

# **International Space Weather Status: Towards Space Situational Awareness**

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

# DLR Institute of Space Systems, Bremen

established 26 January 2007, starting from scratch

today: more than 120 staffs

## ➤ Concepts

- Development and evaluation of concepts for space missions with high visibility on national and international level.
- Processing and generation of fundamental information for political decisions regarding the national and international astronautics strategy.

## ➤ New Applications and Technologies

- Space based applications and technologies for scientific, commercial and security relevant needs.
- Realization in cooperation with research institutions and industry.

## ➤ Education

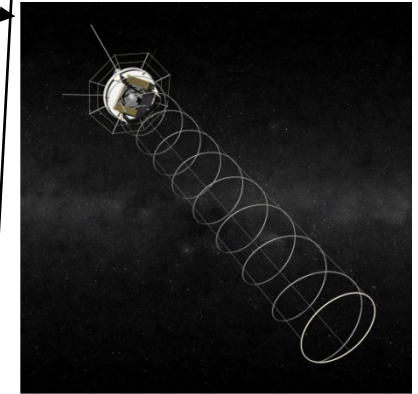
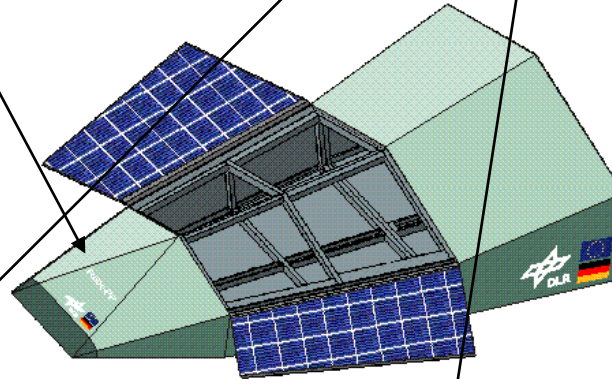
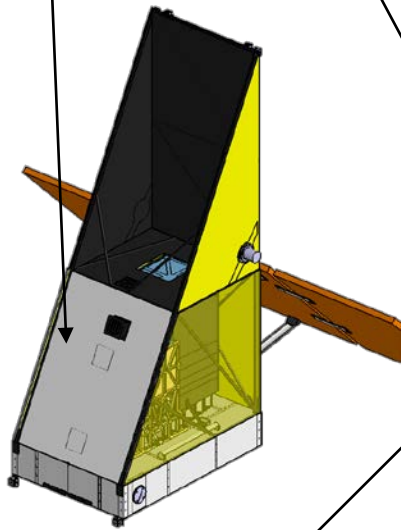
- Support of education at universities in space system engineering (student projects etc.).



Views on u-shaped building of DLR Institute of Space Systems in Bremen including new laboratory building and drop tower.

# Examples of Activities at DLR Bremen

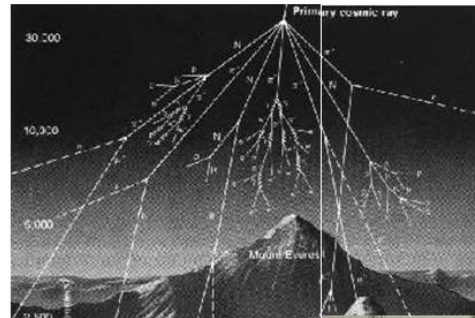
AsteroidFinder, REX-FF, AISat, BEXUS / REXUS, CEF, DLR School\_Lab, GMDN



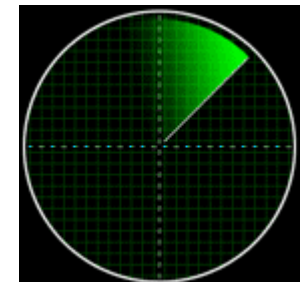
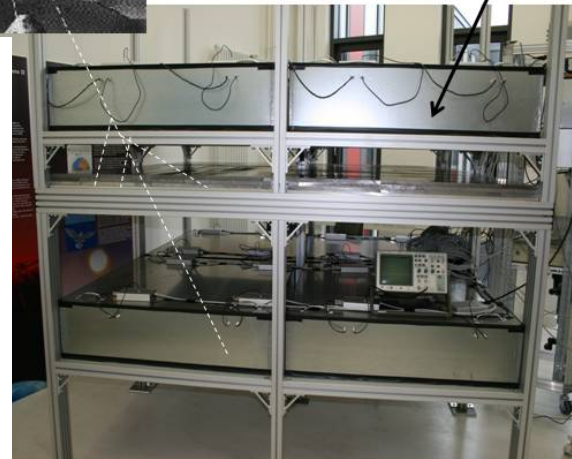
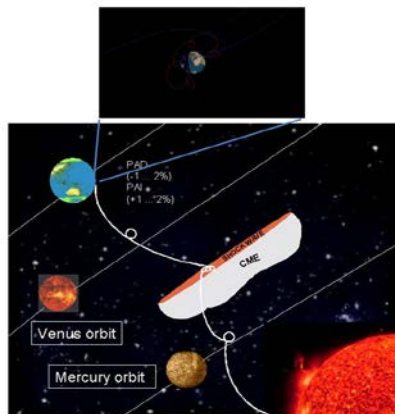
# The Sun, Cosmic Rays: Space Weather => Politics

Towards SSA in Europe: First European SW Telescope MuSTanG (2004-2006)

Funded by:



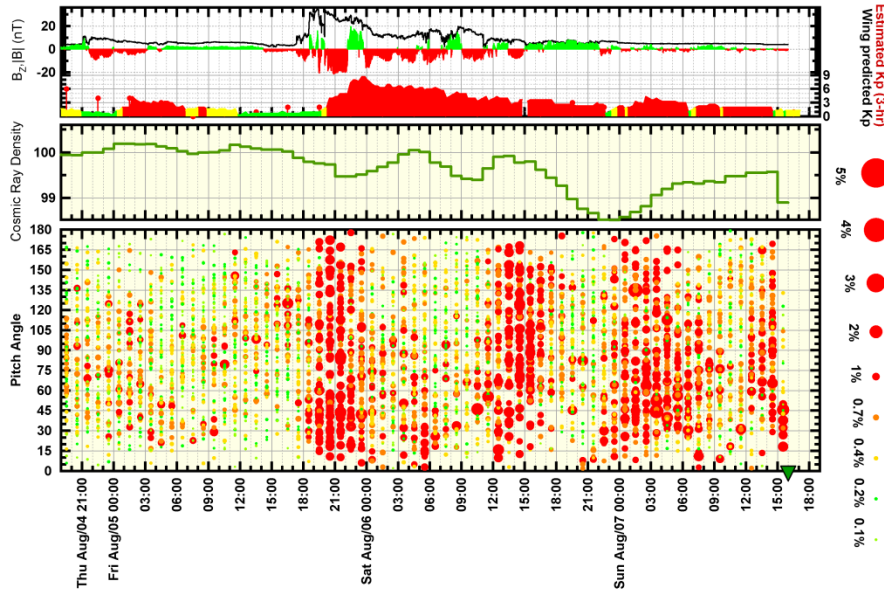
GMDN (Global Muon Detector Network) is like a cosmic ray radar.



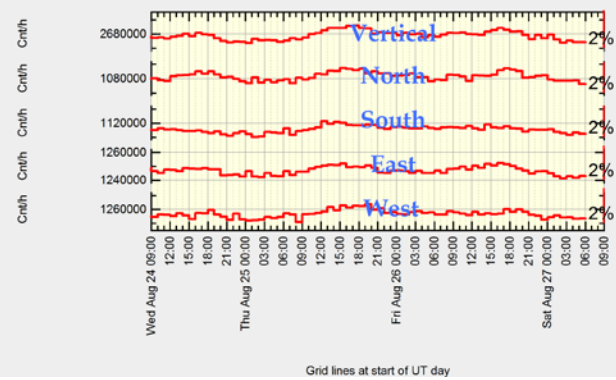
# GMDN CME Data August 2011

DLR Bremen data processing: NST, HST, KPC, SMST, GST

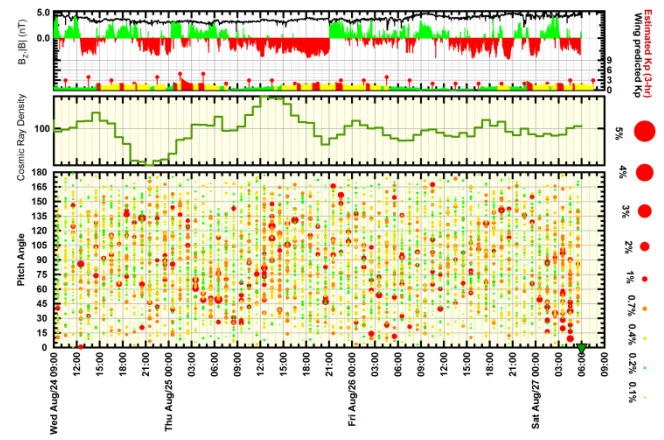
Real Time Space Weather Cloud Warning (Network: NST, HST, SMST, KPC, GST)  
Last 3 days 04 August 2011 - 07 August 2011



Cosmic Ray Muon Intensities : SaoMartinho  
Last 3 days 24 August 2011 - 27 August 2011



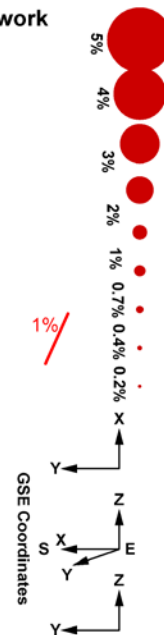
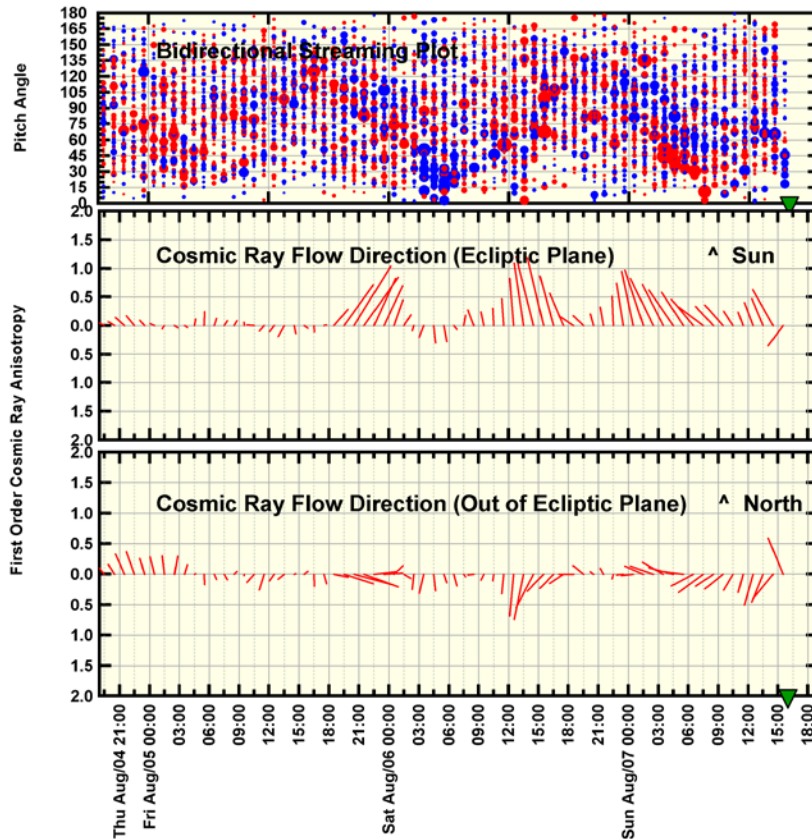
Real Time Space Weather Cloud Warning (Network: NST, HST, SMST, KPC, GST)  
Last 3 days 24 August 2011 - 27 August 2011



# GMDN CME Data August 2011

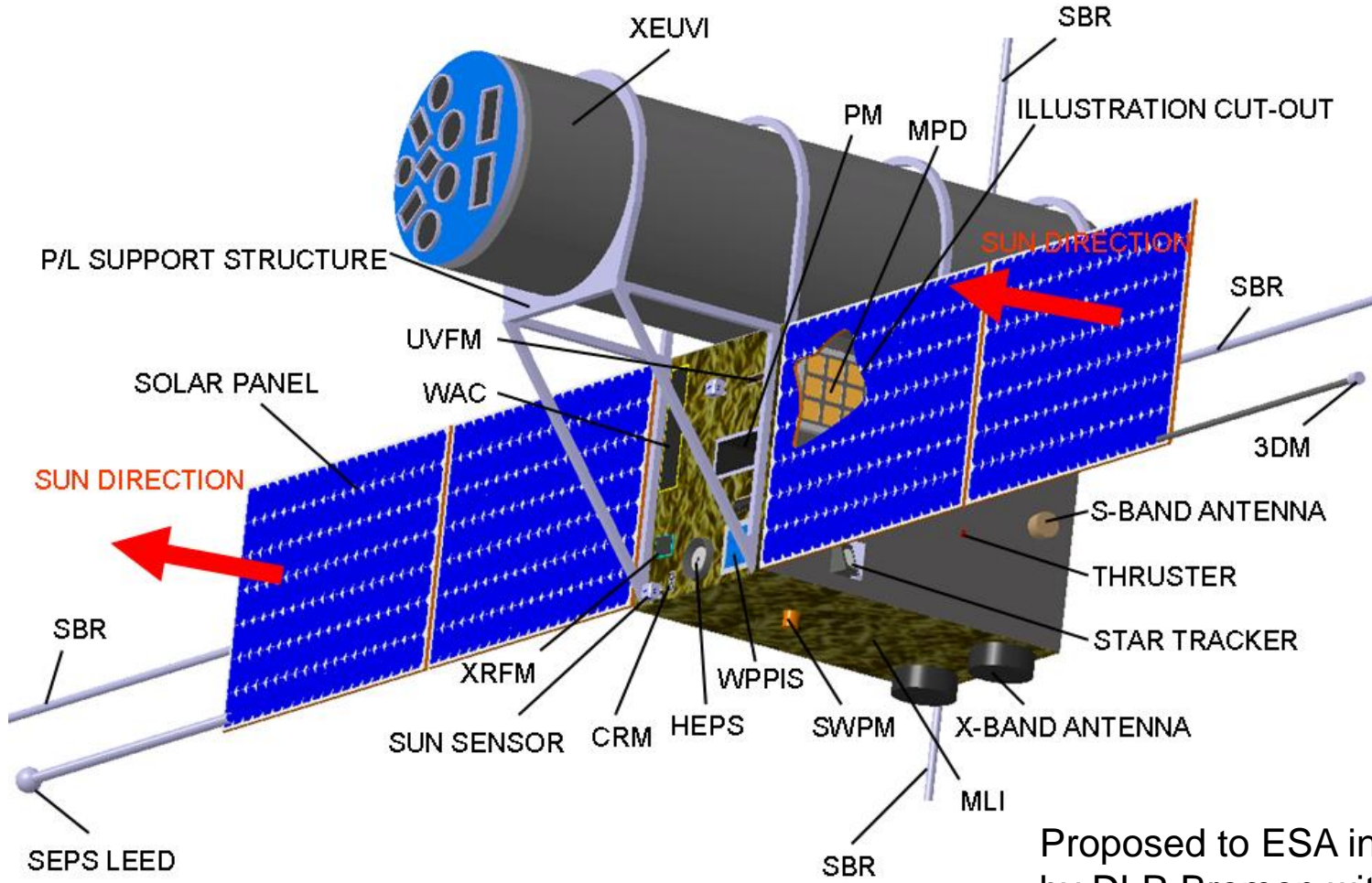
DLR Bremen data processing: NST, HST, KPC, SMST, GST

Bidirectional Streaming Plot and Cosmic Ray Flow Direction from Muon Network  
 Last 3 days 04 August 2011 - 07 August 2011



GMDN will be a use case in the new ESA ViSpaNeT (Virtual Space weather Applications Network of Tools)!

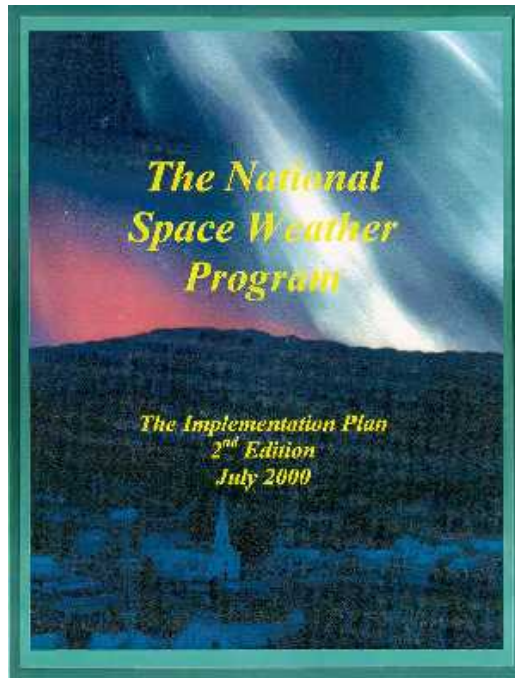
# The Sun, Cosmic Rays: Space Weather / SSA Satellite



Proposed to ESA in 2010 by DLR Bremen within Kayser-Threde consortium.

# The Sun, Cosmic Rays: Space Weather => Politics

How all started?



2003 – 2007 EU COST 724 Aktion:  
Space Weather: Data, Models, Service



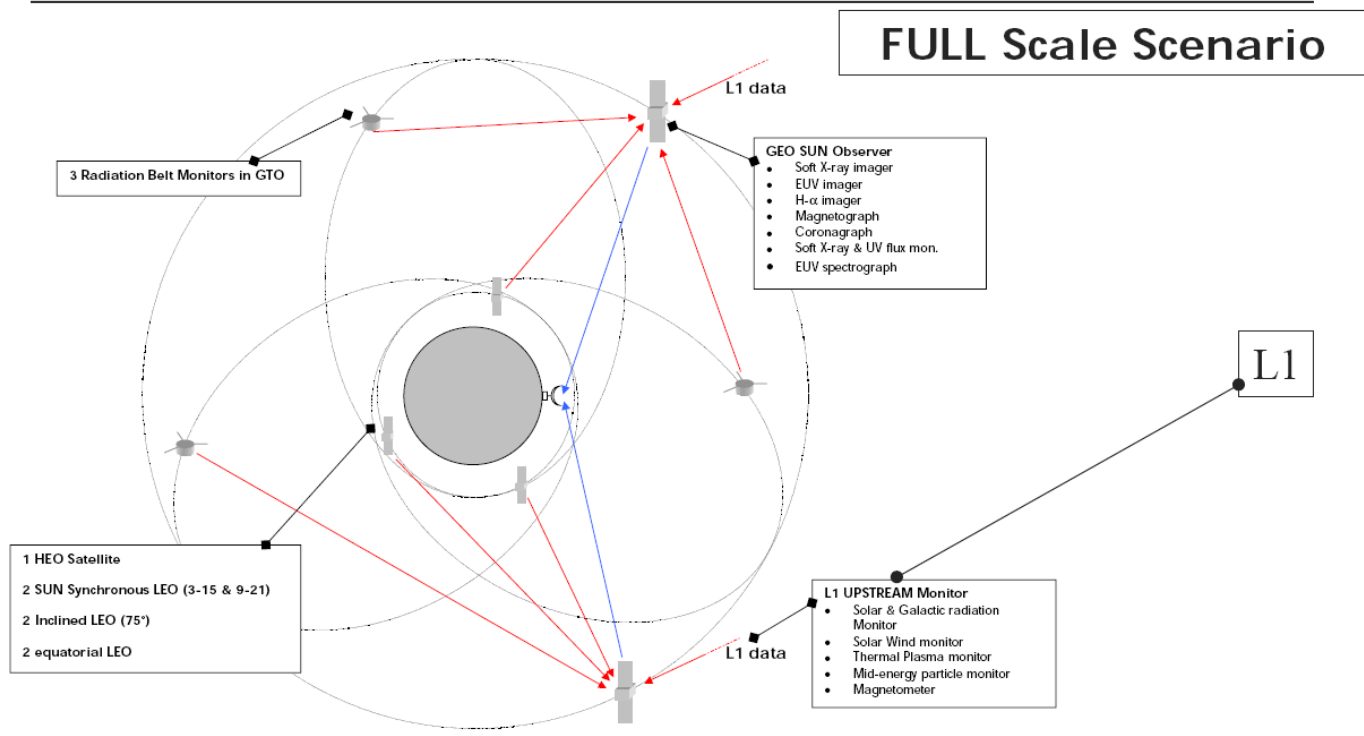
EU FP5 and FP6:  
SWE and SWEETS



EU 2003: White Paper  
ESA 2008: Space Situational Awareness (SSA)



# The Sun, Cosmic Rays: Space Weather => Politics



**ESA Study for SPACE WEATHER PROGRAMME**

Alcatel Space Industries

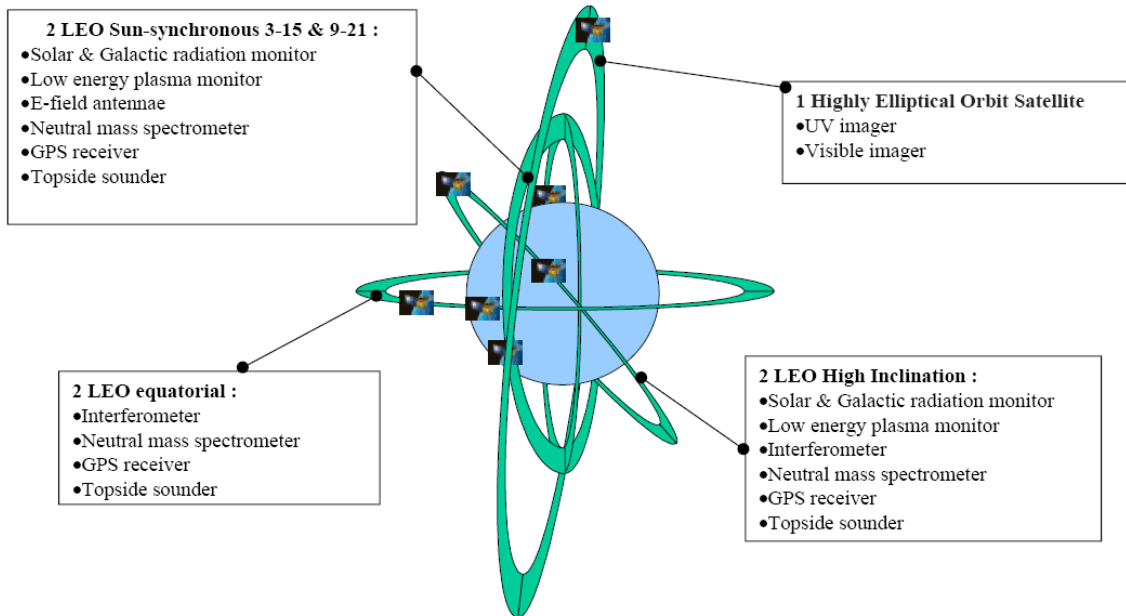
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# The Sun, Cosmic Rays: Space Weather => Politics



## FULL Scale Scenario : Ionosphere/Thermosphere Monitors



ESA Study for SPACE WEATHER PROGRAMME

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# The Sun, Cosmic Rays: Space Weather => Politics

Towards SSA in Europe: First European SW Telescope MuSTanG (2004-2006)



## Operational Scenarios : Ground Segment

	Full Scale	Medium Scale	Low Scale
Solar observations	Broad frequency radio spectrographe (above 40 MHz) Radio imaging.	Broad frequency radio spectrographe (above 40 MHz) Radio imaging.	Broad frequency radio spectrographe (above 40 MHz) Radio imaging.  Magnetograph network. H <sub>z</sub> network.
Upstream (including interplanetary)	Broad frequency radio spectrograph. Radio imaging.  Neutron and Muon detectors.	Broad frequency radio spectrograph. Radio imaging.  Neutron and Muon detectors.	Broad frequency radio spectrograph. Radio imaging.  Neutron and Muon detectors.
Magnetospheric monitoring	Covered under I/T monitoring	Covered under I/T monitoring	Covered under I/T monitoring
Ionosphere/thermosphere Monitoring	Magnetometer networks. Positioning networks SuperDARN network. F10.7cm	Magnetometer networks. Positioning networks SuperDARN network F10.7cm Ionosonde Network	Magnetometer networks. Positioning networks SuperDARN network F10.7cm Ionosonde Network



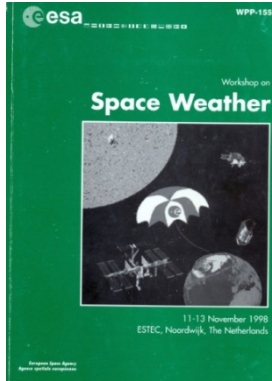
ESA Study for SPACE WEATHER PROGRAMME

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# The Sun, Cosmic Rays: Space Weather => Politics



- European Space Policy (ESP) im White Paper (2003)
- Implementation of European Space Policy (ESP) via **ESA Space Situational Awareness (SSA) programme (2008 – 2018)**
- ESA Ministerial Conference **25 - 26 November 2008**:

## SSA domains: Space Weather, Space Debris, NEOs

### Next ESA Ministerial Conference in 2012 (SSA comparable with GALILEO?)!

- New Space Strategy of the German Government from December 2010 (Sun, Space Weather, Space Debris, NEOs very often mentioned)

# The Sun, Cosmic Rays: Space Weather => **Politics**



COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 11 November 2003  
COM(2003) 673

## WHITE PAPER

**Space: a new European frontier for an expanding Union**

**An action plan for implementing the European Space policy**

Only on page 17 of 59, but starting point for SSA in Europe.

A specific effort might also be needed to ensure that Europe has the capacity to supply to the different users critical information on solar flares, near Earth objects, space debris, (“space weather” prediction).

# The Sun, Cosmic Rays: Space Weather => Politics

IP/11/398 Brussels, 4 April 2011

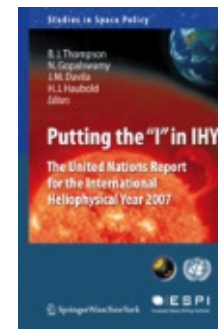
A new space policy for Europe: Independence, competitiveness and citizen's quality of life...

*Improving the safety and daily lives of European citizens thanks to radio navigation, guiding tractors by satellite for high-yield crops, optimizing response to humanitarian crisis... This is not science fiction but just a few examples of innovations related to space technologies developed today...*

**= > Protect space infrastructures against space debris, solar radiation and asteroids by setting-up a European Space Situation Awareness (SSA) system...**

In addition for example:

- 1) European Space Policy Institute in Vienna: publication like International Heliophysical Year achievements towards ISWI
- 2) BBK (Federal Office of Civil Protection and Disaster Assistance) in Bonn: publication like – space weather as a new challenge for civil protection?
- 3) German Space Situational Awareness Centre in Udem



# The Sun, Cosmic Rays: Space Weather => Politics

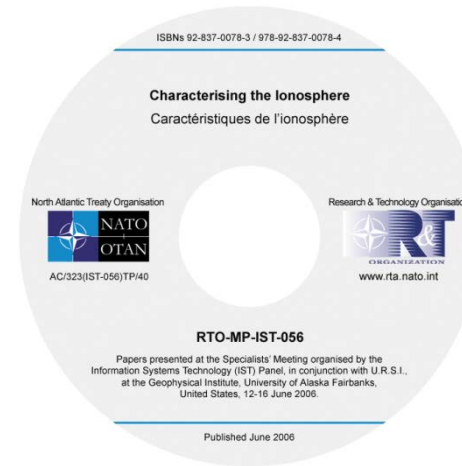
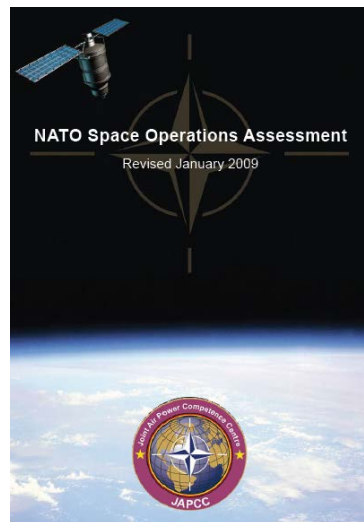
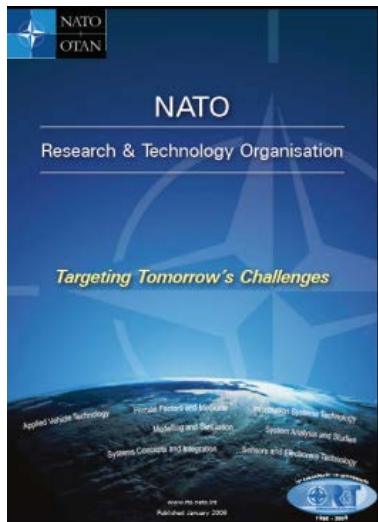
SSA and security aspects:

- publications from JAPCC (Joint Air Power Competence Centre) in Kalka
- NATO Research & Technology Organisation (RTO) activities related to the ionosphere (2006) and space environment support to NATO SSA (during solar maximum up to 2013 (see under <http://www.rta.nato.int/activities.aspx?RestrictPanel=SCI> ), SCI – System Concepts and Integration meeting in 2009 at



AKADÉMIA OZBROJENÝCH SÍL  
GENERÁLA MILANA RASTISLAVA ŠTEFÁNIKA  
ARMED FORCES ACADEMY  
OF GENERAL MILAN RASTISLAV ŠTEFÁNIK

(French Army General  
& Slovak Astronomer)



# SSA – Space Situational Awareness in Europe

*Domains:*

Space Weather

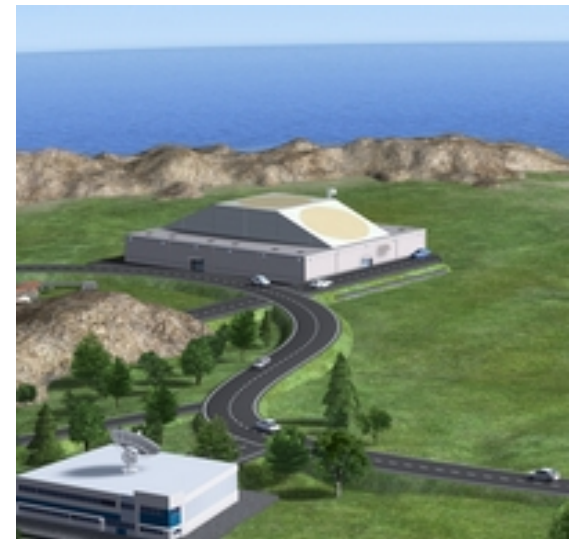
Space Debris

Near Earth Objects  
(NEOs, NEAs, IEOs)

Radar



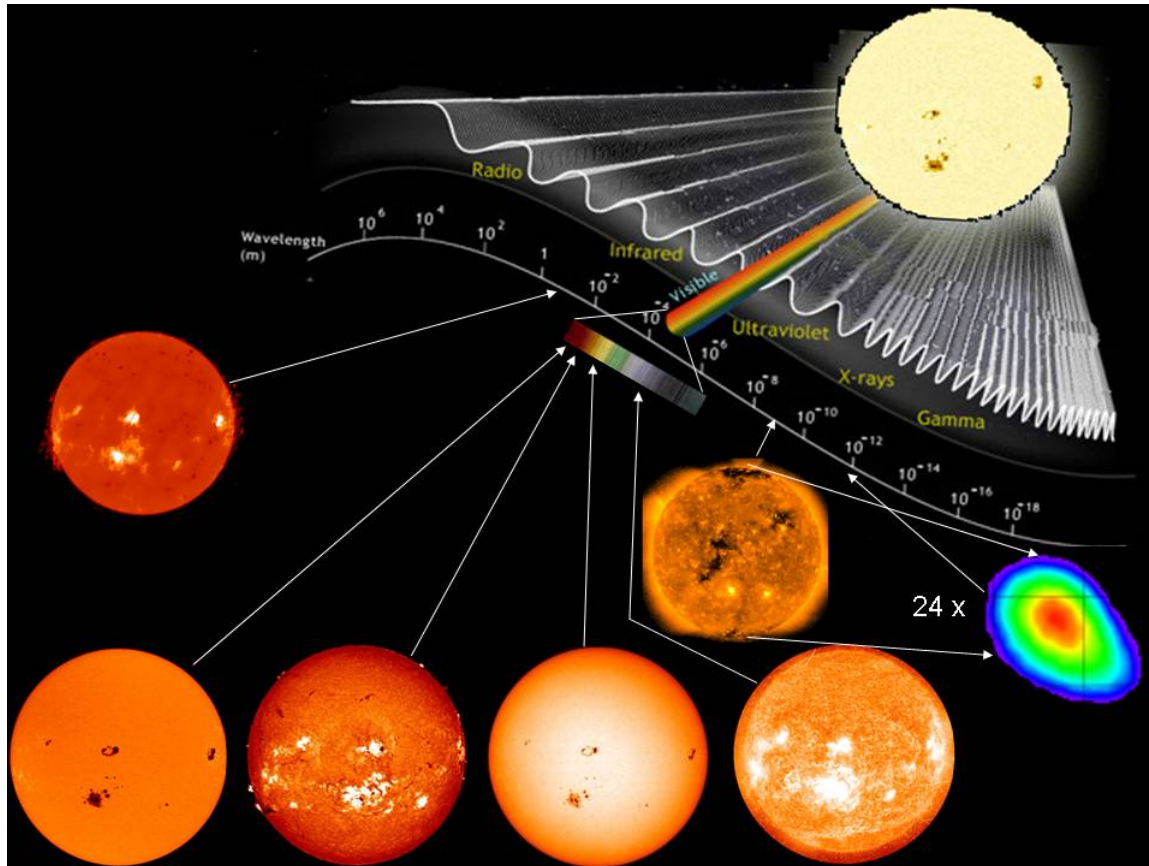
EISCAT



ESA SSA Radar



# The Sun, Cosmic Rays: Space Weather => Politics



October – November 2003

ESA, NASA, JAXA ...

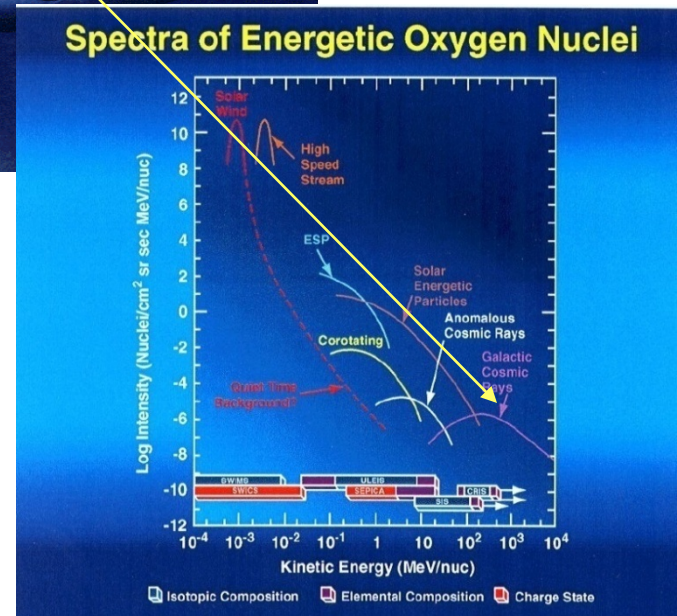
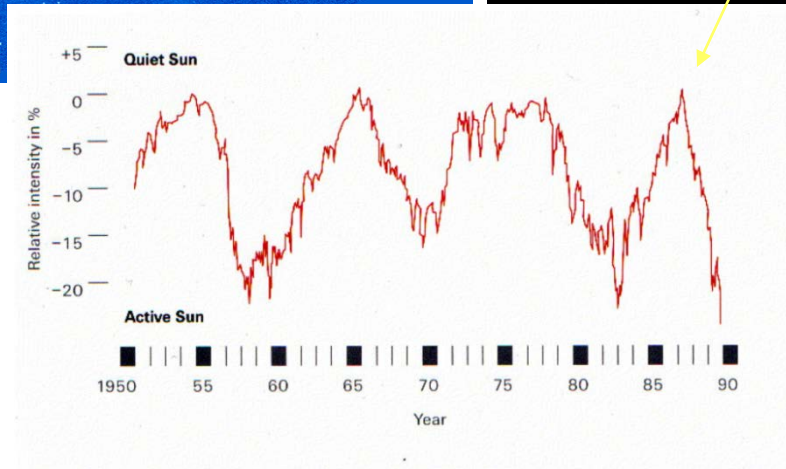
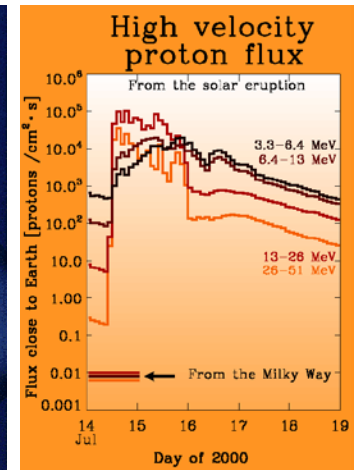
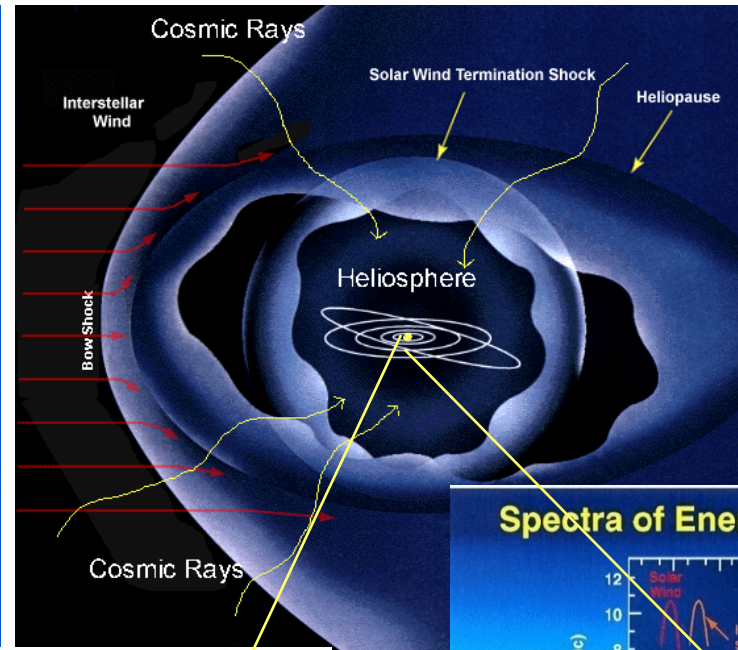
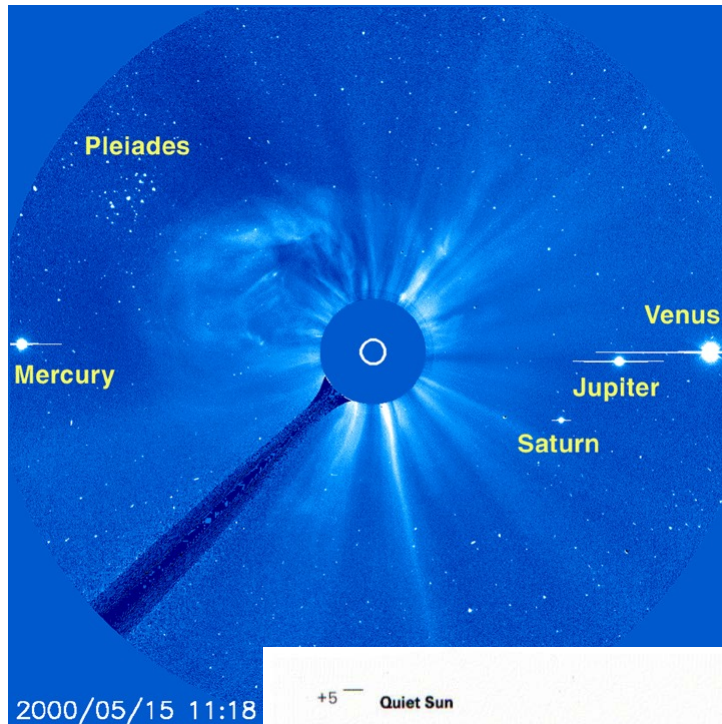
⇒ multi wavelength (space and ground based) observations of the Sun are necessary

**plus**

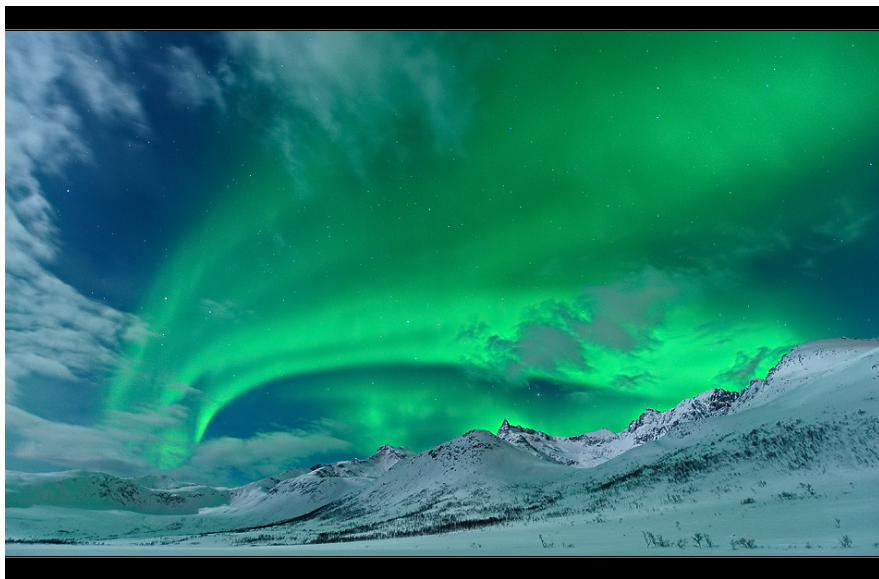
solar particle and cosmic ray observations

High resolution solar radio to X-ray images during Halloween storm in 2003. **Still open: high resolution gamma ray imaging of the Sun.**

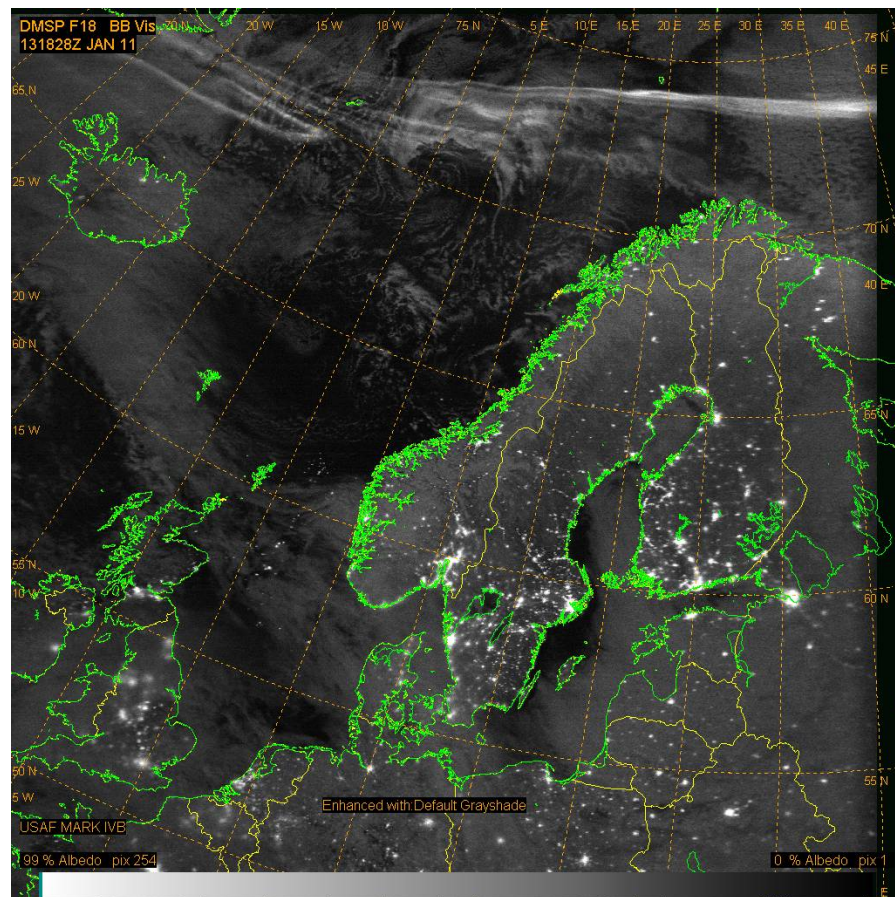
# The Sun, Cosmic Rays: Space Weather => Politics



## Most Visible Effect: Aurora (Polar Lights, Northern Lights...)

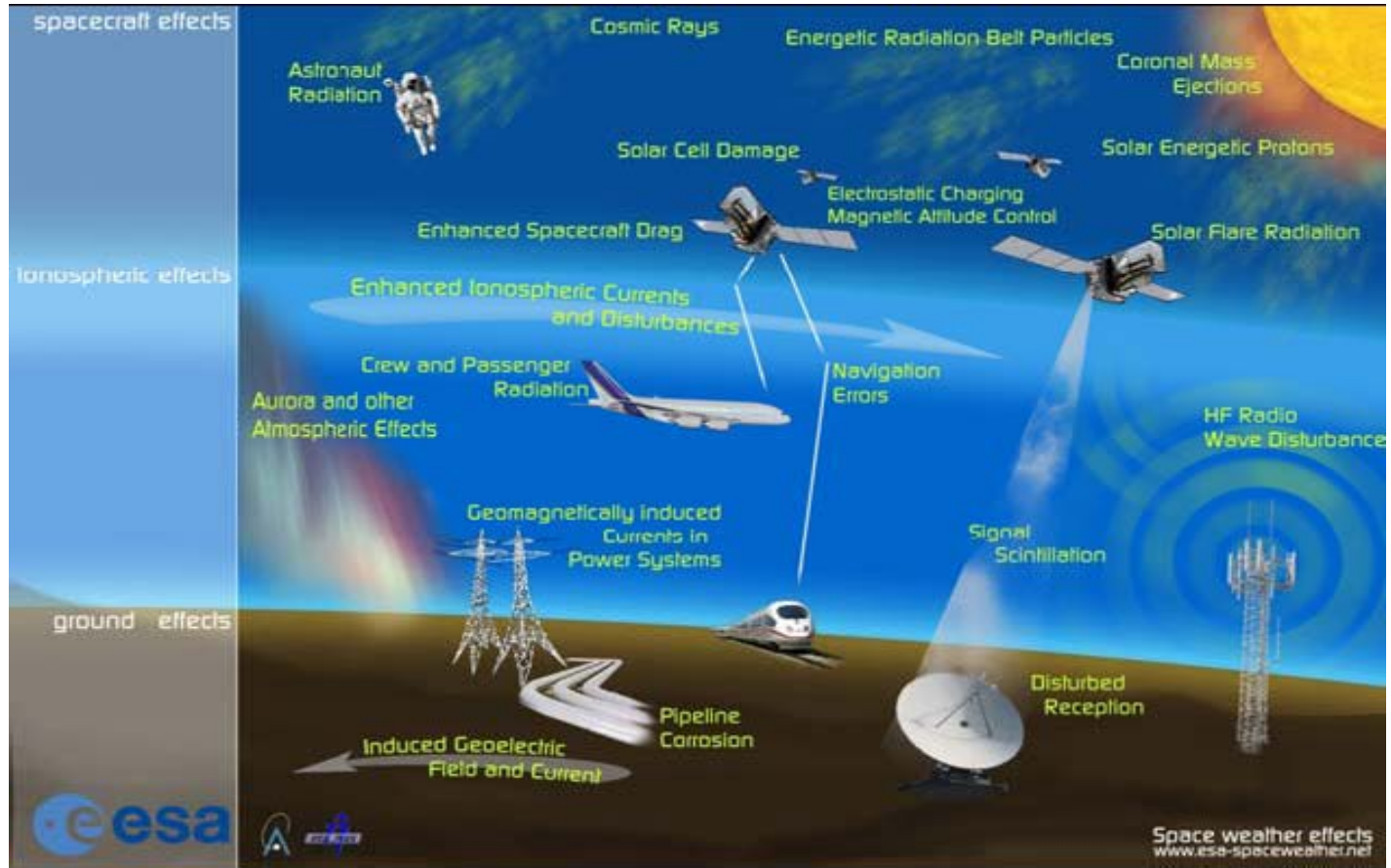


Northern light in Scandinavia (Thilo Bubek).



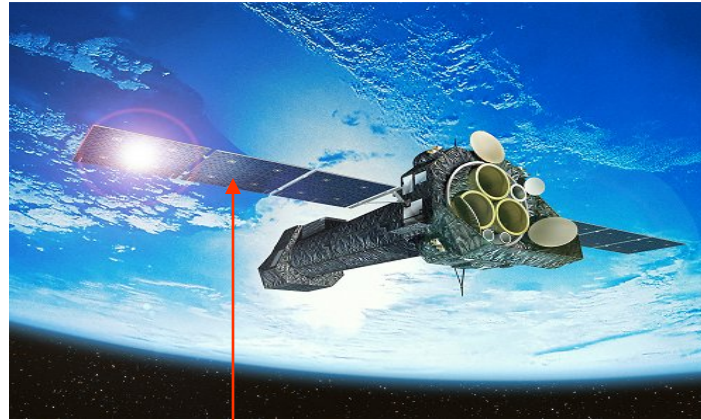
Satellite image of comparable brightness of city light and northern light in Europe.

# The Sun, Cosmic Rays: Space Weather => Politics

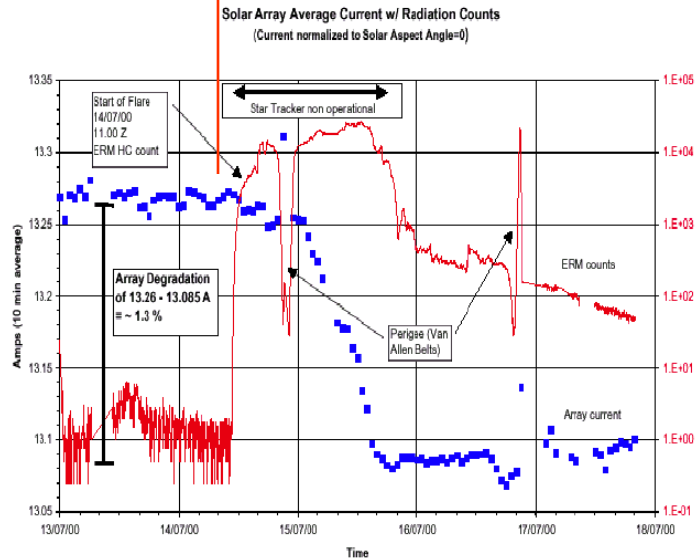


# The Sun, Cosmic Rays: Space Weather => Politics

○ Space industry: jobs...

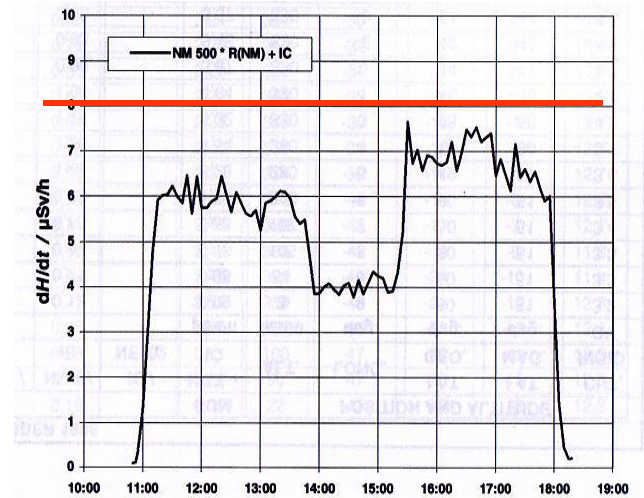
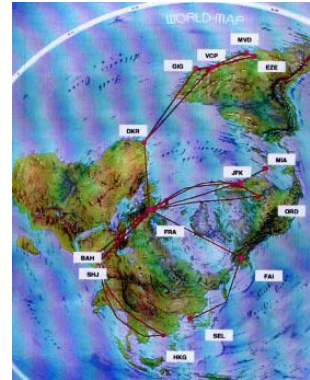


- 31 problems and **total losses (12 total losses)**  
 Meteosat, ERS-1, XMM ...  
 Equator-S, Anik 1&2,  
 Telstar 401, ASCA ...
- financial losses in 4 years more than **500 Millionen US\$**

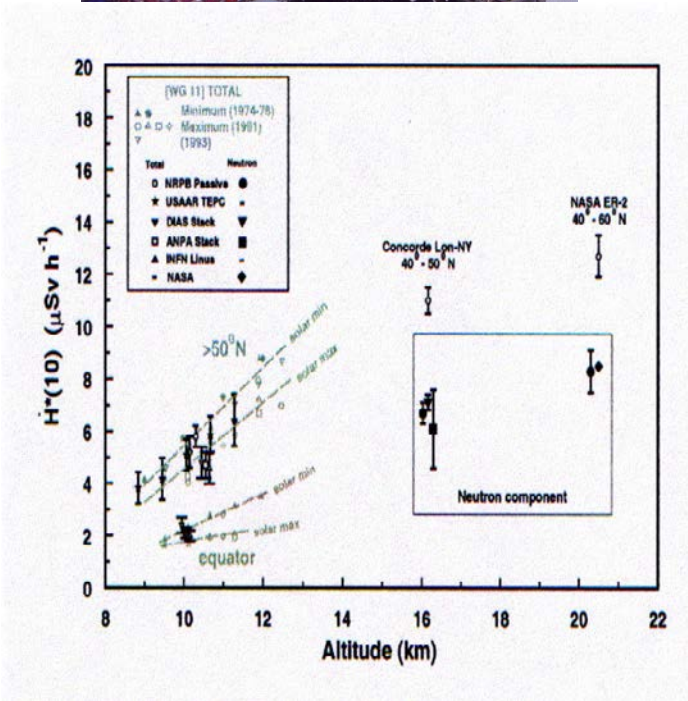


# The Sun, Cosmic Rays: Space Weather => Politics

○ Aircraft industry: jobs ...



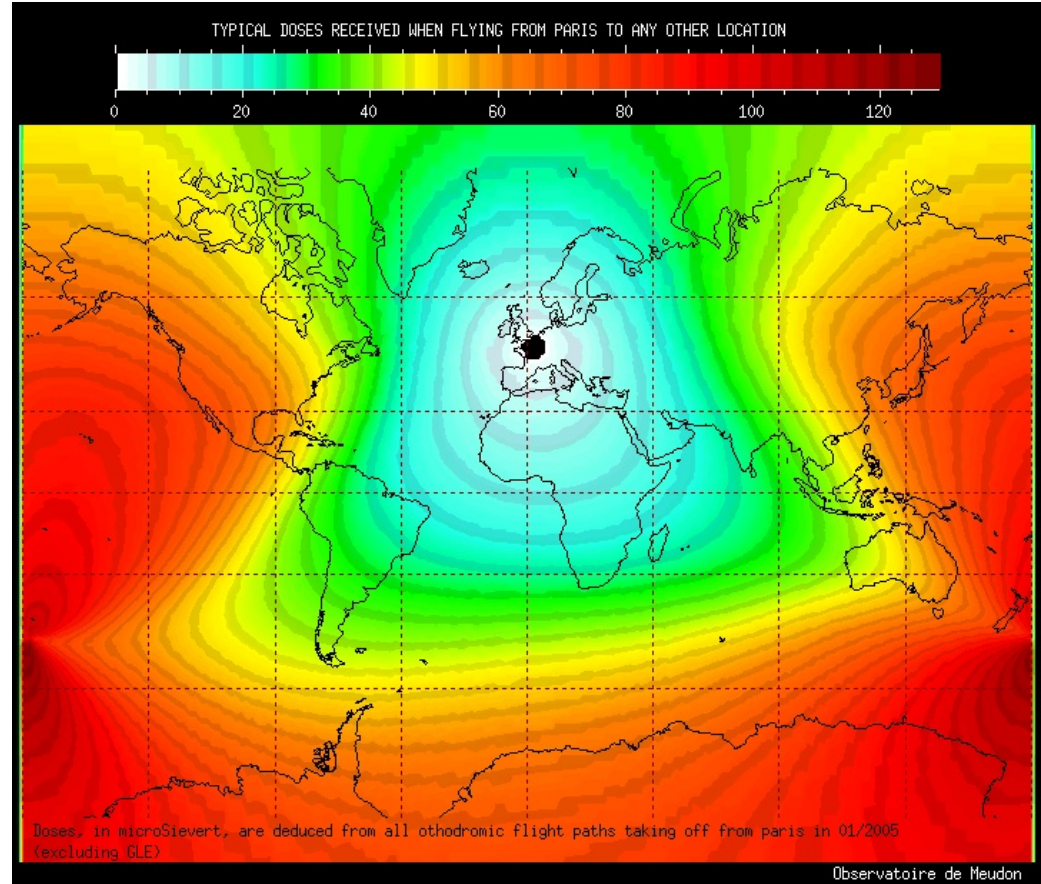
Flight Chicago – Frankfurt 4 Oct 98 (PTB)



- EC recommendation
- new radiation protection law (BfS, BMU) since 1 June 2001:
- for airlines estimation of radiation exposure (effective dose 1 mSv, upper limit 20 mSv per calendar year)

# Which Risks Are Known?

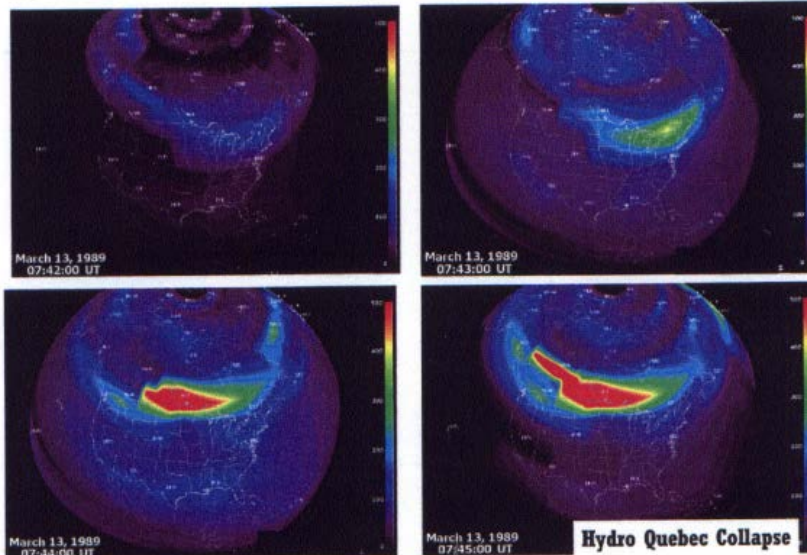
## Personal Flight Dose in the Web



# Which Risks Are Known?

Power supply 13 March 1989, US just before blackout

## Four Minutes of a Super Storm - March 13, 1989



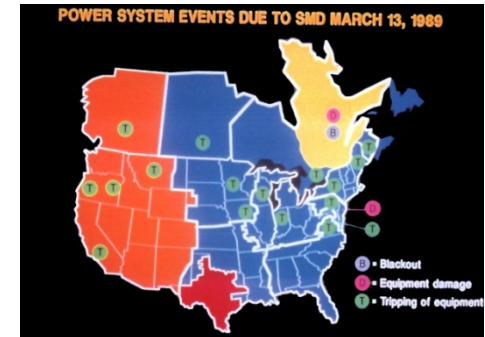
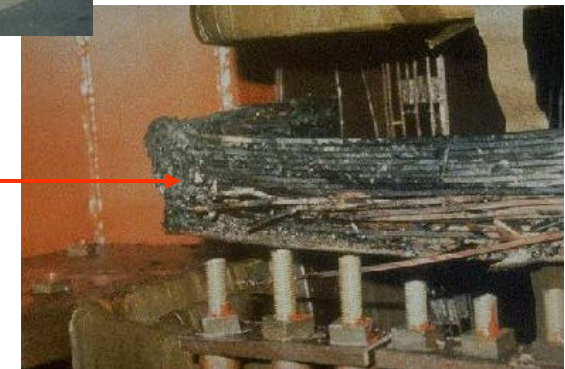
- Hydro Quebec: collapse time 90 sec ! (400nT/min) (9 hours power black out for Millions of humans in winter)
- Minnesota 865 nT/min was measured !

**10<sup>10</sup> US\$**

- Rep.: 10 Mill. US \$ (up to 1 year, in this case only 6 weeks)
- Sweden: 6 130- kV-lines
- Cu-coils up to 3000 A
- April 94: 5 transformers in Chicago
- Finland: power lines with 143 A measured
- Sweden: 2003 – Malmö 50000 inhabitants



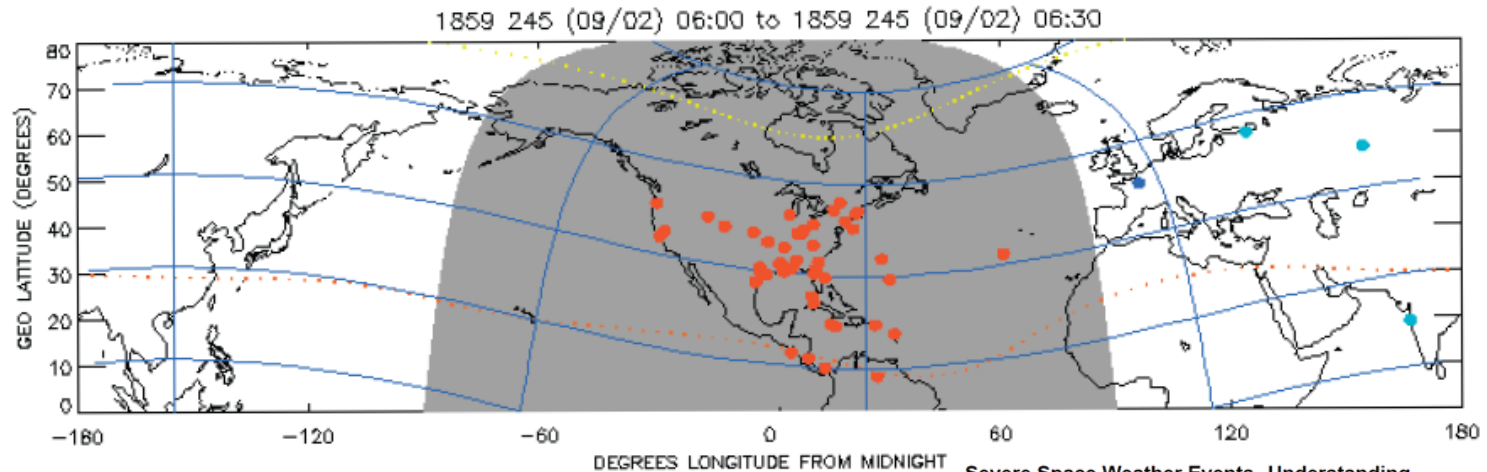
**New Jersey**



- normally 3000 A
- several amps more, insufficient working regime of the transformer
- measured in trans. 200 A



# Power Failures: Super Storm 2 September 1859 and Today?



Severe Space Weather Events--Understanding Societal and Economic Impacts Workshop Report

Committee on the Societal and Economic Impacts of Severe Space Weather Events:A Workshop, National Research Council

ISBN: 0-309-12770-X, 131 pages, 8 1/2 x 11, (2008)

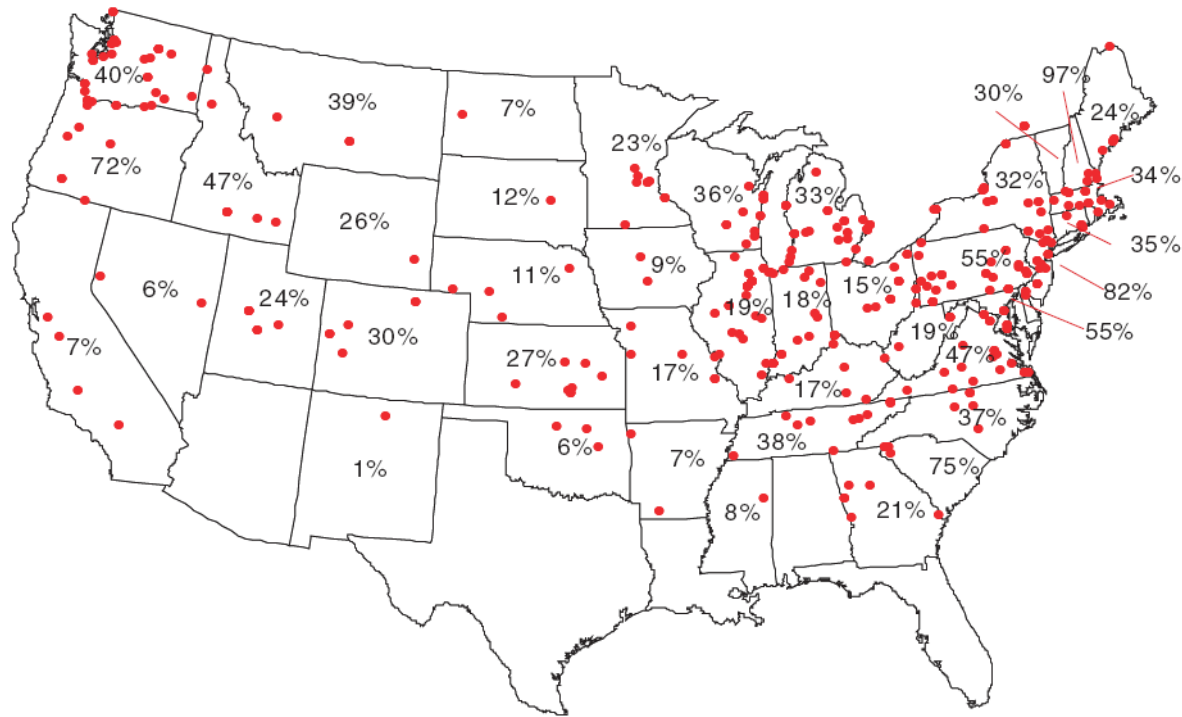
This free PDF was downloaded from:

<http://www.nap.edu/catalog/12507.html>

- Katrina: 81 – 125 Bill. US \$
- Space weather super storm: 1 – 2 Trillionen US \$ in the first year
- 365 transformers are in danger (4800nT/min)
- regions in % with several years of power failure (4 – 10 years)
- effected population in the USA 130 millions



# Power Failures: Results for Super Storm Today



Power failures: not only disrupted electrical light is a huge problem, but also not properly working cooling systems in hot or desert like areas are dangerous for humans.



# Which Risks Are Known?

## ○ Telecommunication

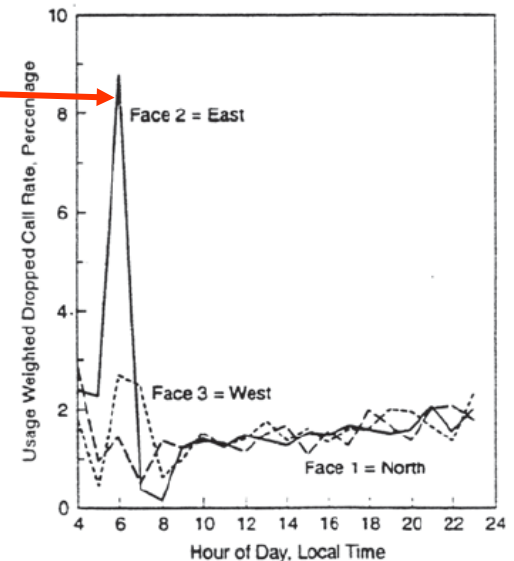
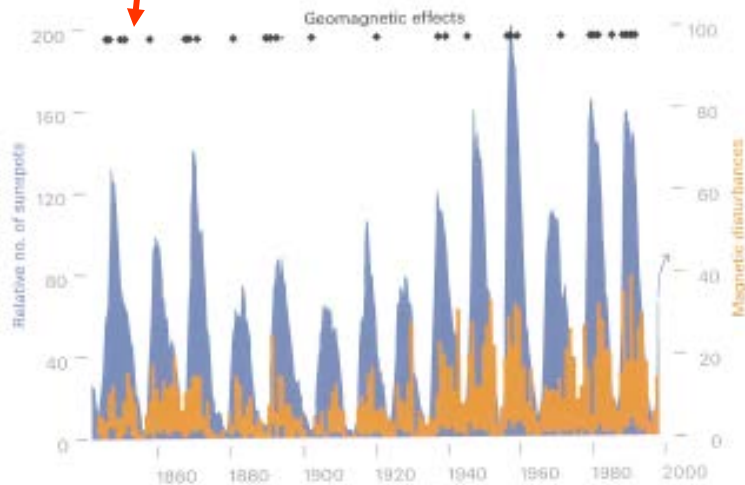


*Space weather effects in the pioneering days of telegraphy*

- 17 November 1848: telegraphy lines between Pisa and Florence were disrupted
- September 1851: telegraphy lines in New England
- GICs made it possible that telegraphy lines worked without batteries:

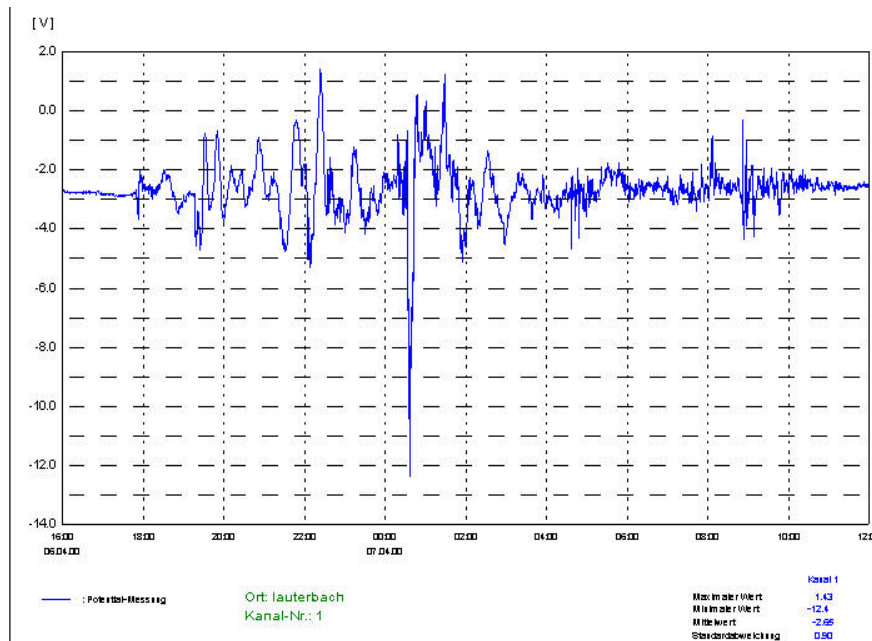
- Portland: “Please cut off your battery, let us see if we can work with the auroral current alone”
- Boston: “I have already done so! How do you receive my writing?”
- Portland: “Very well indeed - much better that with batteries”

Past and current telecommunication systems (non-civil and civil (like mobile phones)) were and are effected by space weather.



# Which Risks Are Known?

- Gas- and oil industry
  - Ruhrgas pipelines
  - North Sea drilling
  - Alaska, Sweden, Finland



# Which Risks Are Known?

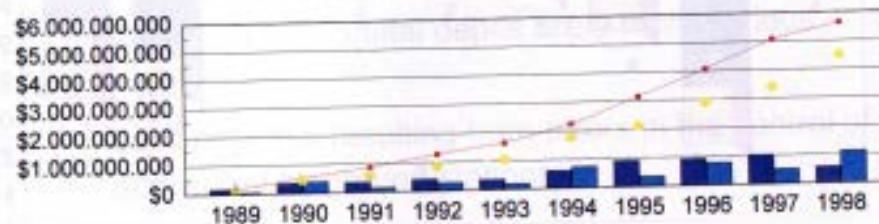
- Space weather and insurances

CECAR &  
JUTHEAU

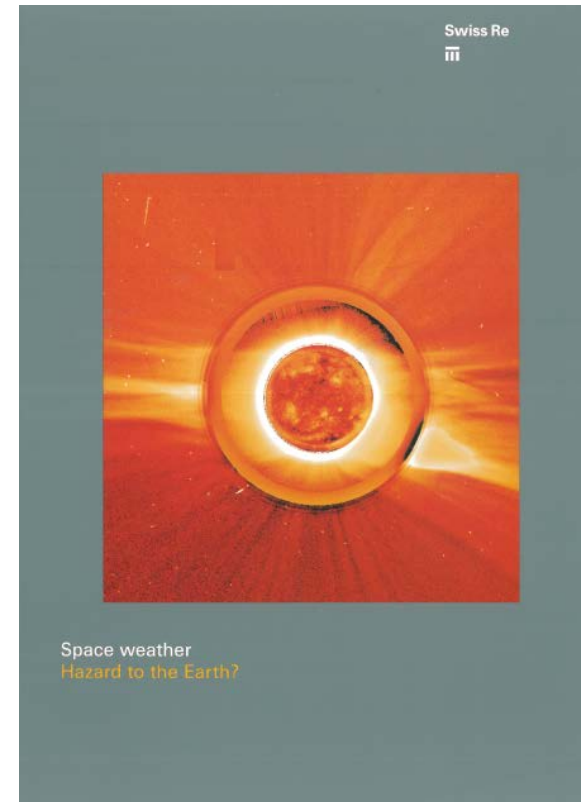
## STATUS OF SPACE INSURANCE MARKET

### LAUNCH PLUS LIFE INSURANCE POLICIES

Earned Premium and Recorded Policies  
From 01/01/89 to 01/10/98



Earned Premium  
Recorded Losses  
Cumulated Earned Premium  
Cumulated Recorded Losses



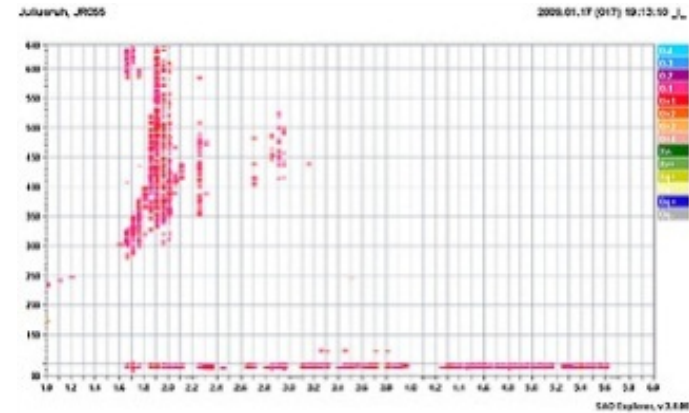
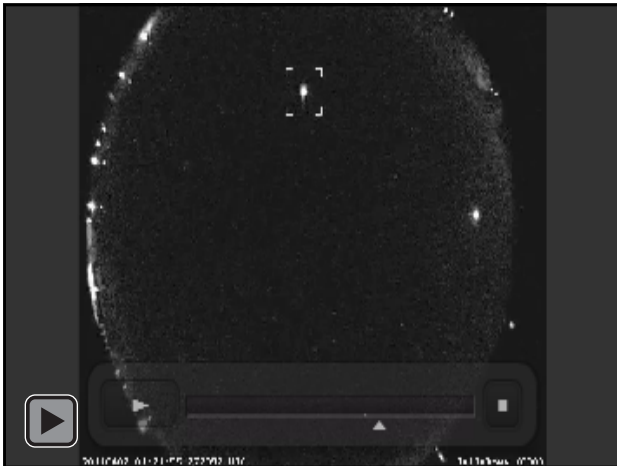
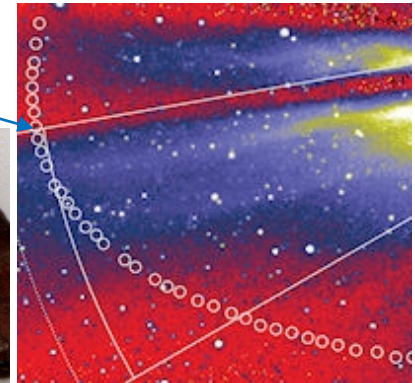
<http://www.swissre.com/>



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

# Observation of Meteors

- NASA / MSFC and DLR: full sky camera system
- Geminide Meteors (December) part of collision **on** asteroid Pallas
- 3200 Phaethon (see STEREO observation) is also due to collision on Pallas



Click on the Meteor video.

Meteor in ionogram data of IAP.

# Asteroids: DLR Bremen AsteroidFinder (AF)

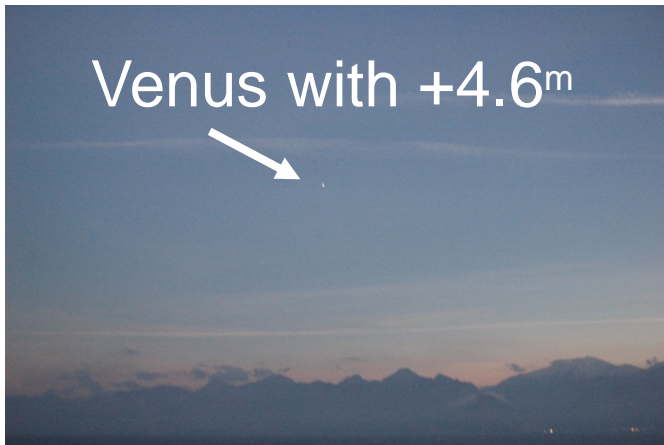


29 Mar 2006 Antalya: total eclipse

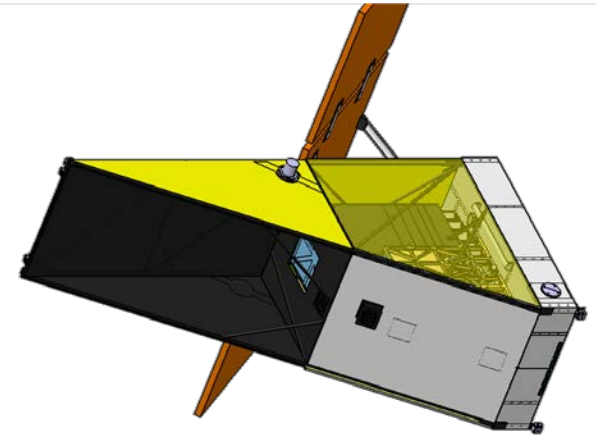
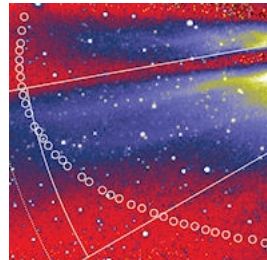
Not asteroids between Mars and Jupiter but with AF:

Inner Earth Asteroids (IEOs) down to visuell magnitude of  $-18.0^m$  => asteroids with magnitude  $1.2 \times 10^{-9}$  lower than maximal Venus magnitude in a solar distance of about  $\pm 60^\circ$

3 observations: new IEO

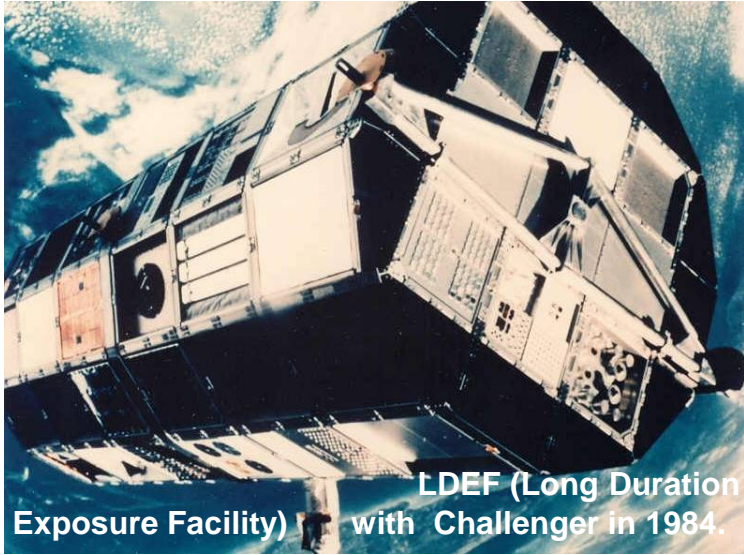


STEREO: IEO  
3200Phaethon  
with  $-10 \dots 12.5^m$



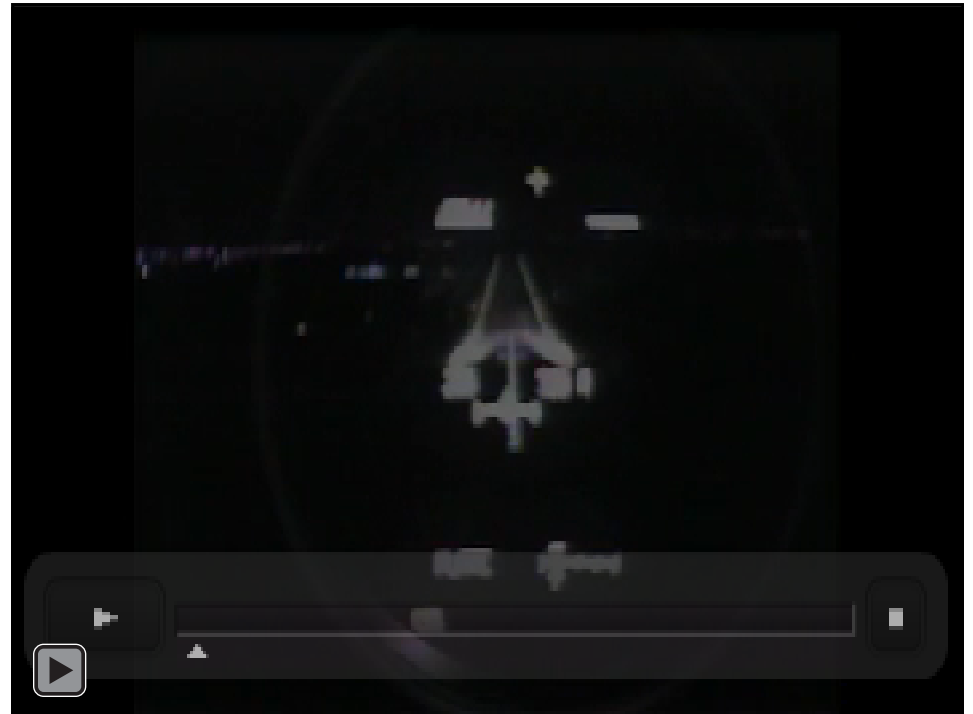
Space Shuttle Era (12 April 1981 – 21 July 2011), Space Debris and LDEF (1984 – 1990)

Columbia → 12 April 61 ↓ Gagarin's first (Soviet) manned space flight,  
21 July 69 ↓ Armstrong/Aldrin (US citizen) first steps on the Moon



(Challenger exploded on 28 January 1986)

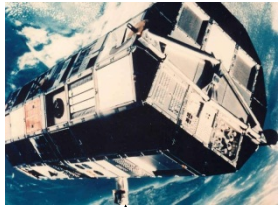
NASA video: landing (21 July 2011) of space shuttle Atlantis on it's final flight.





# 69 months in space: LDEF and space debris

Long Duration Exposure Facility (LDEF): UHCRE for CR nuclei detection with  $Z = 1 \dots 92$



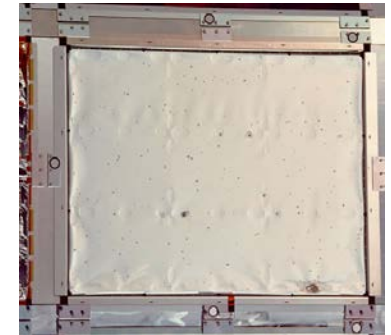
1984

1990

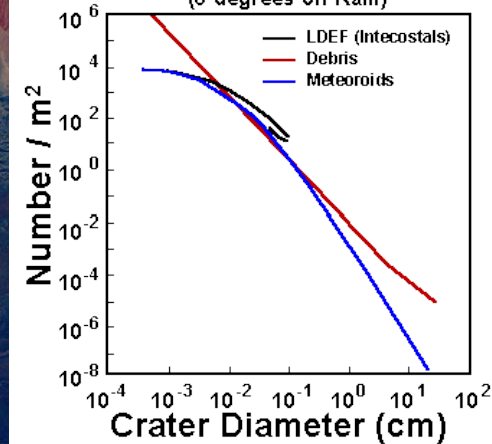
return with Space Shuttle Columbia (decay 1 Feb 2003) in January 1990  
 => entire surface: spurs / holes from meteoroids and space debris



Tennis ball space debris flown between Columbia and LDEF during LDEF capture.

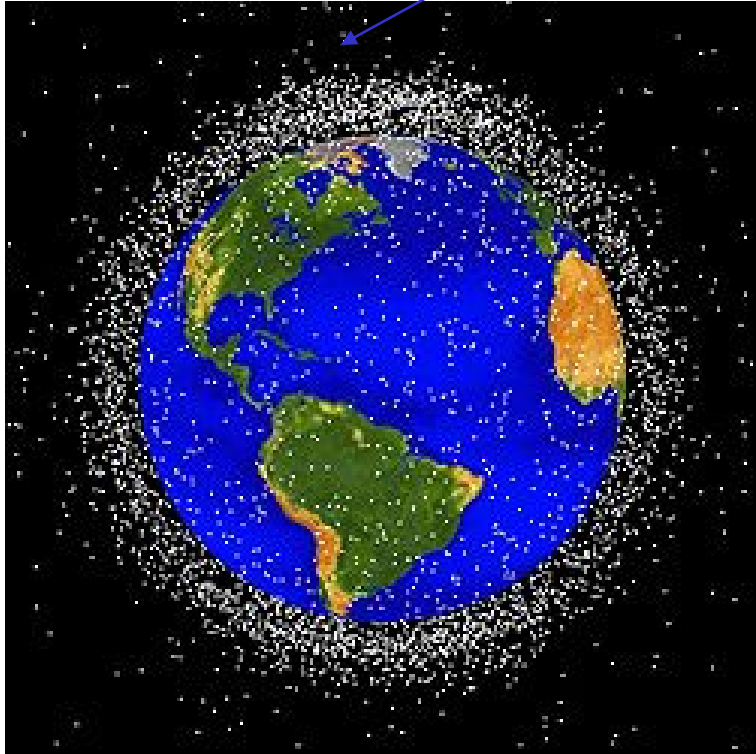


Comparison of LDEF Data to Model Prediction (8 degrees off Ram)



# Space Debris Distribution in LEO/GEO and on Earth

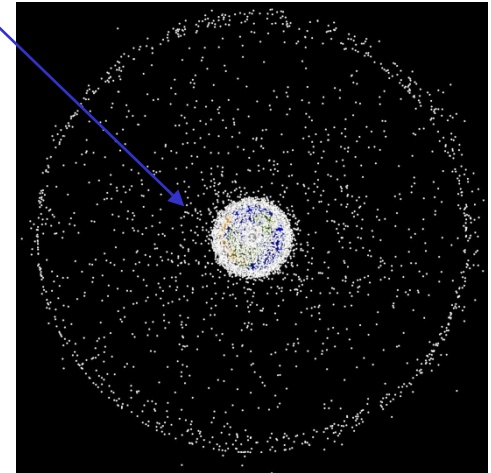
LEO: 200 – 1200 km orbit  
GEO: ... up to 36000 km orbit



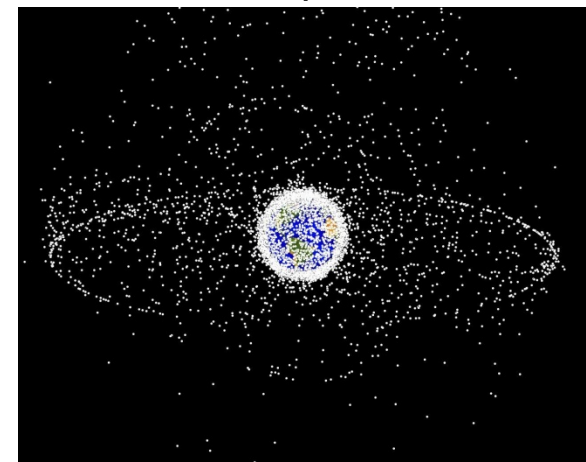
**21 Jan 01** 70 kg  
Engine 3rd stage Delta 2 rocket  
(Saudi Arabia)



Uruguay: **2 Jan 11** (like  
21 Jan 01 – Delta 2...  
for new GPS (Navstar53)  
satellite!

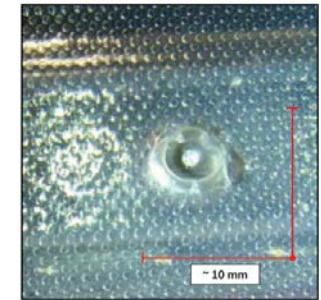
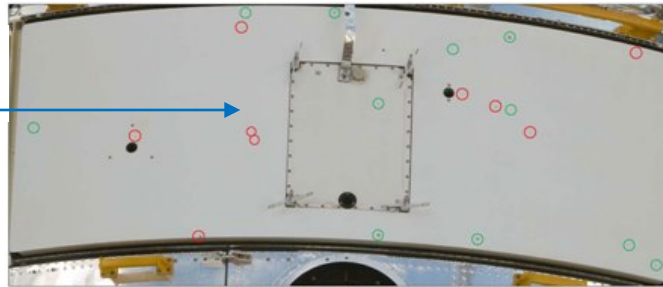


Top view



Equator view

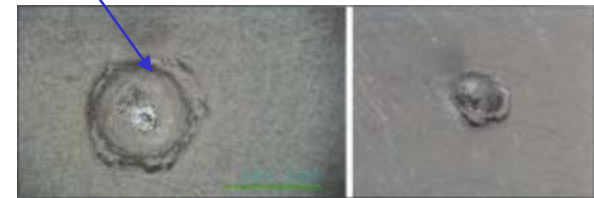
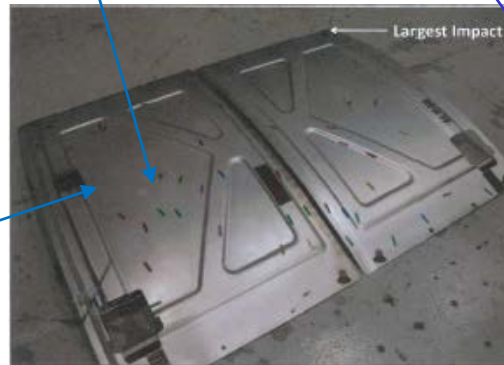
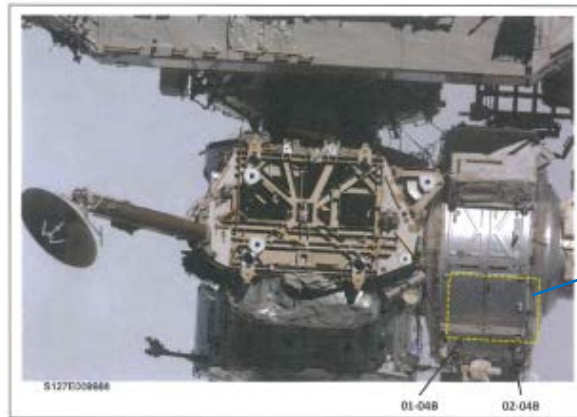
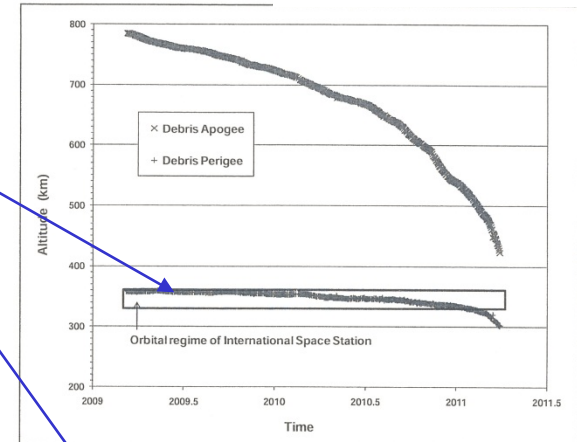
# Space Debris on HST and ISS



STS-128 inner side of cargo bay door

Reason for effects on ISS in 2009 / 2011

58 crater with maximal 1.8 mm diameter



# Code of Conduct for Space Debris



**General Assembly**

Distr.: General  
10 January 2008

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Sixty-second session  
Agenda item 31

## **Resolution adopted by the General Assembly**

*[on the report of the Special Political and Decolonization Committee  
(Fourth Committee) (A/62/403)]*

- 62/101. Recommendations on enhancing the practice of States and international intergovernmental organizations in registering space objects**



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

# Space Weather and Europe – an Educational Tool with the Sun (SWEETS)





## Weltraumwetter und Heliosphäre

**D**as Ziel dieser Ausstellung ist es, das Weltraumwetter und seine Auswirkungen auf unser tägliches Leben im Zusammenhang mit dem Internationalen Heliosphärischen Jahr und der Europäischen Wissenschaftswache zu erklären.

Das Weltraumwetter beschreibt die Bedingungen auf der Sonne und im Sonnenwind, aber auch die in der kosmischen Strahlung, in der Magnetosphäre, in der Ionosphäre und in der Thermosphäre, die die Verfügbarkeit und Nutzung von Weltraumsegmenten und Erdoberden gebundenen technologischen Systemen beeinflussen und das Leben und die Gesundheit von Menschen gefährdet. Da unsere Gesellschaft zunehmend Technologien benutzt, die vom Weltraumwetter beeinflusst sind, ist das Verständnis von Weltraumwetter, Magnetosphären und ihren Auswirkungen auf technologische Systeme – die wir im täglichen Leben nutzen – mehr und mehr bedeutsam.

Die Heliosphäre ist das Gebiet im Weltraum, welches durch die Sonne und den Sonnenwind dominiert wird. Dieses Gebiet schließt die Erde und alle anderen Körper im Planetensystem ein und hat eine Ausdehnung von ca. 120 Millionen Kilometer Entfernung von der Sonne. Die primäre Aufgabe des Internationalen Heliosphärischen Jahres (IHJ) in 2007 ist es, unser Wissen über heliosphärische Prozesse – die die Sonne, Erde und die Heliosphäre beeinflussen – zu erweitern. Das IHJ ist die Fortführung der Tradition von internationaler Forschung und findet aus Anlaß des 50. Jahrestages des Internationalen Geophysikalischen Jahres von 1957 statt. Das IHJ verdeutlicht auch der gesamten Welt die Schönheit und Bedeutung der Weltraum-, Geo- und Umweltforschung.

## Space Weather and Heliosphere

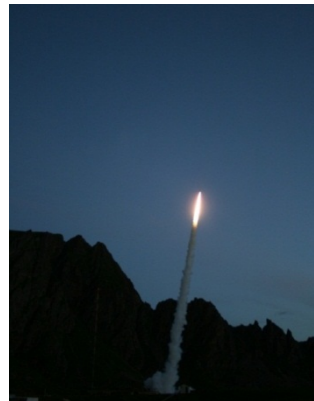
**T**he goal of the exhibition is to explain space weather and how it affects our daily life within the context of the International Heliospherical Year and the European Science Week.

Space weather is described as conditions on the Sun and in the solar wind, as well as cosmic rays, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health. As society makes increasing use of technologies that can be influenced by space weather, understanding space weather phenomena and their impact on technological systems that we use throughout our daily lives becomes more and more important.

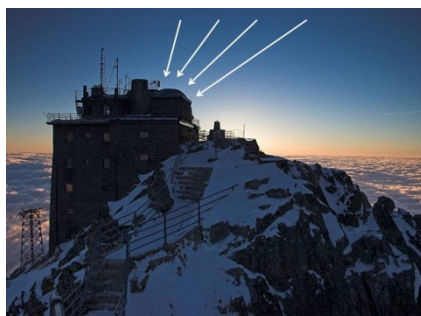
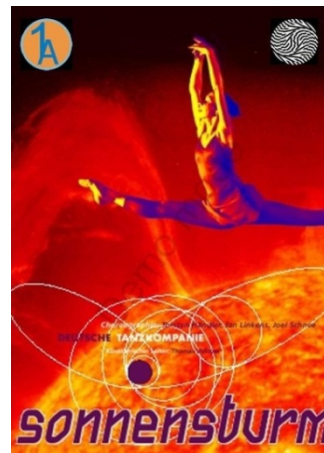
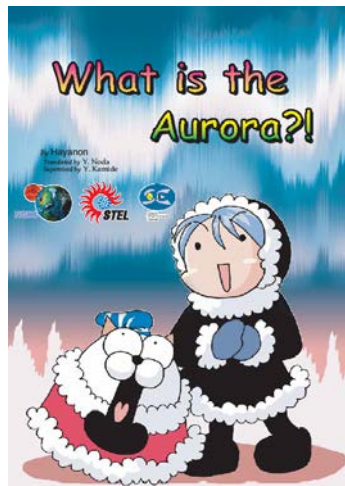
The heliosphere is the region of space dominated by the Sun and solar wind. This region includes the Earth, all other bodies in the planetary system and extends up to about 120 billion km away from the Sun. Advancing our understanding of the heliospherical processes that govern the Sun, Earth and heliosphere is a primary objective of the International Heliospherical Year (IHJ) in 2007. The IHJ is a continuation of the tradition of international research and is taking place on the 50th anniversary of the International Geophysical Year in 1957. IHJ also demonstrates the beauty, relevance and significance of space, Earth and environmental science to the world.




## SWEETS Bus



# SWEETS: Booklets, Poster, Planetarium & Dance Show, TV Film and DVD (next page)



# MANY THANKS AND QUESTIONS?

The end of the lecture: video - dancing under **cosmic ray showers** (C. Timmermans Radboud University Nijmegen).



## Space Weather DVD