New European Space Weather Telescope - MuSTAnG – (Muon Spaceweather Telescope for Anisotropies at Greifswald)

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SME 1A: http:www.1A-FirstApplications.com

- Space weather sources
- Technical effects
- International activities + MuSTAnG

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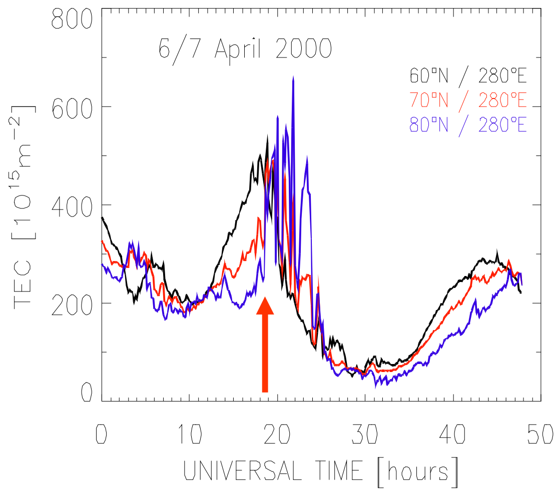
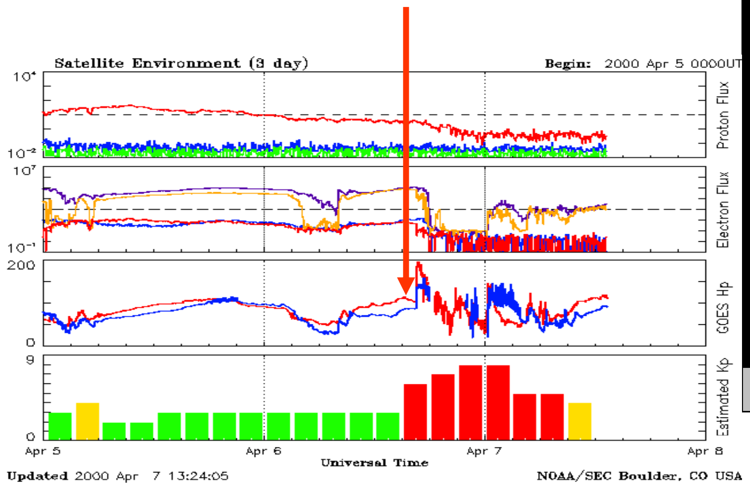
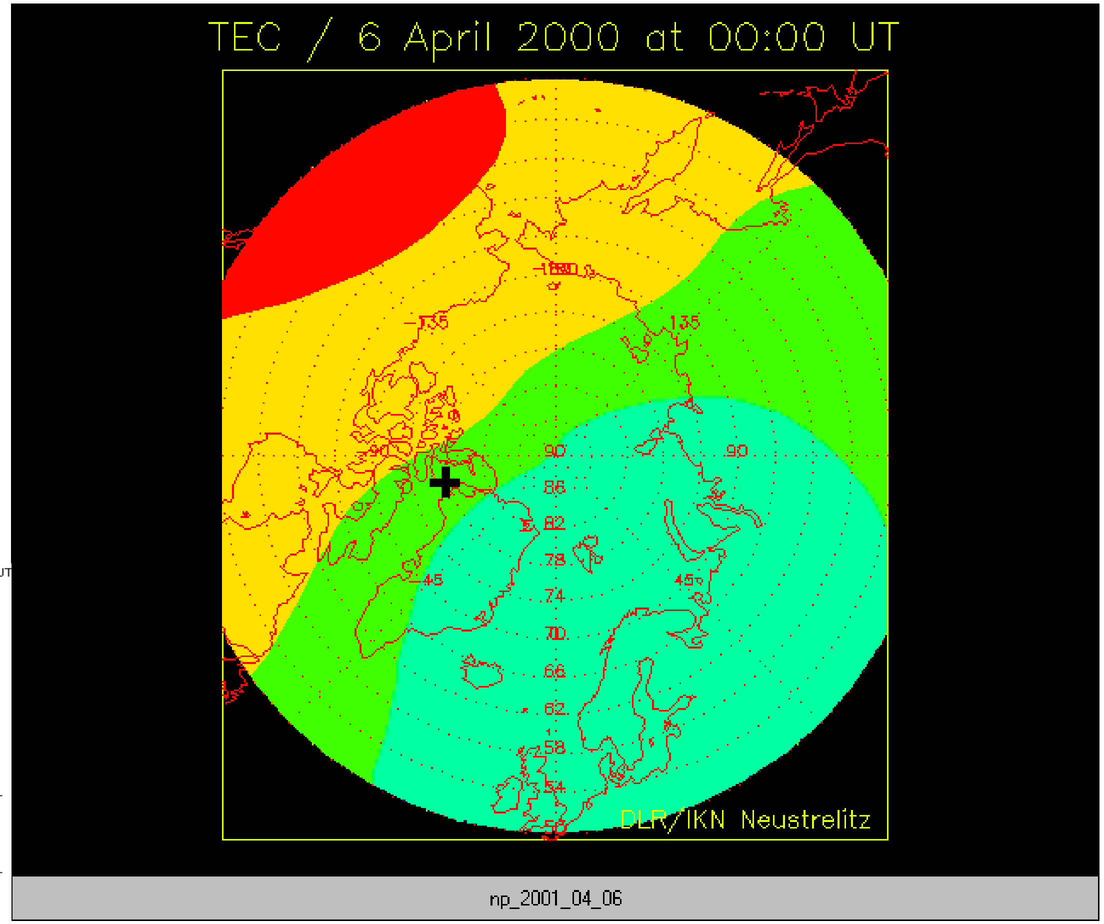
Space weather sources

❍ionosphere 6 April 2000

DLR/IKN







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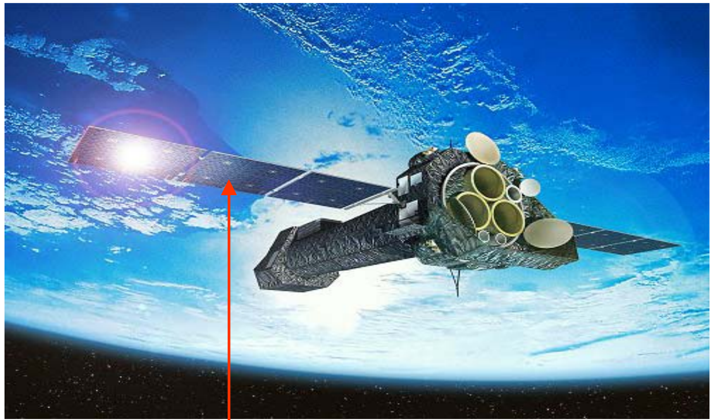
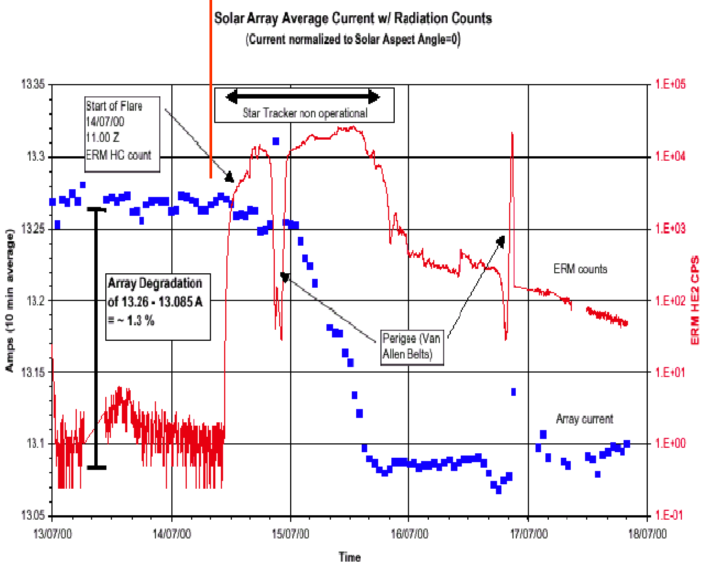
Technical effects

- space missions





- 31 failures and losses
  (12 total losses)
  Meteosat, ERS-1, XMM ...
  Equator-S, Anik 1&2,
  Telstar 401, ASCA ...
- losses in the last 4 years are higher than 500 Millionen USD

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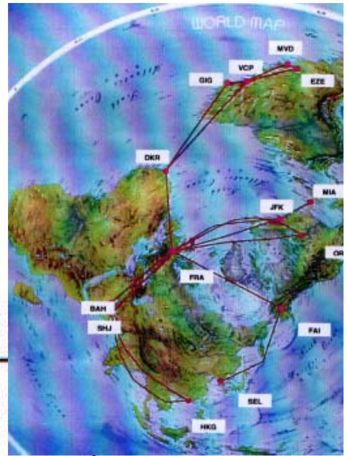
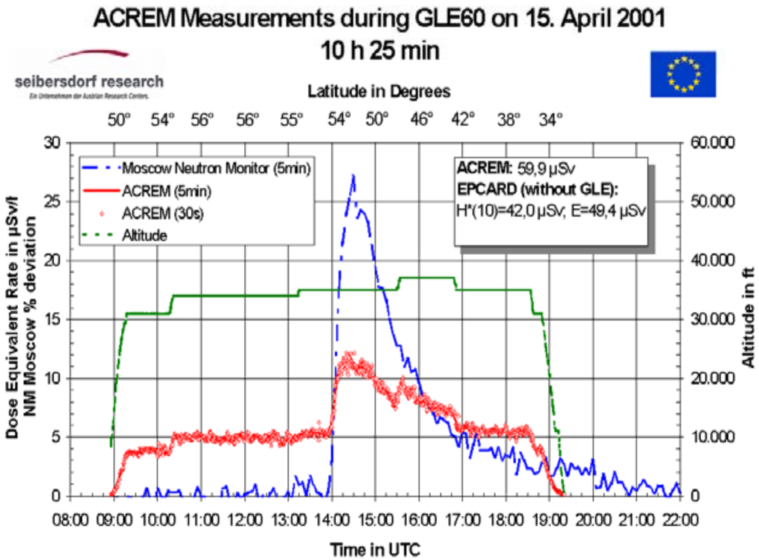
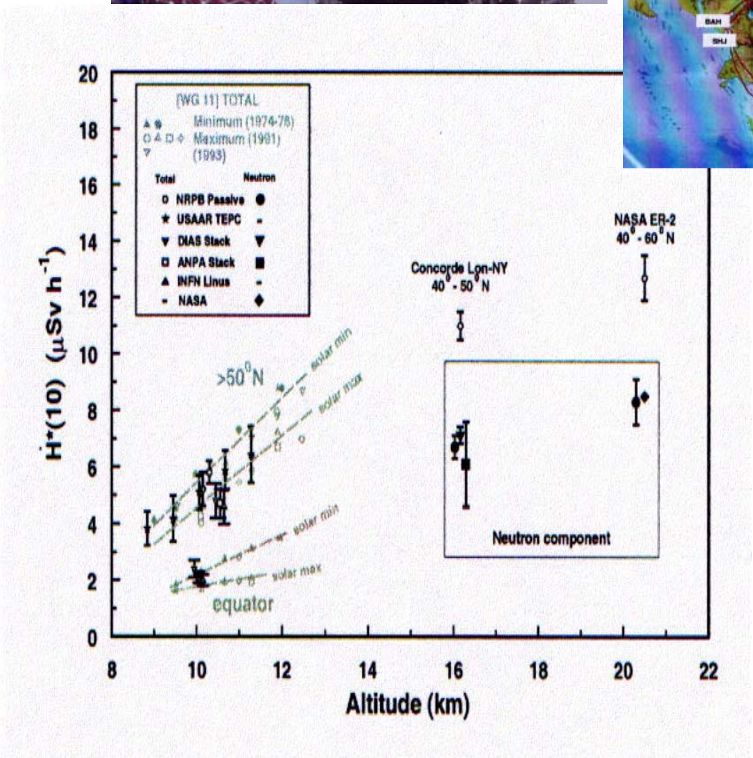
Technical effects

- aviation







- European Directive to EU member states
- new radiation protection law in Germany (BfS, BMU since 1/6/01) and other EU member states:

  for airlines: employer must assess the exposure of air crews if annual dose is likely to exceed 1 mSv, annual upper limit 20 mSv

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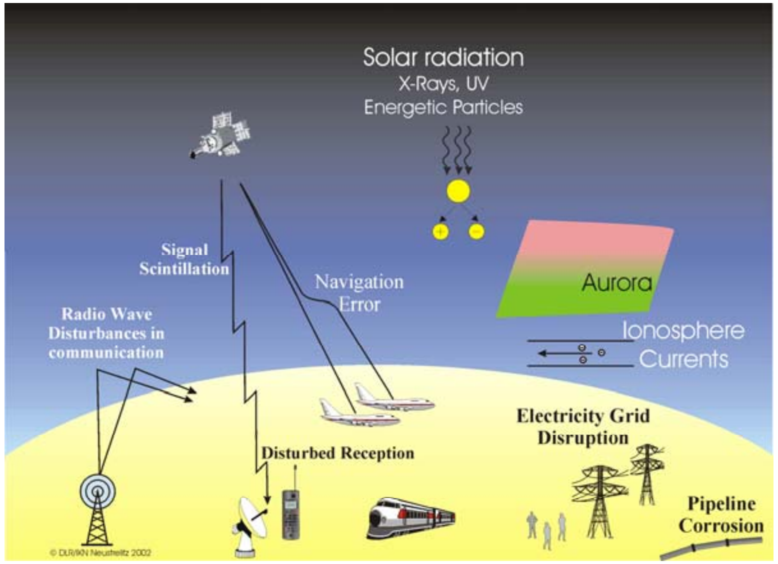
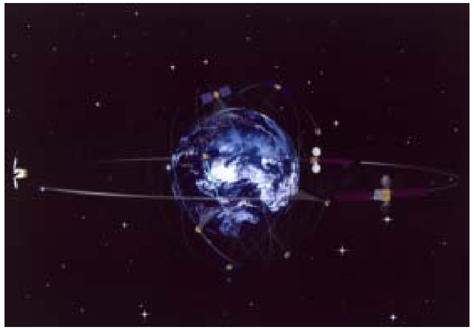
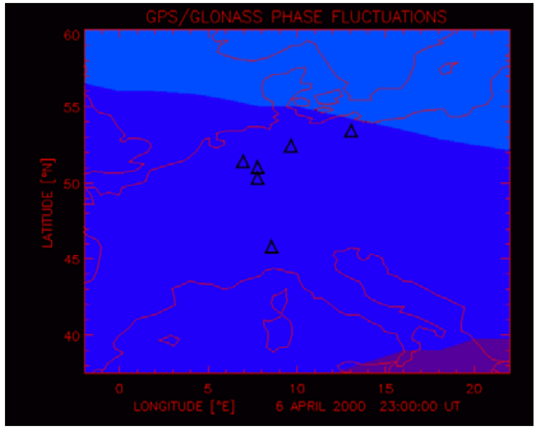
Technical effects

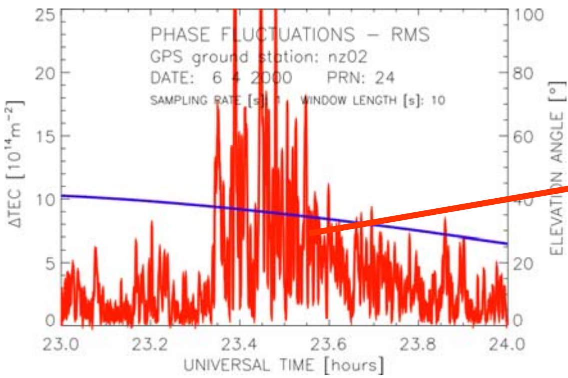
- satellite navigation and telecommunication





Galileo Navigation System





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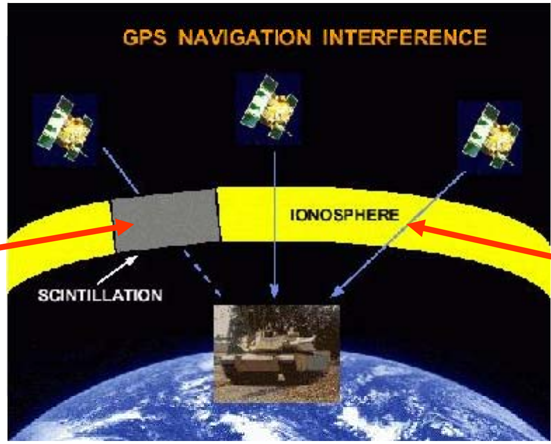

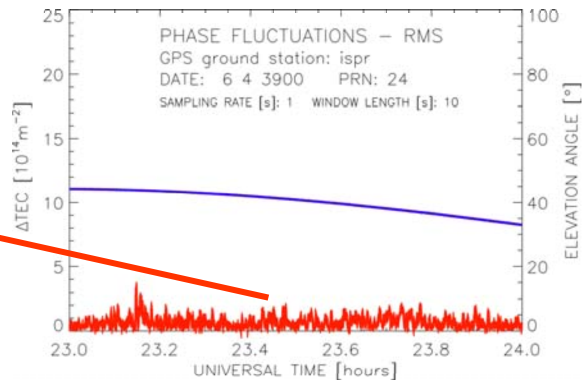

DLR/IKN Neustrelitz

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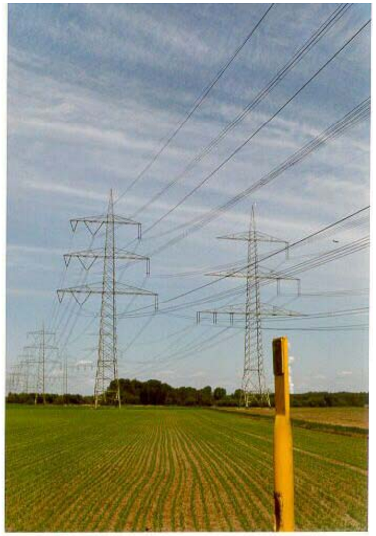
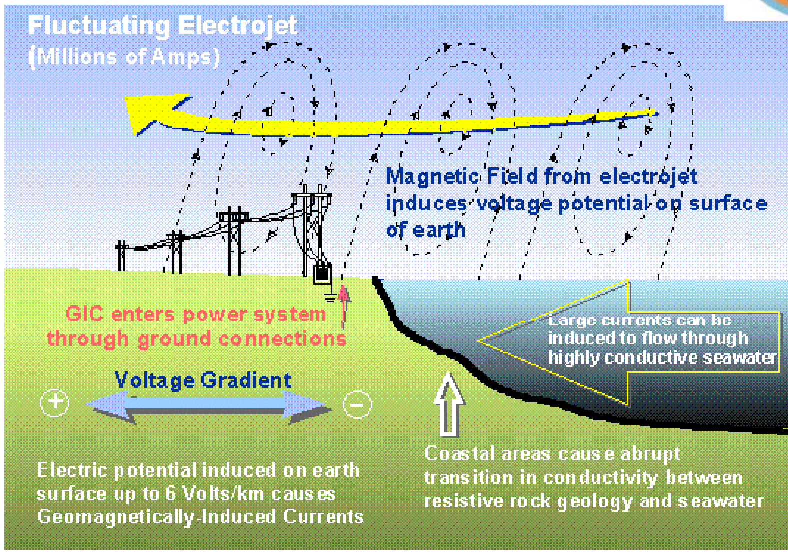
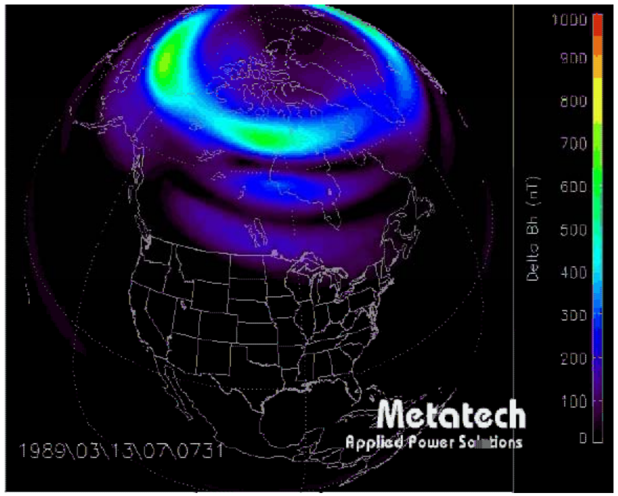
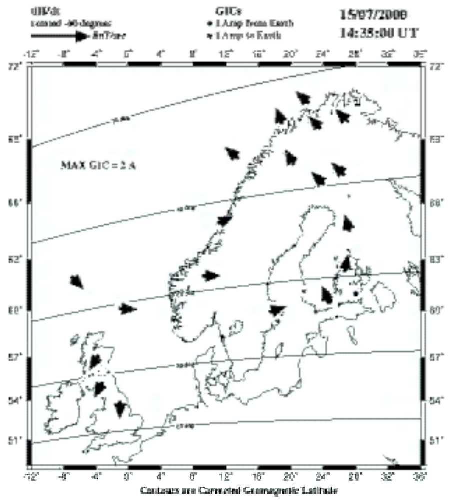
Technical effects

- electric power transmission









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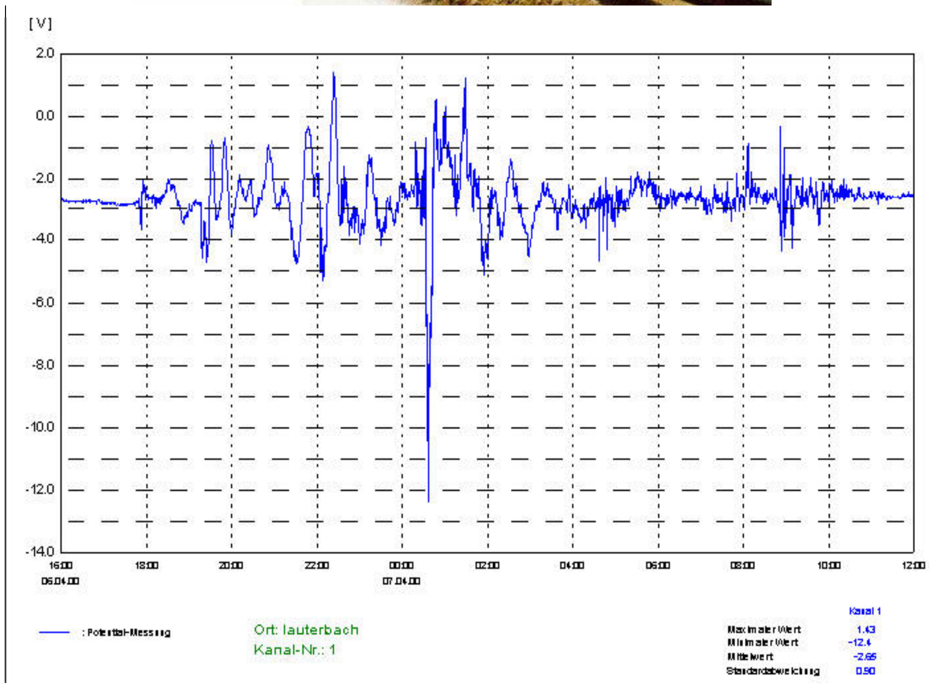
Technical effects

- oil, gas and drilling industry



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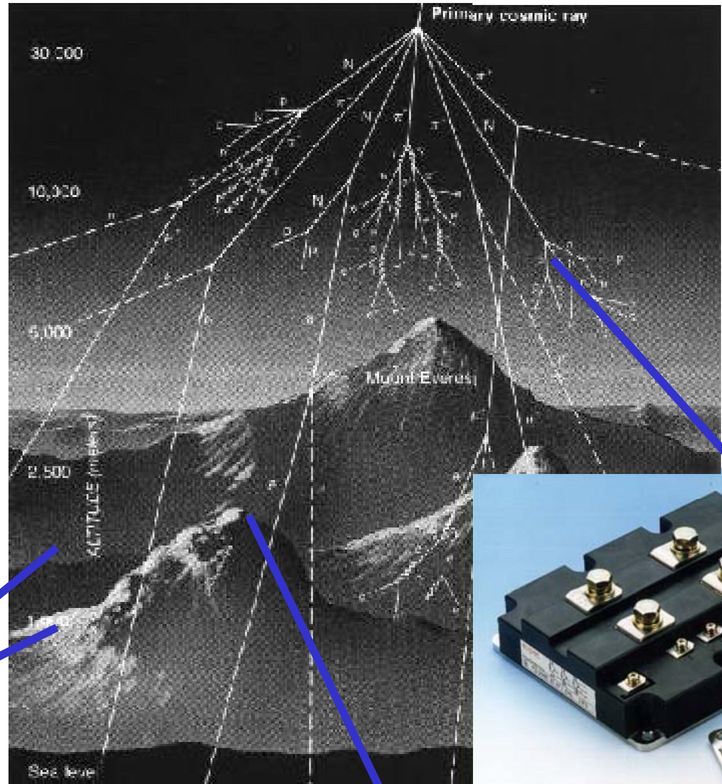
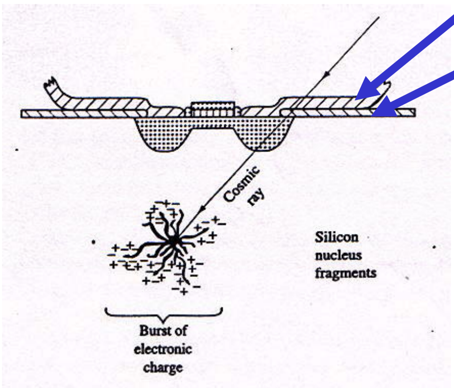
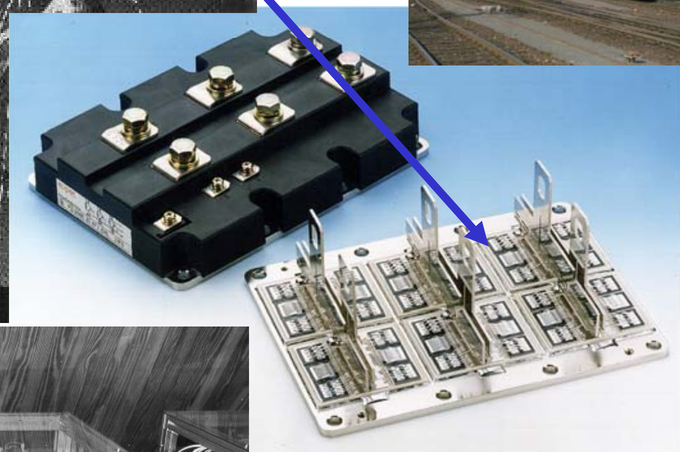
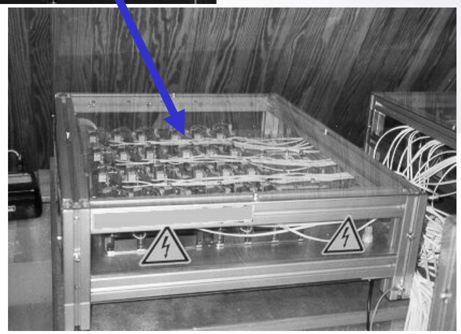
Technical effects

- electronics and transport









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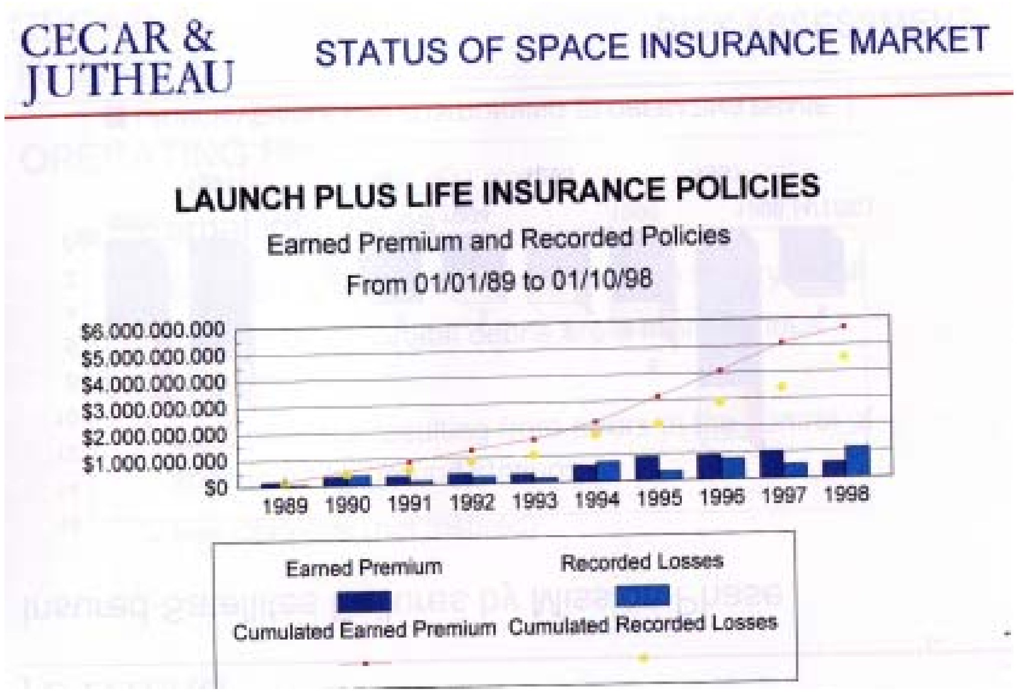
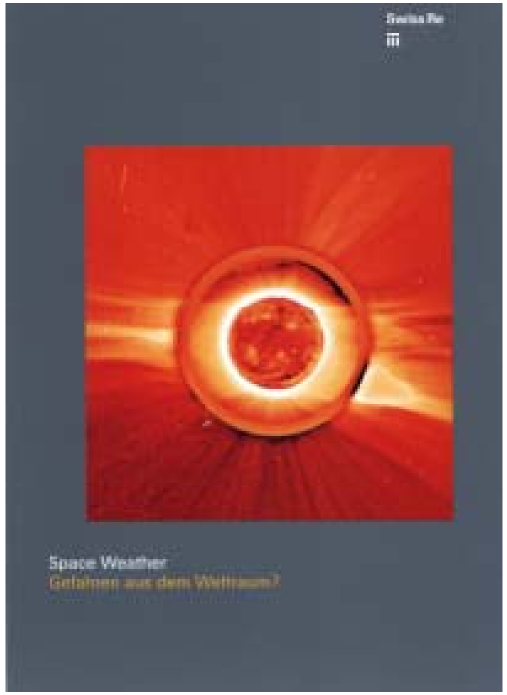
Technical effects

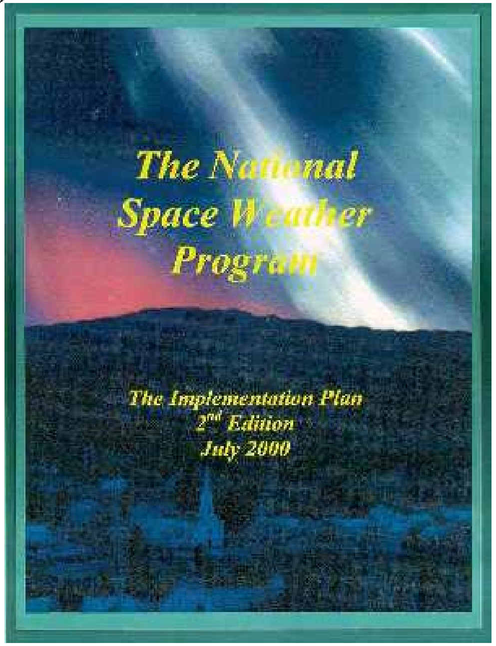
- **space weather and insurance**





http://www.swissre.com/

International activities



1) ESA Space Weather Feasibility Studies

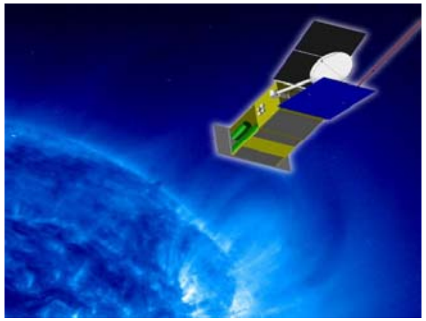
CLRC

ALCATEL SPACE

2) ESA Space Weather Application Pilot Projects

3) SWENET

www.estec.esa.nl/wmwww/wma/spweather/



EU / ESF COST Action 724

International activities

ESA SW Feasibility Studies

1) Benefits of a space weather programme
2) Establishment of detailed rationale for a SW programme
3) Establishment of detailed programme contents, including
   space and ground segment, prototyping of services
4) Definition of structures which need to implemented by ESA and member states
5) Draft programme proposal, cost estimates, risk analaysis
6) Development of a web-based data base ...
7) Secretarial management of a European SWWT

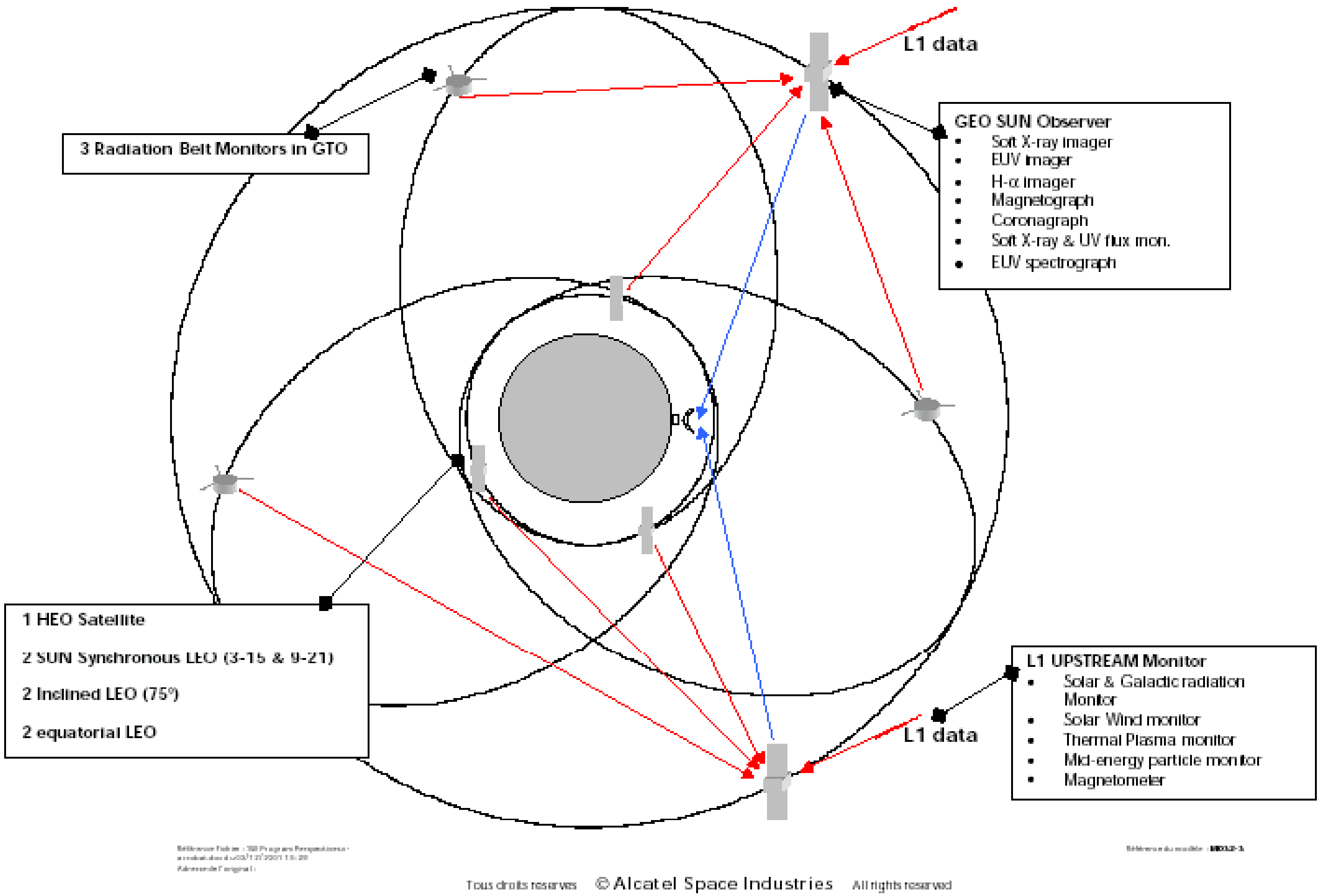
Companies	Key personnel
ALCATEL Space Industries - Cannes / France	B. Huet[1] ; O. Pansart ; P. Kamoun
Laboratoire de Physique & Chimie de l'environnement - Orléans / France	F. Lefeuvre[1]; P. Gilles ; T. Dudok De Wit
British Antartic Survey Cambridge / United Kingdom	R. Horne[1]
Swedish Institute of Space Physics - IRF Lund / Sweden	H. Lundstedt[1]
Mullard Space Science Laboratory - UCL London / United Kingdom	A. Coates[1] ; R. Bentley ; N. Crosby
ESYS - Surrey / United Kingdom	A. Shaw[1]
Observatoire de Paris- LPSH Meudon / France	M. Pick[1]
Laboratoire de Planétologie de Grenoble - Grenoble / France	J. Lilensten[1] ; C. Lathuillere
Imperial College - London / United Kingdom	P. Cargill[1]
University of Greifswald - EMAU Greifswald / Germany	F. Jansen[1]

(1) : contact persons

International activities

ESA Space Weather Feasibility Studies

- space-born, full scenario + global data communication



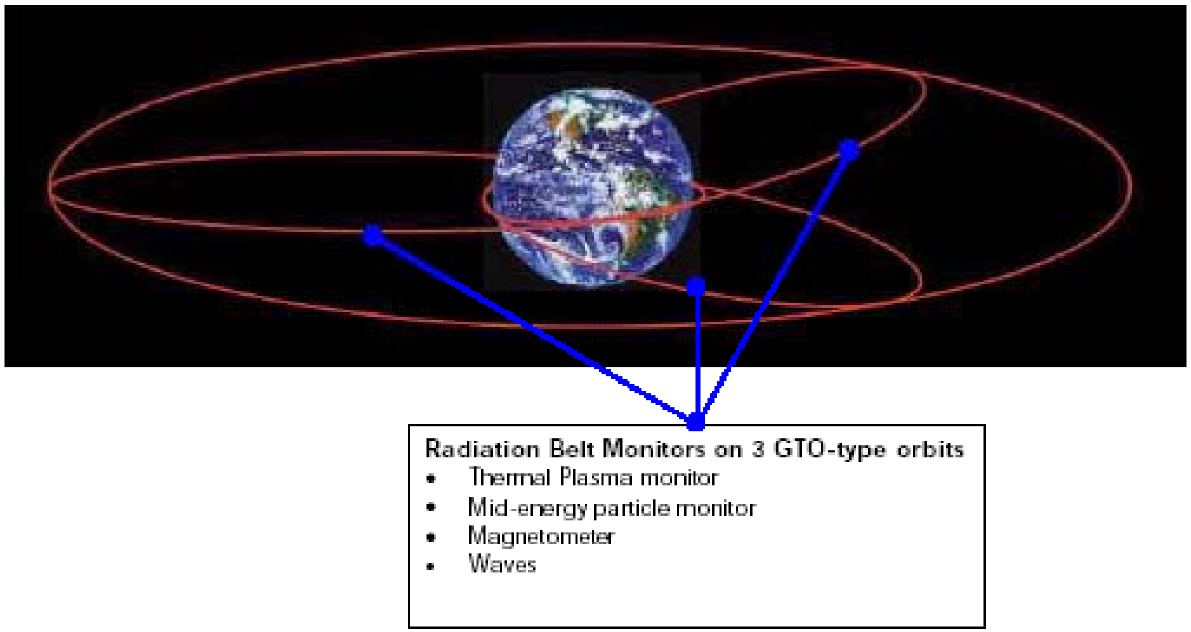
International actvities

ESA Space Weather Feasibility Studies

- **space-born, full scenario:**

magnetosphere / radiation belt monitoring:

GTO-type orbits, 120 ° against each other



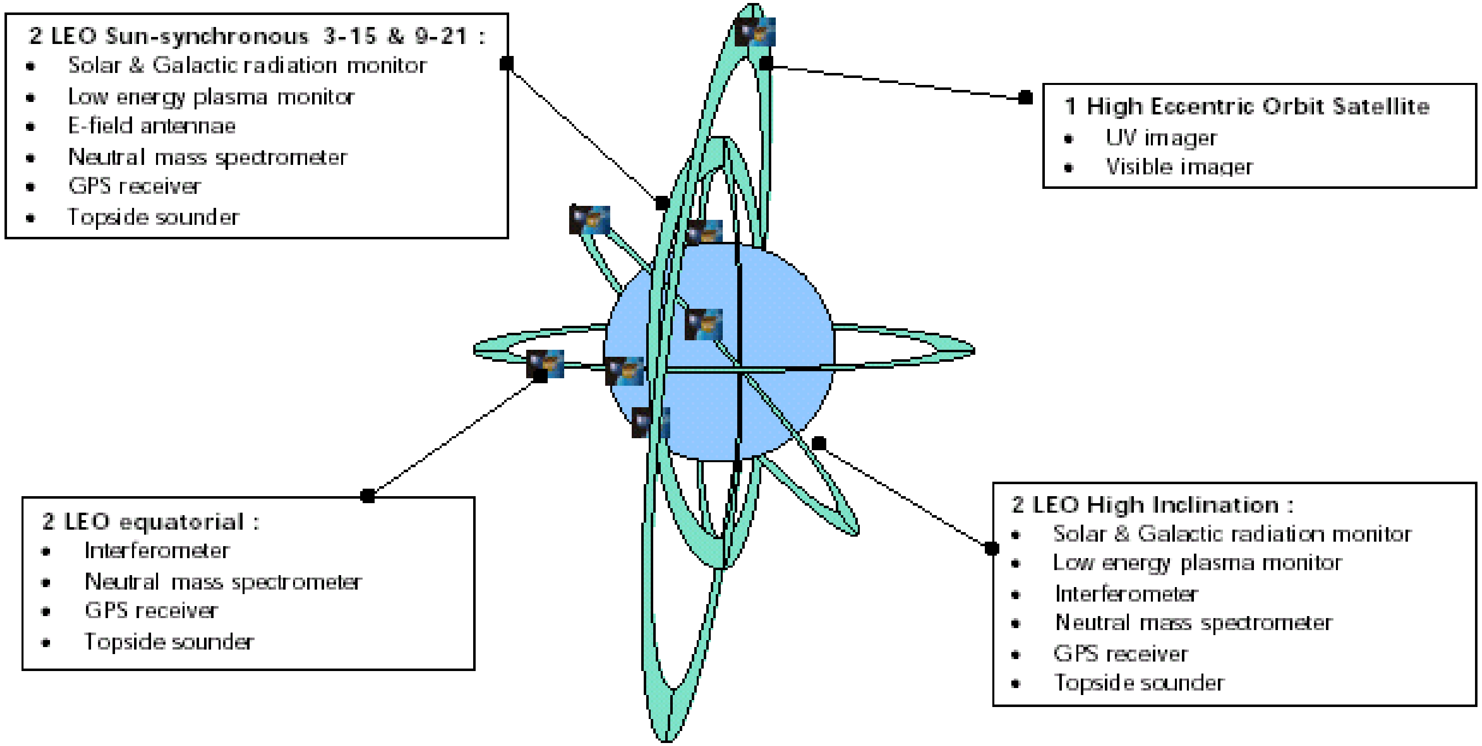
International activities

ESA Space Weather Feasibility Studies

- **space-born, full scenario:**

  ionosphere and thermosphere

  HEC and LEO satellite orbits



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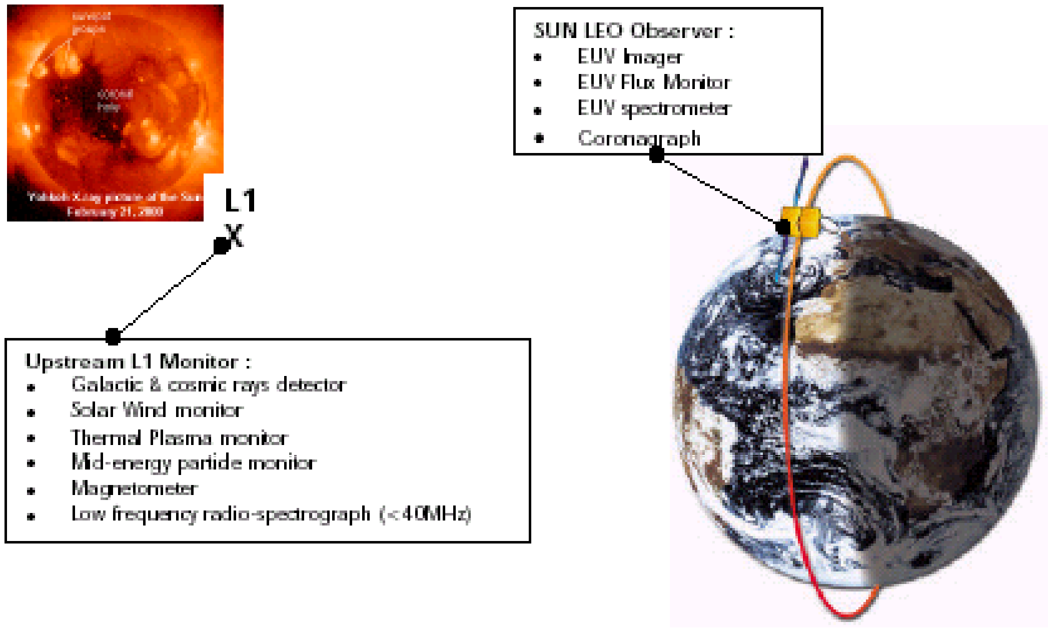
International activities

ESA Space Weather Feasibility Studies

- **space-born scenario with lowest priority**



International activities

ESA Space Weather Feasibility Studies

- **ground based segment (part 1)**

Region	Instrument	Current status	Deduced Parameters	Use for SW	Remarks	Recommendation
Sun	Full disc magnetograph	Networks under construction.	Mean field Solar rotation and oscillations Vector magnetograms	To detect onset of solar events	Networks include GONG+ USAF-ISOON, SOLIS	Accessibility uncertain. Use existing networks if available. Augment/implement network to provide 24hr coverage Priority to space
Sun	Full disk Ha network	Network under construction	Velocity profiles of solar chromospheric structures Moreton waves	To detect onset of flares and CMEs	Networks include USAF-ISOON, BBSO (coordinator)	Accessibility uncertain. Use existing networks if available. Augment/implement network to provide 24hr coverage Priority to space
Sun	Coronagraph	Research	Plasma density	Proxy for CME propagation	No established network. Seeing limitations.	No ground network recommended.
Sun and Interplanetary	Broad frequency radio spectrograph (> 10MHz)	Research	Velocities of shocks, electron beams and energetic particles. Proxy for moreton waves.	Detection of SEP events. Shock propagation.	No established network.	Network needs to be set up with minimum of 3 sites for 24hr coverage.
Sun and thermosphere	10.7 cms flux monitor	Network exists	10.7 cms flux	Proxy for solar activity. Required for thermospheric models	US network Data fully accessibility	To be maintained for continuity of geophysical records
Sun and interplanetary	Radio imaging below 1 GHz	Research	Intensity and polarization maps	CME onset and development SEP events. Proxy of Moreton waves and shocks	No established network. Cannot be done from space.	Network needs to be set up with minimum of 3 sites for 24hr coverage.
Interplanetary	Interplanetary scintillations	Research	Starlight intensity fluctuations	Presence and motion of shocks out to several AU	No established network. Dual site measurements show CME structure and propagation	Promising technic. Needs more investigation to establish SW capability.

International activities

ESA Space Weather Feasibility Studies

- **ground based segment (part 2)**

Interplanetary	Neutron and muon detectors	Operational networks	Cosmic ray flux variations. Anisotropies.	Radiation dose. Detection of interplanetary shocks and CMEs propagation	International neutron networks exist, operational 24 hrs/day. Present muon networks has big gap over Europe. Cannot be done from space. Real time data freely accessible.	Use existing neutron network. Muon detector required in European region.
Magnetosphere and ionosphere	Magnetometer network	World wide networks exist. Operational	Absolute values of B. Ionospheric currents	Geomagnetic indices. Storm and substorm detection	24 hr coverage Data freely accessible. Gaps over Russia and Northern asia	Use existing networks Fill gaps in local time.
Ionosphere	SuperDARN coherent radars	Research	Velocity maps. Boundary location, Convection electric field	Electric field and convection maps.	18 hr MLT coverage in northern hemisphere, 12 hrs in south. Data is freely available, convection maps available in real time.	Establish 24hr coverage, and operational capability.
Ionosphere	Ionosondes	Research	Ionospheric density profile below F region.	Maximum useable frequency for HF communications TEC, scintillations.	Over 50 stations in Europe, only 6 automated and provide. Pressure to close down.	Intercalibrate instruments. On-line data access required. COST are assessing for SW. Recommend use for absolute Ne measurements
Ionosphere	Positional receivers	Operational for GPS	TEC, position, neutral density corrections	Prediction of HF communications Scintillations	GPS data is freely available	Higher spatial resolution required (COST are assessing for SW). Intercalibration required. Future data must be freely available for SW.
Ionosphere	Incoherent scatter radar	Research	Ionospheric Density, temperature, velocity	Calibration tool	Useful for model development	Support continued operation.
Thermosphere	Optical interferometers	Research	Neutral density and temperature	Potential use for atmospheric drag	Limited to clear skies.	Potential use for model development
Ionosphere	Riometers	Research	Radio wave absorption	Scintillations. Electron precipitation	Long term future at risk. 23 sites providing limited spatial coverage	Potential use for model development

International activities

EU / ESF COST Action 724

„Developing the scientific basis for monitoring, modelling and predicting space weather“

http://cost724.obs.ujf-grenoble.fr

COST - COperation in the field of Science and Technology

- coordination of European activities in science and technology funded by the EU through the European Science Foundation (ESF)

- funding related to coordination, i.e. Managment Committee (MC) meetings, expert meetings, travel and publications

International activities

EU / ESF COST Action 724

„Developing the scientific basis for monitoring, modelling and predicting space weather“

http://cost724.obs.ujf-grenoble.fr

General aims of COST action 724

- coordinate European research into modelling and predicting space weather
- to promote the deployment of new instrumentation to satisfy new data requirements and the devlopments of new models
- to educate potential users of space weather data
- to gather feedback from users to improve the services
- to creat a forum on „best practice“ among users and providers of space weather services
- to sets standards on data exchange

International activities

EU / ESF COST Action 724

1. **Kick off November 2003:** duration 4 years, 24 European (and nearby European) countries, ESA as well

2. **Four working groups:** WG 1 M. Messerotti INAF Triest,
W.Schmutz PMOD/WRC Davos
Monitoring and Predicting Solar Activity for Space Weather

WG 2 R. Vainio Univ. of Helsinki,
D. Heynderickx BIRA Brussels
The Radiation Environment of the Earth

-

WG 3 J. Waterman DMI Farum,
S. Poedts Univ. Leuven
Interaction of Solar Wind Disturbances with the Earth

International activities

EU / ESF COST Action 724

3. MoU aims for WG 4: Leader F. Jansen / Univ. Greifswald WWW
Co-Leader M. Candidi / IFSI - CNR Rome

Space Weather Observations and Services

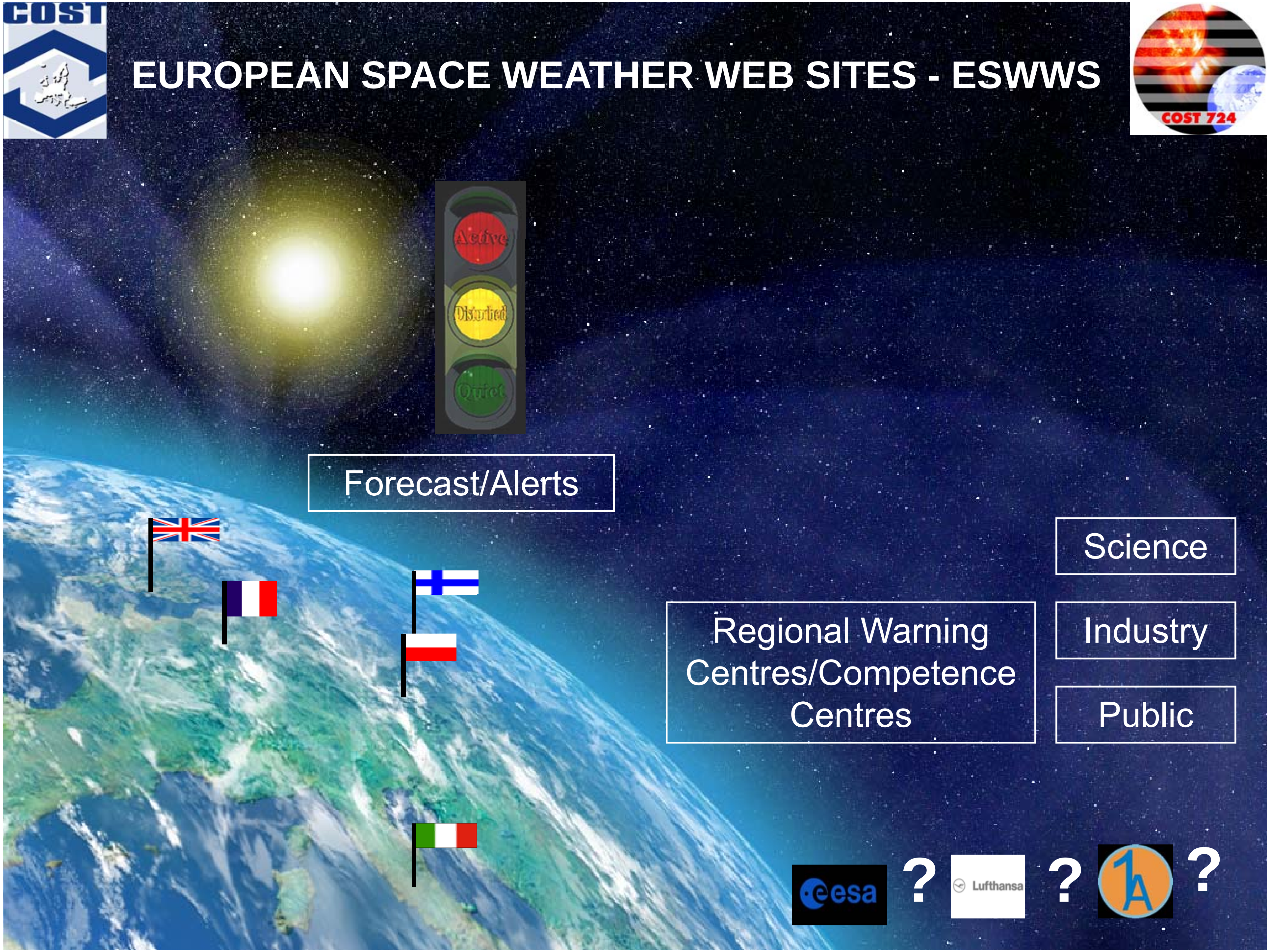
a) coordination of a network of European websides, relevant to data, models, prediction and public outreach

b) development of methods and standards for data exchange to enable coupling of different sw model and to disseminate relevant information to users

c) liaise with COST action 271 (ionosphere)

d) maintain data base for users and statistics about the service

4. <u>MAIN AIM:</u> ESWWS


COST
EUROPEAN SPACE WEATHER WEB SITES - ESWWS
COST 724
Active
Disturbed
Quiet
Forecast/Alerts
Science
Regional Warning Centres/Competence Centres
Industry
Public
esa
?
Lufthansa
?
?

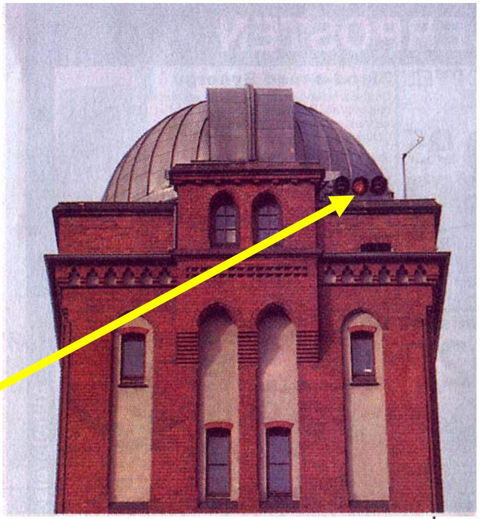
International activities

German Army
Infineon
Lufthansa
PTB
Ruhrgas
SENSYS

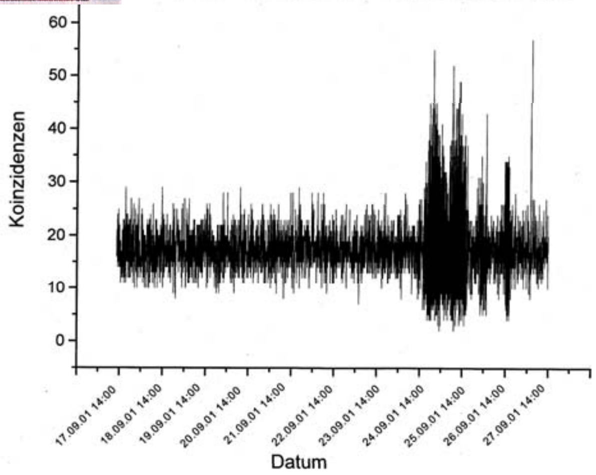
Alcatel Space
Astrium U.K.
National Grid
Virgin Atlantic ...
Sydkraft
Fin. Power Grid
Gasum Oy
Swiss Re ...

Bell Labs
Metatech

<u>EU: SW</u>
European
Science and
Technology
Week
<u>4 to 10</u>
<u>November 02</u>



Meßdaten der Sternwarte Greifswald



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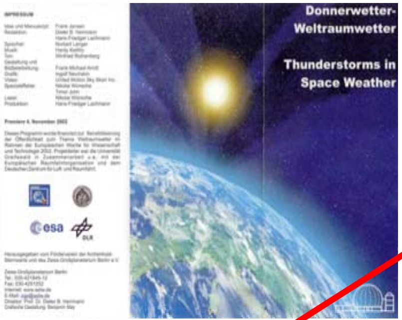
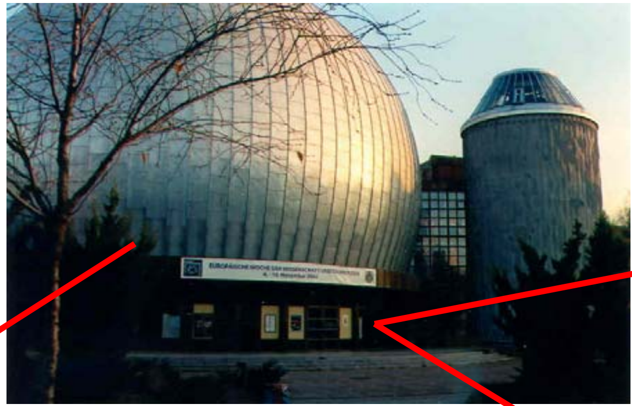
Space Weather Week - ESTW

(4 – 10 November 2002)

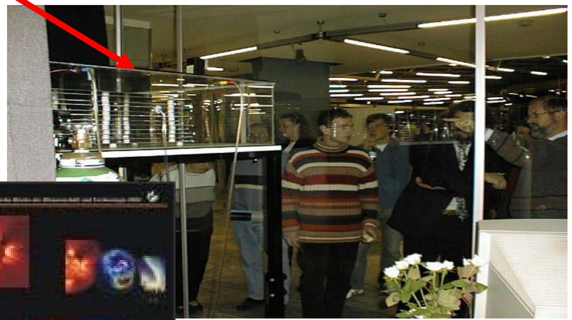




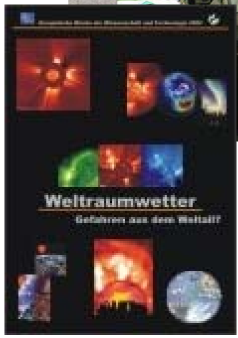
SW exhibition

SW planetariun show:
„Thunderstorms in Space Weather “

Interactive SW CD-ROM
+ Science Museum Edition



spark chamber



poster

WWW Greifswald

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)

Interplanetary CMEs and shocks

❍ no real time data about interplanetary CMEs and shocks

contemporary status:

Solar environment

1) - Soho (UV) observations up to 30 solar radius R_S or only about 1/3 Mercury orbit
   - very good due to Soho: in space and near real time, data are used for estimations /simulation of arrival time at Earth

2) - radiospectrogaphs on the ground measure up to 1. 7 R_S
   - very good: instruments on the ground and real time data

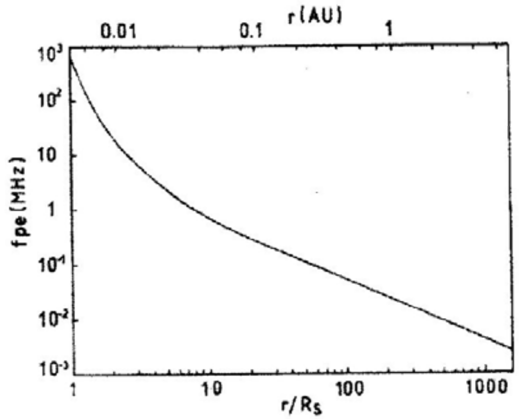


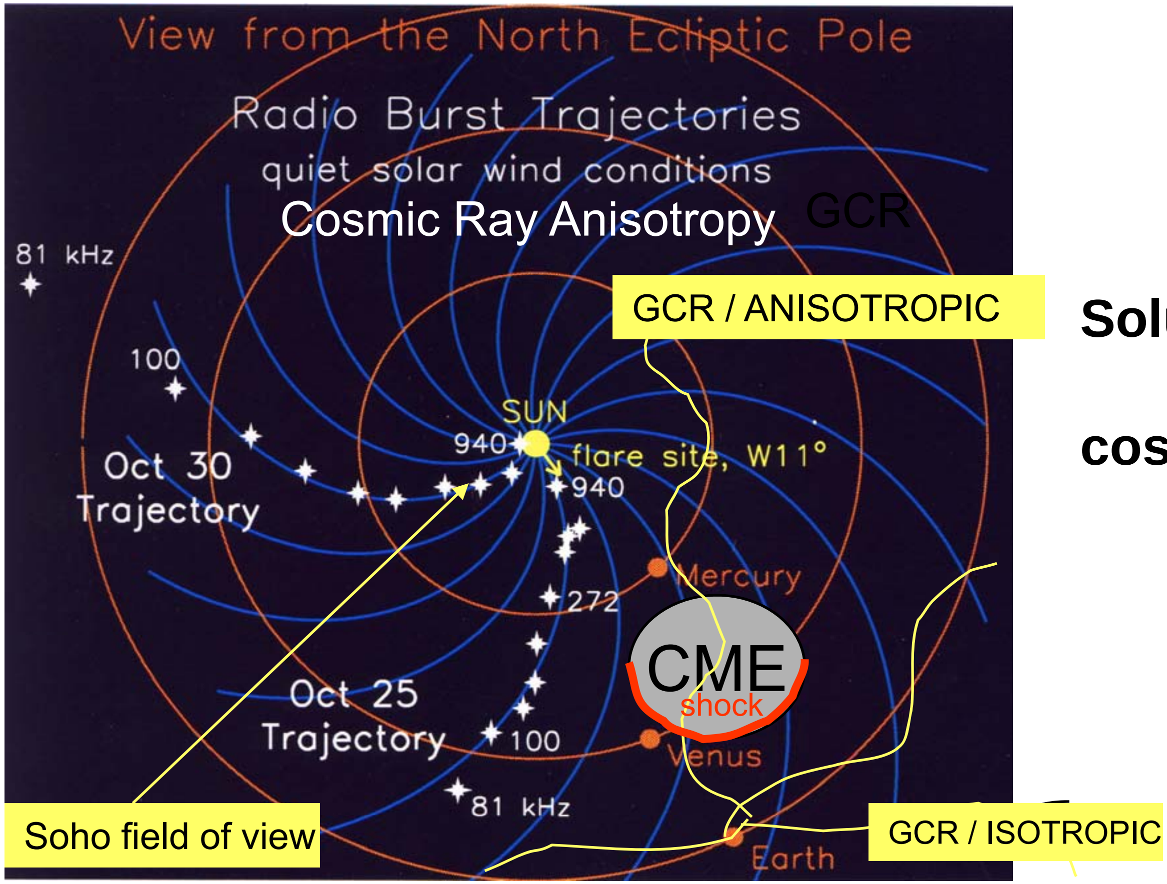
Fig. 2. Radial dependence of the local electron plasma frequency $f_{pe}(r)$

problems:

1) - from 30 R_S to Earth orbit no remote or in-situ real time data

2) - only radiospectrographs for instance on Ulysses and WIND s/c measure the interplanetary propogation of CMEs or shock waves (position is a function of the plasma frequency (Mann, Jansen, MacDowall et al. Astron. Astrophys. 348, 614 (1999)), but data are not available in real time (data transfer to Earth about 2 to 5 days later)

SOHO, radio and cosmic ray observations of interplanetary CMEs with shock waves



Solution:

cosmic ray anisotropy

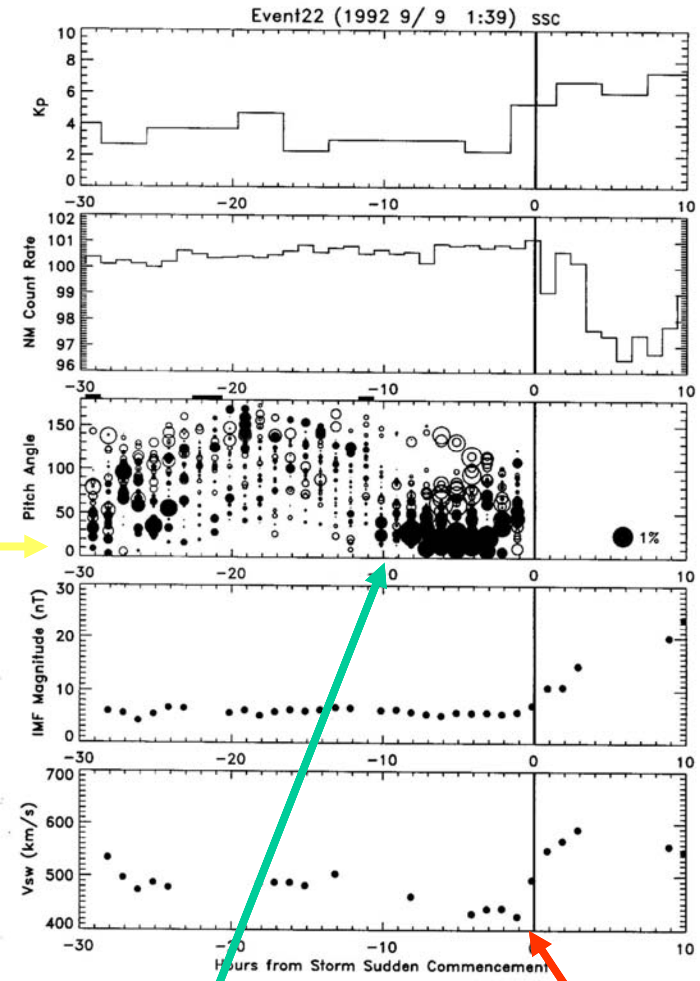
Space weather related physics behind cosmic ray measurements

Example: space weather storm on 9th September 1992

(Figures right (from top to bottom,
black line is the sudden commencement (SSC))

1) change of Kp index versus time
2) cosmic ray neutron monitor counts versus time
   (no hints for changing counts rate before SSC)
3) ***pitch angle versus time, but with cosmic ray muon telescope data (Nagoya Scintillator Telescope) enhancement of comic ray muon anisotropy into Sun direction (black circles) about 10 hours before SSC***
4) change of interplanetary field magnitude
5) change of solar wind velocity

Details see in
Munakata et al. J. of Geophys. Res. 105 (A12) 27457, 2000



Sun direction

10 hours before SSC

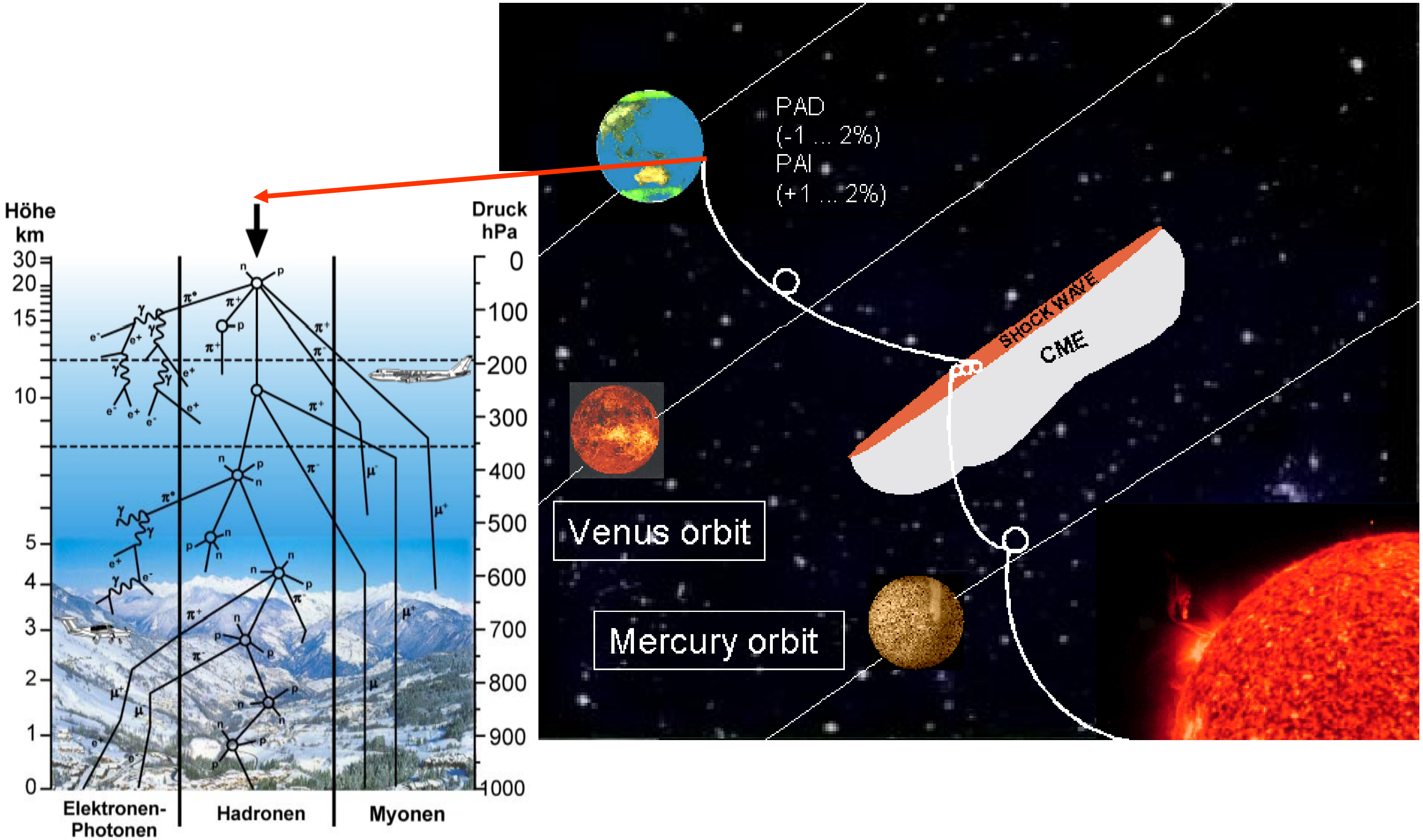
Space weather physics

and muon telescopes on ground

1) Ground-level CR detectors scan various directions in space (including to the Sun) as Earth rotates.
2) Daily variations in counting rates on ground reflect anisotropic intensity distribution of cosmic rays in space.
3) Semidiurnal variation due to interactions in the heliosphere of outward moving solar wind and inward diffusing galactic cosmic rays.
4) Semidiurnal variations were observed by neutron monitors, ion chambers and muon telescopes.
5) Detectors observe reduced flux of CR particles moving away from the shock (with small pitch angles), due to CR depleted region behind the shock.
6) CR intensity deficit in the order of 1 % to 2 %.
7) First detection of the shock at a distance of $r \sim 0.1\ \lambda_P \cos ß$
   (λ_P scattering mean free path of cosmic rays, angle between Sun-Earth line and the mean IMF at Earth)
8) λ_P about 1 AU for 10 GeV CRs (neutron monitor energy range) => 5 hours before shock wave arrival

9) Muon telescopes measure at 50 GeV
=> λ_P much longer
=> 24 hours before shock wave arrival !!!

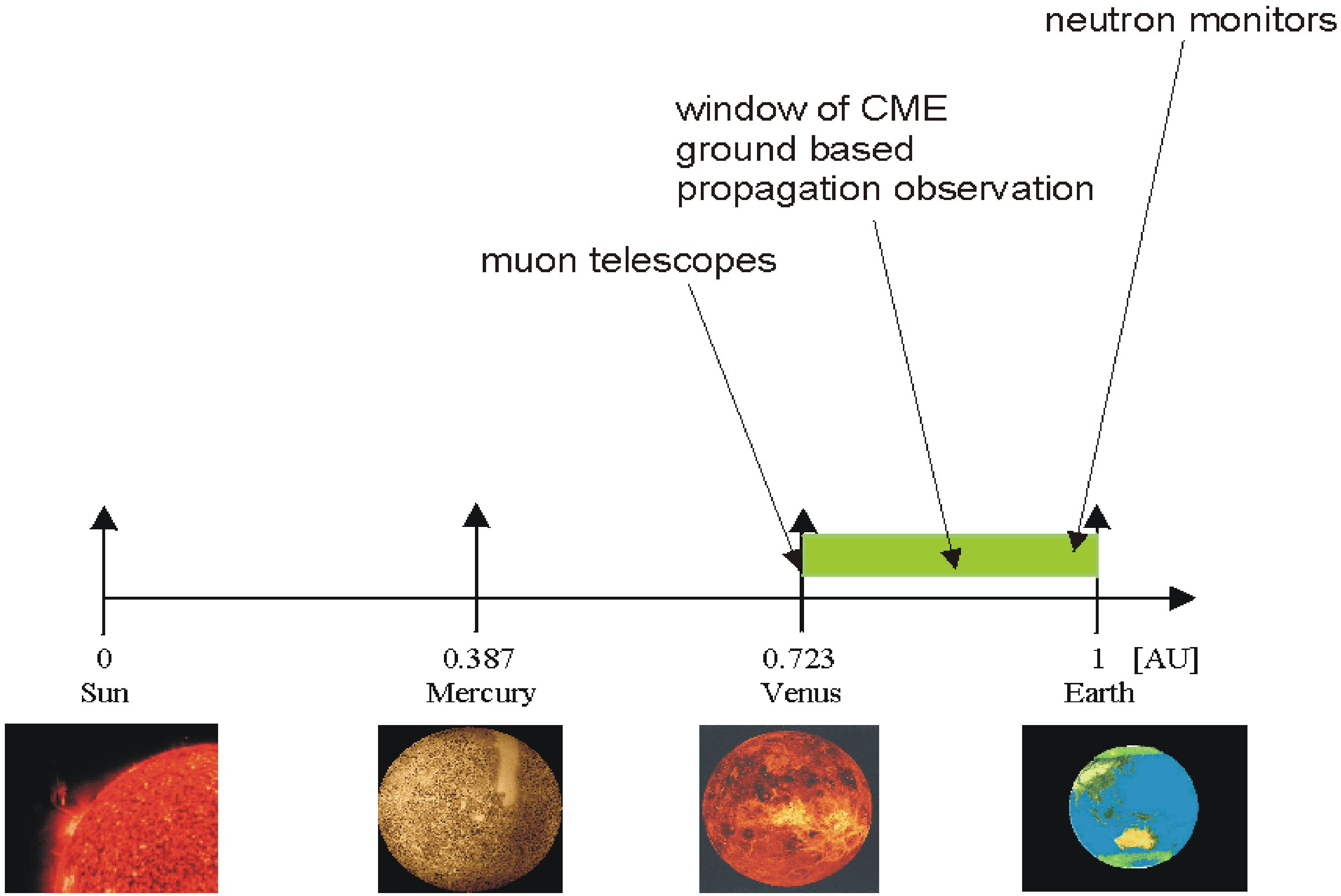
Physics behind the detection of CMEs by cosmic ray anisotropy



Pre-warning time:

up to 24 hours before CME arrival

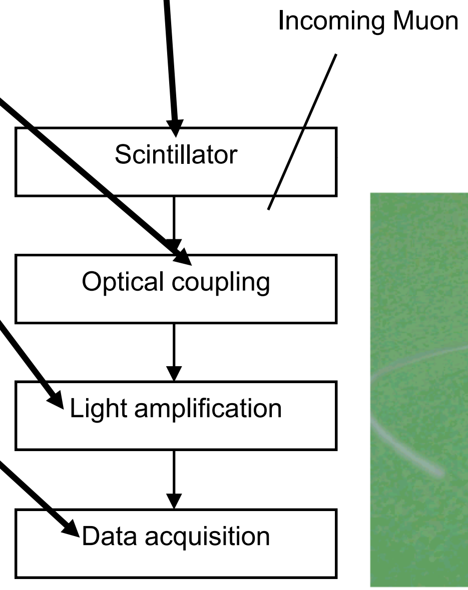
first CME detection

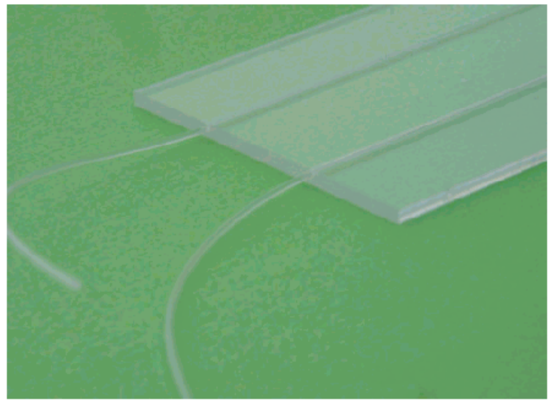


Construction and schedule for MuSTAnG

Detection / construction principle:

- two layers (8 sqm) of plastic scintillators (PS) with wavelength shifter, lead layer (4 sqm) between the PS layers for low energy CR absorption
- high voltage photomultiplier tubes for signal detection and direction determination due to coincidence measurements at different plastic scintillator plates
- electronics and data recording





Schedule:

- start of construction January 2005
- data available summer 2006

MuSTAnG

$4m^2$ prototype: 2m x 2m

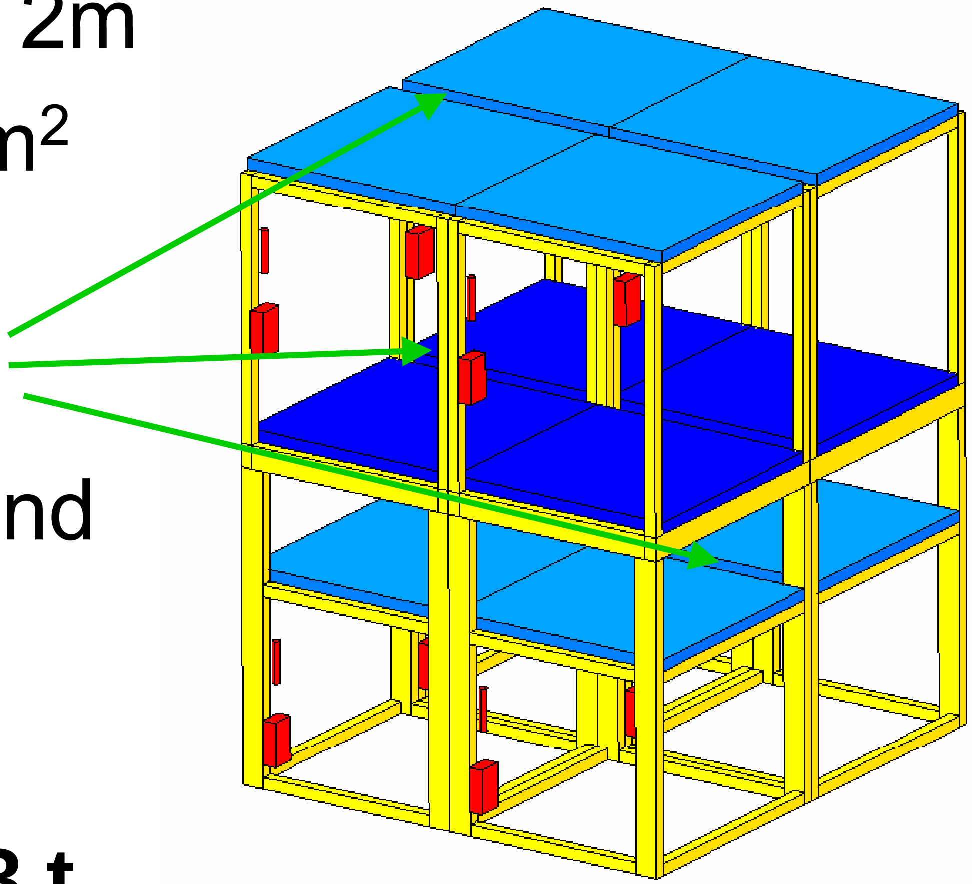
2 detector layers: $8m^2$

1 lead layer: $4m^2$

readout electronics:

wavelength shifter and

8 PMTs



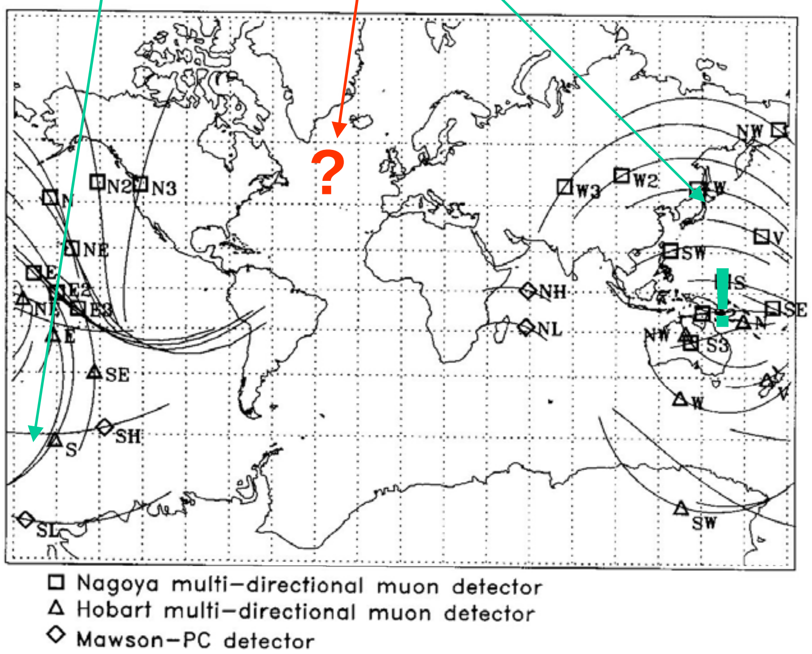
entire weight: 3 t

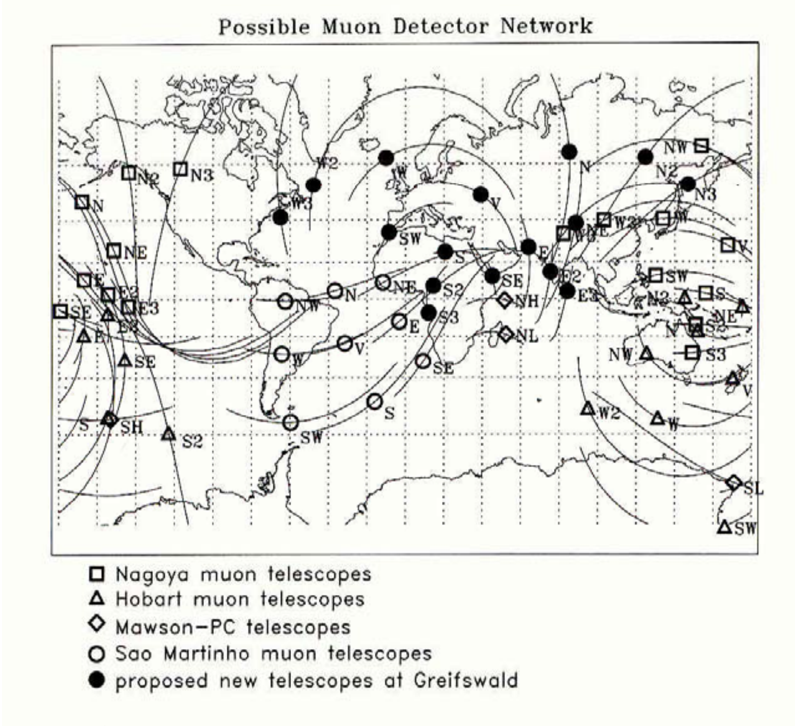
World-Wide Muon Telescope Network

- MuSTAnG becomes part of the international Australian - Brazil - European (including Armenia) - Japanese muon telescope network

Viewing angles of muon telescopes in Australia and Japan:

no data from European and Atlantic Ocean regions





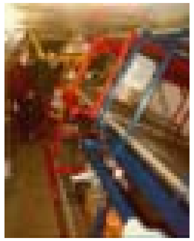
Viewing angle with MuSTAnG and SMST:

this means also a 24 hour data coverage

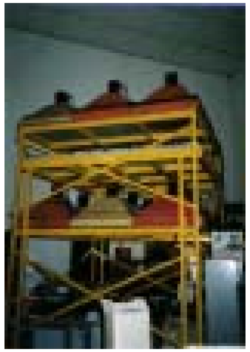
World-Wide Muon Telescope Network

- **<u>MuSTAnG</u> becomes part of the international Australian - Brazil - European (including Armenia)- Japanese muon telescope network**

Mawson PC, HST, NST, SMST and MuSTAnG



MPC

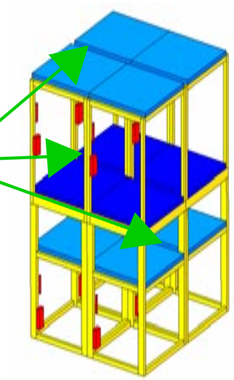


HST

NST

SMST

MuSTAnG



THANK YOU: Solar Storm Dance Show