Rationale for a European Space Weather Programme

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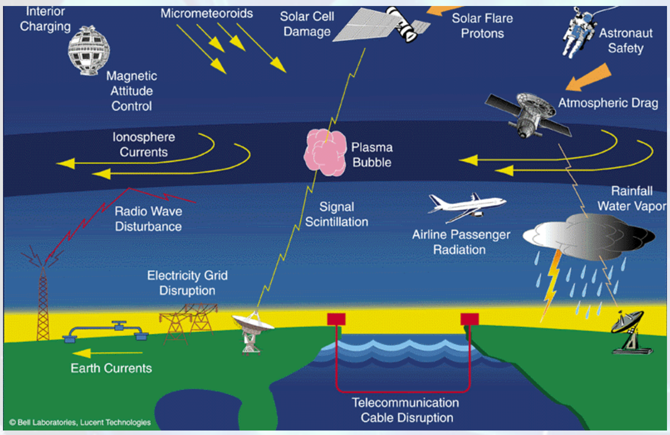
Scope

- WP 300 of ESWS: ”Establishment of detailed rationale”
- input to
  - system definition studies
  - programme definition studies
- benefits and markets studied separately
- documents:
  - Space Weather Effects Catalogue (ESWS-FMI-RP-0001)
  - Rationale for a European Space Weather Programme (ESWS-FMI-RP-0002)
  - both are available through the public ESWS website at RAL

Basics

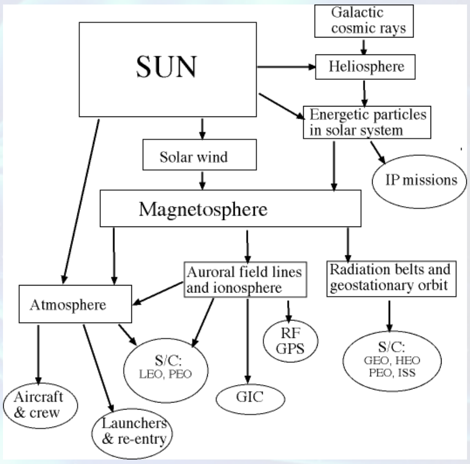
- Underlying reason
  - The time-variable solar-terrestrial interaction affects technological systems in space and on ground and can have consequences to human health and life.
  - Space weather is not synonymous to solar-terrestrial physics
    - effects are central to the rationale, but
    - science is essential to success
- Consequences to
  - technology, economy, society, public awarness, etc.
- What should we do in Europe?

Space weather and its effects



Observable space weather environment

- Sun and solar wind
  - origin of energetic particles
  - energy input to atmosphere
  - control of cosmic ray fluxes
  - drives magnetospheric activity
- Magnetosphere
  - particle acceleration
  - radiation belts
- Ionosphere
  - variable density
  - current systems
- Atmosphere
  - variable density -> drag
  - shielding of cosmic rays



"Non-standard" space weather environments

- Man-made environmental effects
  - debris
    - 30,000–130,000 objects >1 cm around the Earth
    - drag effects important
      - loss of tracking
      - cleaning up the low-altitude stuff
  - electromagnetic noise
    - VLF effects on radiation belts?
  - atmospheric nuclear tests left long-lasting traces
- Meteoroids and micrometeoroids

Systems affected

- A wide variety of space weather sensitive systems:
  - spacecraft on orbit
  - humans in space
  - launchers
  - communications and satellite navigation
  - aircrew and avionics
  - power and information transmission on ground
- The problems and requirements for their solutions are different
- Approach: Produce a catalogue
  - ESWS-FMI-RP-0001

Space weather catalogue(s)

- Goal
  - produce a catalogue to summarise space weather phenomena, effects, systems affected, and measurable parameters
- Problem
  - the material can be organised in several ways
    - need for a multidimensional catalogue
- Solution
  - three different catalogues compiled

Space weather catalogue(s)

- Domain-oriented catalogue
  - interplanetary space, magnetosphere, ionosphere and thermosphere, neutral atmosphere, Earth surface
- Phenomenon-oriented catalogue
  - energetic particles, debris and meteoroids, RF disturbances, cosmic radiation, solar particle events, GIC, atmospheric weather, atmospheric drag
- System-oriented catalogue
  - spacecraft, manned space flight, launchers, aircraft, communications, navigation, power transmission, pipelines, telecables, railways, geophysical surveys

Domain-oriented catalogue (sample)

Spatial domain	Systems affected	Effects	Measurable parameter
Interplanetary space			
Magnetosphere	spacecraft	SEE, radiation damage, noise, current loss, charging, ESD, debris/meteoroid impact	particle flux & composition mass, velocity, charge
	manned spaceflight	tissue damage	dose equivalent
Ionosphere and thermosphere			
etc.			

Phenomenon-oriented catalogue (sample)

Phenomenon	Dynamic process	Measurable parameter	Predictability
Energetic electron flux Energised plasmasheet Trapped proton flux in LEO Trapped proton flux in slot	Magnetospheric storm Substorm Atmospheric removal, solar cycle SPE + magnetic storm	peak flux, fluence, spectrum density, temperature flux, spectrum flux, spectrum	nowcast (at GEO), prospects of day ahead nowcast, prospects of day ahead days ahead + solar cycle not enough knowledge yet
Debris, Meteoroids			
RF disturbances			
etc.			

System-oriented catalogue (sample)

System	Phenomenon	Effect	Predictability
Spacecraft	Energ. electrons, protons and ions, plasma Debris Meteoroids Magnetic field Atmosphere	SEE, charging, dose, damage, noise Damage, stimul. discharge as above Induced currents, attitude control Drag	cosmic rays good; SPE poor relativistic electrons 1 day ahead in prospect trapped protons in LEO good trapped protons in slot not possible statistical predictions weeks (statistical) hours after solar eruptions, solar cycle
Manned space flight			
etc.			

From observations to effects

- The observations needed for

  spacecraft charging, impacts and single event effects on S/C, effects on humans in space, drag, communications and satellite navigation, aircrew and avionics, ground-based systems

  were analysed considering:
  - critical parameters
  - forecasting
  - nowcasting
  - after-the-event reconstructions

- These were fed to the system requirements (WP 400)

Forecasting viewpoint

- Forecasting requires observations of
  - the Sun; where and when solar eruptions take place
    - e.g., LASCO and EIT of SOHO
    - X-rays, radiobursts
  - the solar wind; estimate the geoefficiency of the phenomena
    - at least: magnetic field, velocity, density
    - in situ, preferably L1
  - the state of the magnetosphere
    - ground-based indices (direct space observations may be useful)
    - solar-wind derived proxies
- Fast data transfer, processing and dissemination are essential

Nowcasting viewpoint

- Nowcasting requires observations of
  - partly the same parameters as forecasting
    - at least they are useful
  - the state of the immediate environment of interest, e.g.,
    - particle fluxes at GEO
    - ionospheric profile (communications)
    - ionospheric currents (GIC)
- Nowcasts may be more tailored than forecasts
- Fast data transfer, processing and dissemination are essential

After-the-effect analysis

- Specification requires
  - wide observational network
    - Sun, solar wind, magnetosphere, ionosphere, ground
  - large and efficient data assimilation system
  - sophisticated models
- After a system failure you may need
  - immediate action to avoid more hazards
    - specification and nowcasting are related
  - understanding the reason of the failure
    - more relaxed time constraints
    - more observations possible to assimilate

But can we forecast, nowcast or specify?

- solar activity
  - statistical predictions based on solar cycle or rotation
  - single eruptions and their effects predicted rather poorly
- magnetospheric state
  - from L1 a few hours ahead well
- magnetospheric details
  - mostly poorly
- ionospheric currents & GIC
  - nowcast OK
  - forecast poor

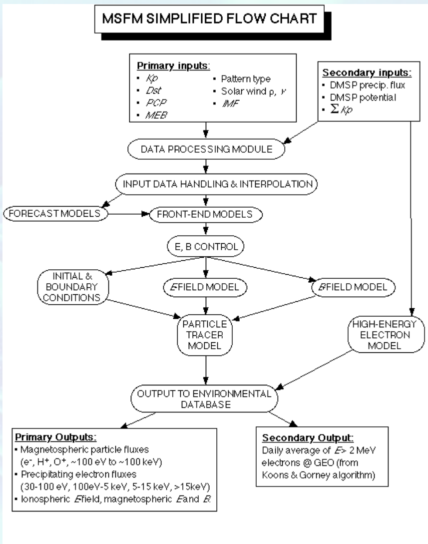


Figure 1

Why is it difficult (except specification)?

- We know much but not enough
- More scientific effort is needed in:
  - Solar atmosphere; where and when events take place
  - Acceleration of solar energetic particles
  - Predicition of the structure and interplanetary propagation of CMEs
  - Magnetospheric acceleration (killer electrons, storms/substorms)
  - Storm dynamics
  - Exceptionally big GIC events
  - Dynamics of the upper atmosphere
  - Coupling to the lower atmosphere
  - Planetary magnetospheres, ionospheres and thermospheres

Without observations no weather services!

- European observational capacity in space is alarmingly low
  - SOHO is great, but it is a science S/C without replacement
    - general problem with science payloads
- A minimum requirement is to observe
  - solar eruptions (X-ray fluxes, CME releases)
  - in situ solar wind (B, V, n)
  - current magnetospheric state (real-time indices based on ground-based observations or solar wind predictions)
  - increased energetic particle fluxes in the magnetosphere

Data systems and modelling

- Input comes from widely different sources
  - problems with data formats
  - efficient data base management structures needed
- Forecasting and nowcasting require fast data streams
- User interface
  - data dissemination
  - tailored products
- See the ESTEC project SEDAT

Data systems and modelling

- Modelling is probably the best developed field of space weather in Europe
  - radiation belts and inner magnetosphere
    - ESTEC projects: TREND, TREND-2, TREND-3, SPENVIS
  - most efforts have been in scientific modelling of
    - solar processes
    - solar wind
    - magnetospheric dynamics
  - however, the efforts are scattered and often ad-hoc
    - more long-term commitments are needed
- See the prototyping activities of this study

Summary

- To have meaningful space weather activities we need
  - investments in basic research
  - improved observation capacity
  - efficient data systems
  - better models
- But to have these in Europe, we need
  - a European Space Weather Programme including
    - own space-based and ground-based observations
    - own data and modelling system

  in active co-operation with world-wide space weather efforts

SO THERE IS THE RATIONALE
GO FOR IT!