costs. **Relevant information and support** are being regularly **exchanged** with SWENET (Space Weather European Network).

Objectives achieved by:

- Operational provision of ionospheric and space weather observations
- Pre-processing and calibration of GPS data
- Generation of TEC maps (and derivative products) over Europe
- Post-processing and analysis of ionospheric / space weather information
- Analysis of ionospheric / space weather effects
- Analysis of benefits for the service users

# Network RTK integrity monitoring





GFZ Potsdam

GALILEO

EMAU Greifswald

SWENET / ESA

IAP Kühlungsborn

ESOC, GSOC

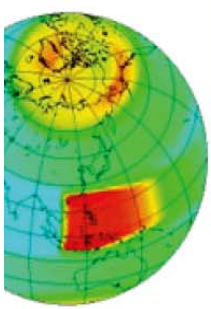
BKG Frankfurt

Allsat GmbH, Hannover

SEC Boulder

SWENET/ESA

DLR, IHR



LAPAN

ISES

ISES

public







DLR-Institut für Kommunikation und Navigation - Microsoft Internet Explorer bereitgestellt von T-Systems SfR

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Address <http://www.kn.nz.dlr.de/>



Institute of Communications and Navigation



## Space Weather Application Center - Ionosphere (SWACI)

**Home IKN**

**Home SWACI**

**About SWACI**

**Space Weather Tour**

**Service Description**

**Product Access**

Registration

CONSORTIUM

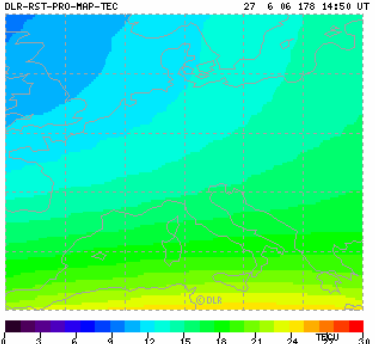
NONCOMMERCIAL

COMMERCIAL

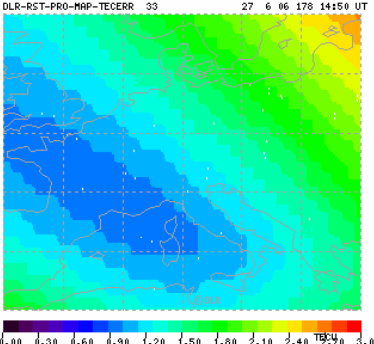
PUBLIC

**News & Features**

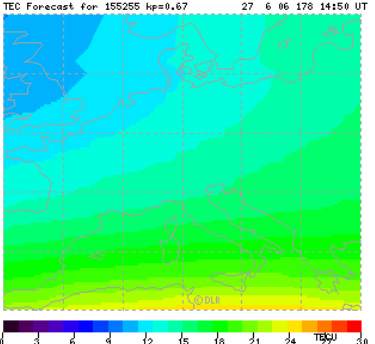
**TEC (data)**



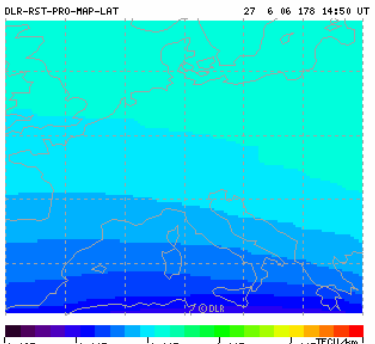
**TEC Error (data)**



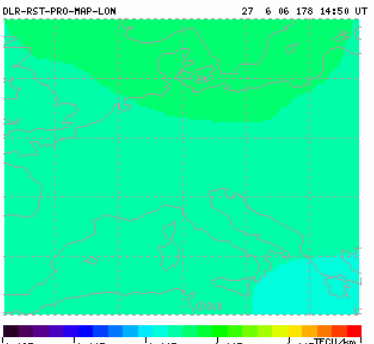
**TEC Forecast (data)**



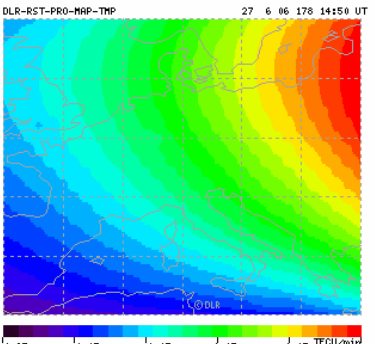
**Latitude Gradient (data)**



**Longitude Gradient (data)**




**Rate of Change (data)**



**Mapping area:**  
 Longitude: -5°, +25°E  
 Latitude: +35°, +60°N

**Grid resolution**  
 (depending on  
 GNSS 'visibility'):  
 Longitude: 1°  
 Latitude: 1°  
 Availability: 24/7  
 Update rate: 15 min  
 Latency: 1 min

<http://www.kn.nz.dlr.de/swaci/>



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

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# MuSTAnG -

## Muon Spaceweather Telescope for Anisotropy at Greifswald



**University of Greifswald:**  
F. Jansen, R. Hippler



**HTS Dresden / Germany:**  
W. Göhler, S. Brunner

**1A Greifswald / Germany:**  
F. Jansen, G. Bartling



**University of Bern /  
Switzerland:**  
E. Flückiger

**IEPSAS Kosice /  
Slovakia:**  
K. Kudela



**AAD Hobart / Australia:**  
M. Duldig, J. Humble

**Hanse city of Greifswald /  
Germany**

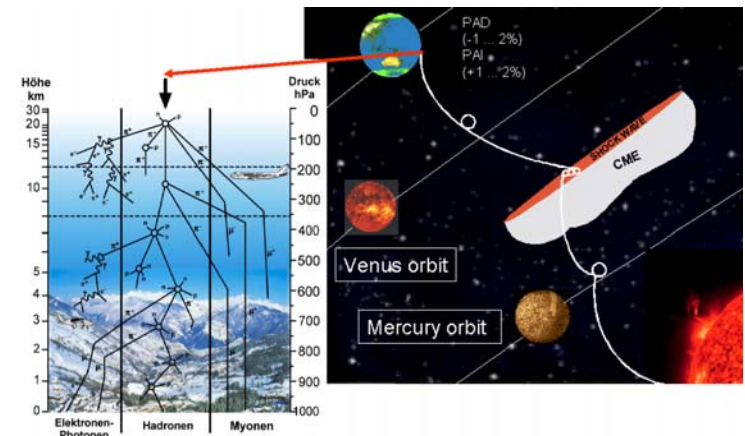
**UAS Stralsund / Germany:**  
G. Kolbe, B. Zehner

**Shinshu University / Japan:**  
K. Munakata

(ESA/ESTEC contract 18835/04/NL/MV)

# Muon Spaceweather Telescope for Anisotropy at Greifswald

- 1) ground based and real time muon telescope data (summer 2006)
- 2) international muon telescope network ( summer 2006)
- 3) CME propagation, changes of cosmic ray intensity
- 4) space weather service orientated, for user of
  - satellite navigation,
  - telecommunication,
  - aviation, airlines
  - power line and pipeline companies,
  - governmental organisations(ESA/SWENET, COST 724 and others)



## World-Wide Muon Telescope Network

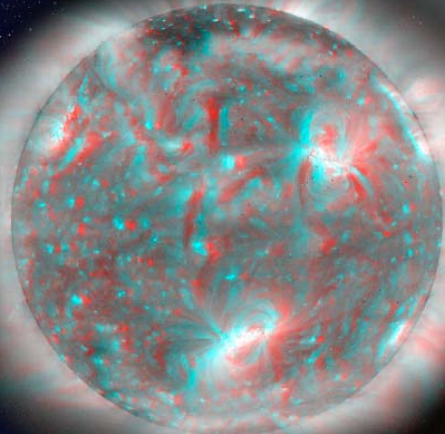
- **MuSTAnG** becomes part of the international European-Australian - Japanese – Brazil muon telescope network

# STEREO

The Solar Terrestrial Relations Observatory

The Frontier  
of Solar Research  
in the 21st Century

*The Sun in 3-D*



The STEREO mission is managed by the  
NASA Goddard Space Flight Center.  
The Johns Hopkins University  
Applied Physics Laboratory is responsible for  
mission definition, implementation and operations.

## STEREO Mission

**Solar Terrestrial Relations Observatory**

**Launch: Mid 2006**

**2 Drifting Spacecraft in Heliosynchronous Orbit**

**Drift Rate: 22°/year**

**Scientific Payload:**

**SECCHI, IMPACT, PLASTIC, SWAVES**

**Science Objectives:**

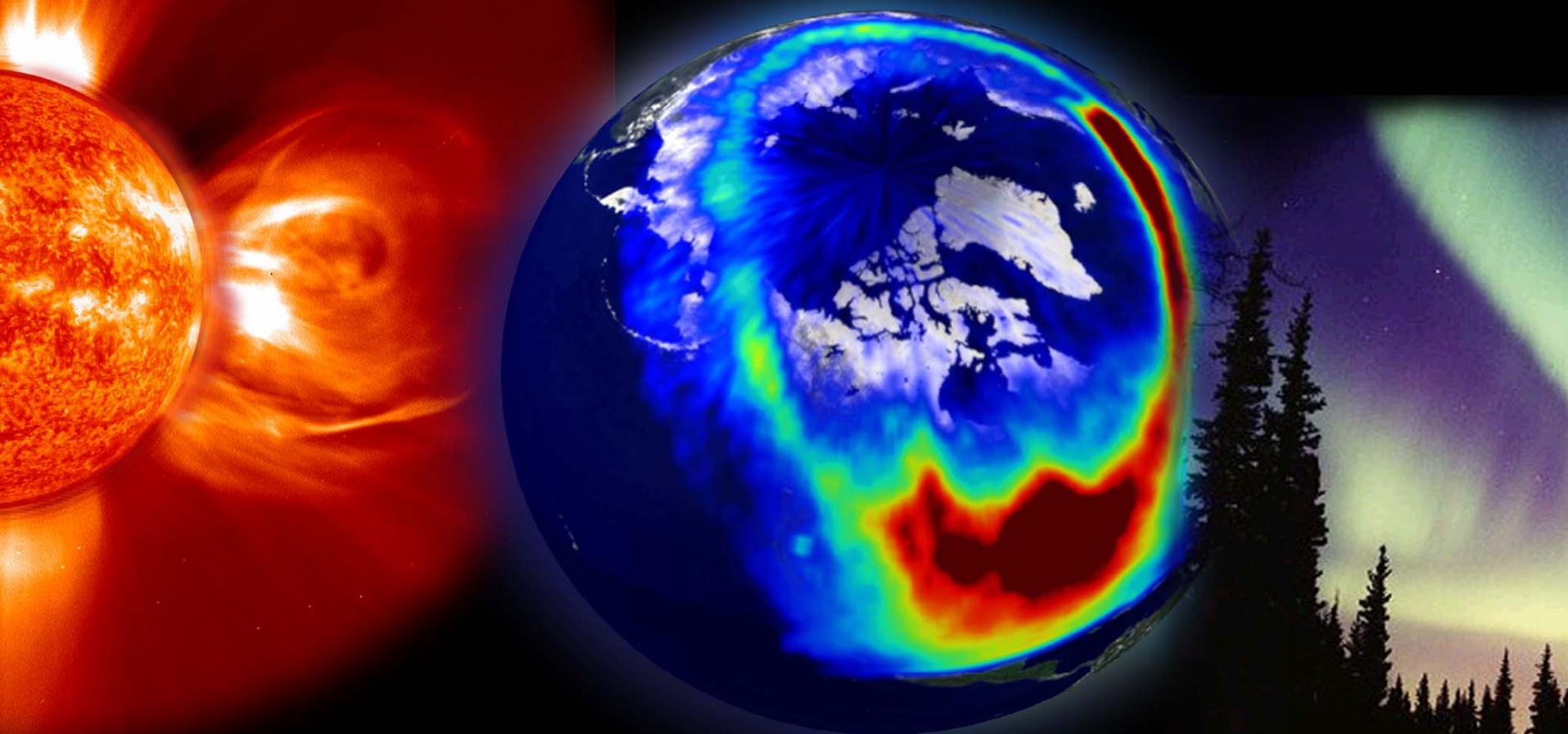
- Understand the causes and mechanisms of CME initiation.
- Characterize the propagation of CMEs through the heliosphere.
- Discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium.
- Develop a 3D time-dependent model of magnetic topology, temperature, density, and velocity structure of the ambient solar wind.

**STEREO Space Weather Working Group  
(Contact: V. Bothmer, Uni Göttingen)**



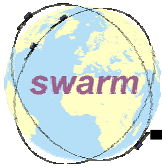
## **STEREO - a milestone in space weather research/forecast activities**

**German contribution** (Uni Göttingen, Uni Kiel, MPS, MPI, etc.): research, hardware and software - contribution to SECCHI Sun-Centered imaging package (SCIP), SECCHI stereoscopy imaging software, IMPACT particle detector, PLASTIC electronic parts, etc.



**STEREO A and STEREO B will:**

- Image the solar atmosphere and heliosphere from two perspectives simultaneously.**
- Track disturbances in 3-D from their onset at the Sun to beyond Earth's orbit.**
- Measure energetic particles generated by solar eruptions.**
- Sample fields and particles in the disturbances as they pass Earth's orbit.**



# Swarm

## The Earth's Magnetic Field and Environment Explorers

Proposers:

Eigil Friis-Christensen, Danish Space Research Institute

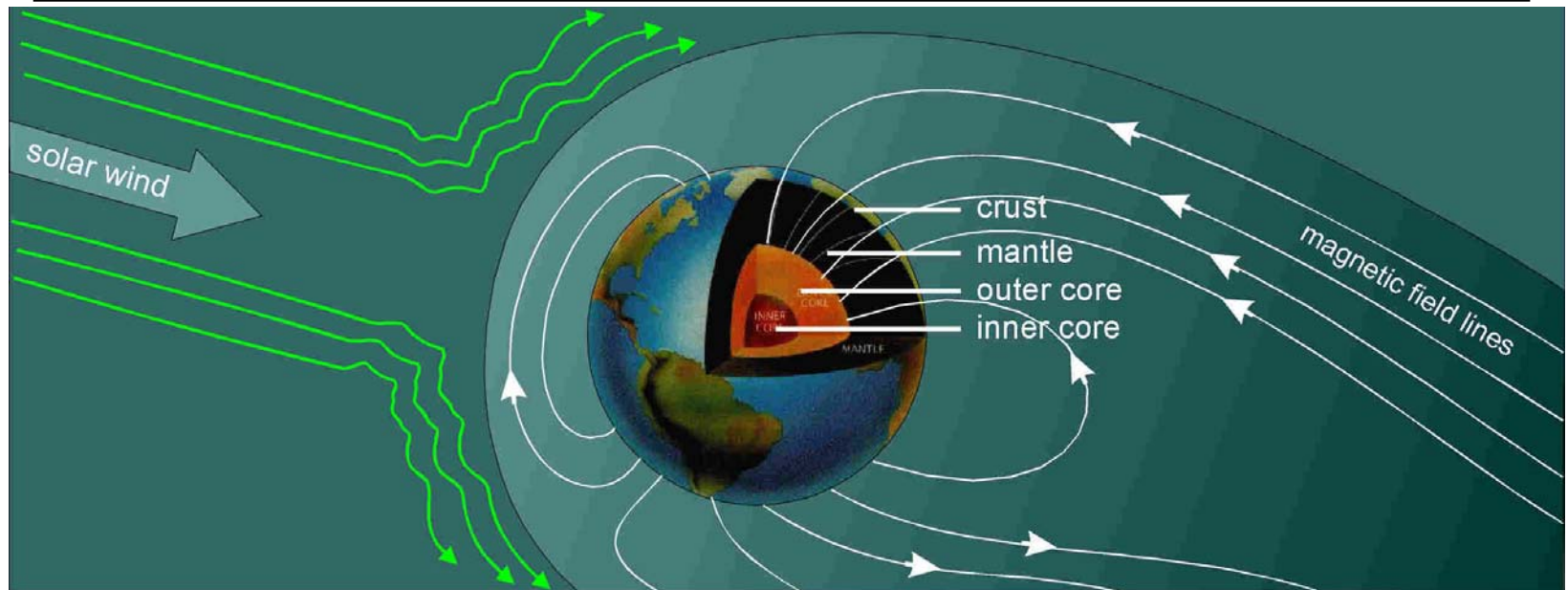
Hermann Lühr, GeoForschungsZentrum Potsdam

Gauthier Hulot, Institute Physique de Globe de Paris



## Mission Aim

The **Swarm** mission will provide the *best ever survey of the geomagnetic field and its temporal evolution*, in order to gain new insights into the *Earth system by improving our understanding of the Earth's interior and physical climate.*





# Summary of Research Objectives



## Primary Objectives

Core dynamics, geodynamo processes, and core-mantle interaction

Lithospheric magnetisation

3-D electrical conductivity of the mantle

Electric currents in magnetosphere and ionosphere

## Secondary Objectives

Magnetic forcing of the upper atmosphere

Magnetic signature related to ocean circulation





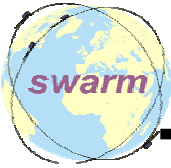
## Relevance for Space Weather Applications

### Quantities that can be derived in the Ionosphere / Thermosphere:

- Field-aligned currents
- Horizontal currents (electrojets) responsible for GIC
- Ring current intensity, index for magnetic storm intensity
- Electric field, possible trigger for plasma instabilities
- Electron density and density gradients, responsible for radio wave disturbances
- Detection of plasma bubbles in the low latitude ionosphere
- Thermospheric density/winds causing air drag and orbit disturbances of LEO spacecraft.

All these quantities can be provided in near-real time, based on an orbit-by-orbit down link.

ESA would consider such an operational mode if there is a European user group taking responsibility for rapid processing and dissemination of data.



# Mission Characteristics

## Mission schedule

Selection of Mission by ESA: May 2004

Realisation phases

Phase B (definition): 2006

Phase C/D (construction): 2007 – 2009

Launch: 2010

Mission Phase: 2010 – 2014 (nominal)

## Constellation

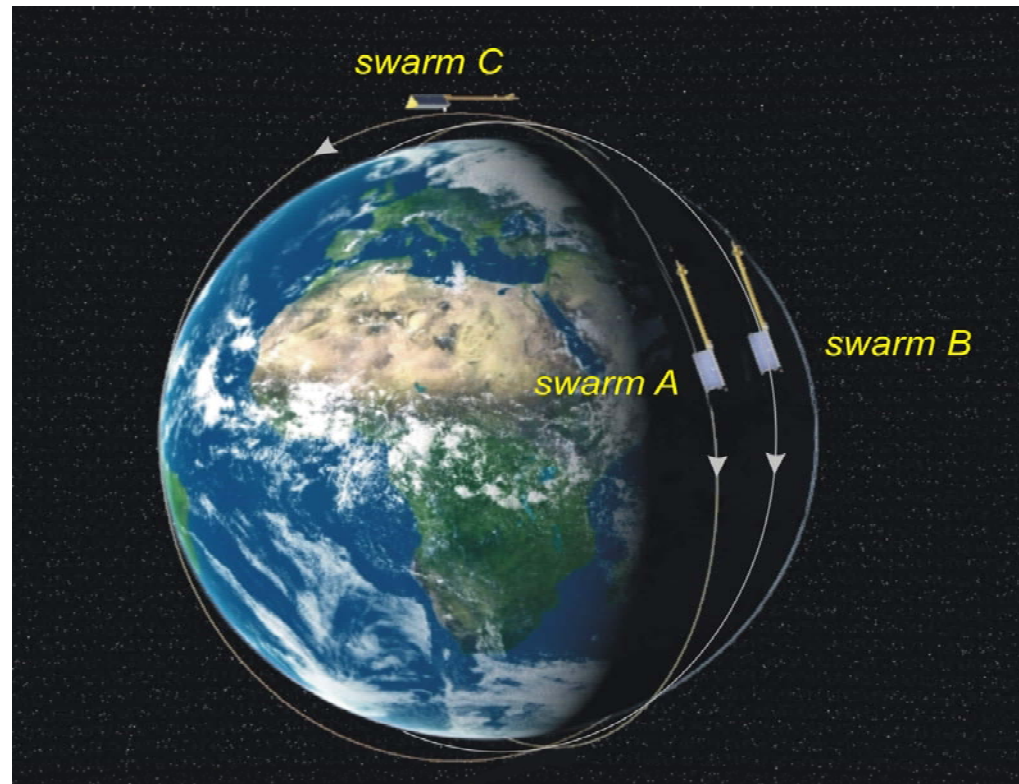
3 satellites:

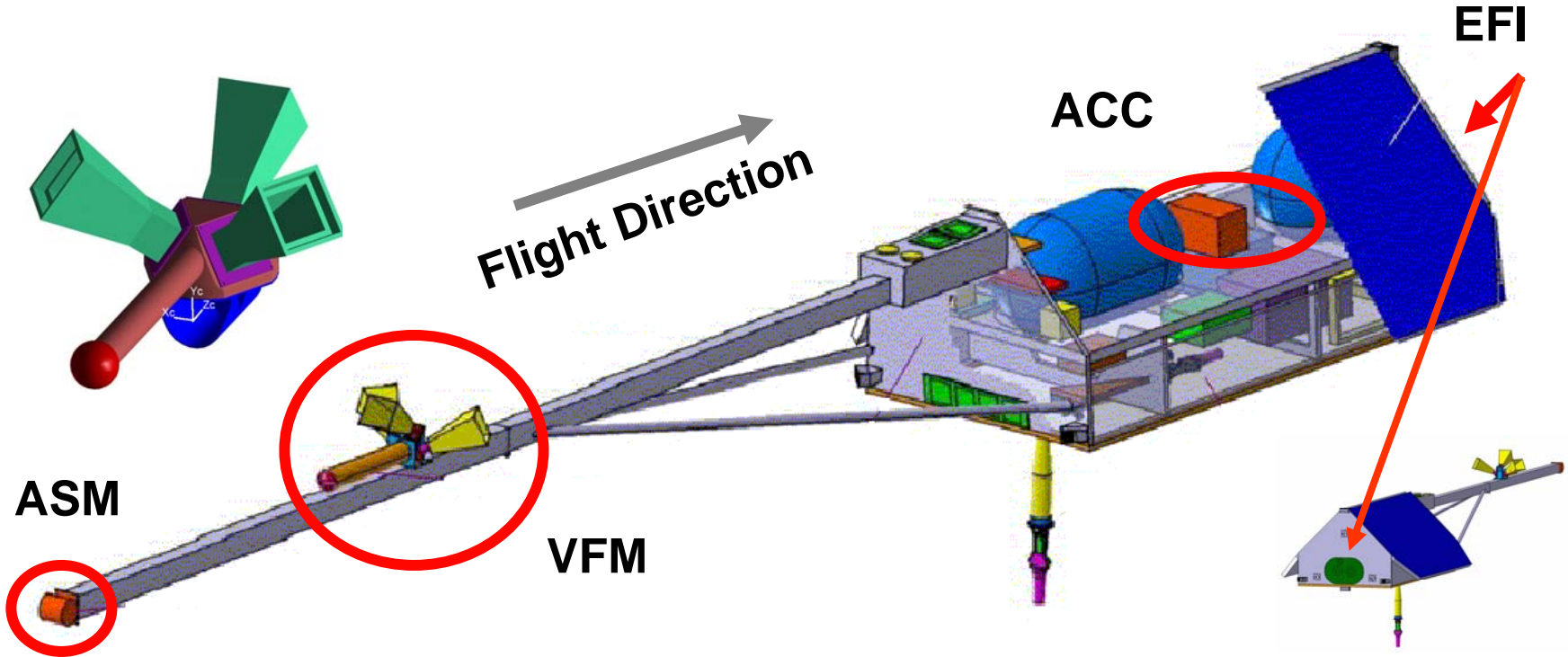
2 side-by-side in low orbit

1 in higher orbit

three orbital planes with two different local times

All have near-polar orbits for global coverage





- Vector Field Magnetometer (VFM) with optical bench
- Absolute Scalar Magnetometer (ASM)
- Electric Field Instrument (EFI)
- Accelerometer (ACC)

## Next Steps

- SWACI: Further improve the services towards better spatial and temporal resolution of the nowcast service. Improve the quality of short-term ionospheric forecast, diversify the forecast products. Extend the current regional mapping towards local and global coverage.
- SWACI-2: Develop new improved services to address a larger set of professional GNSS users.
- SWENET (Space Weather European Network):  
Increase contribution.
- Coordination meeting focused on the further space weather effects research, satellite design issues, and IHY activities planning.  
Venue: EADS-Astrium/Friedrichshafen, July 2006.
- Status meeting/workshop on the National Space Weather Competence Center establishment and space weather satellite design issues.  
Venue: Hamburg, Autumn 2006.

