The importance of Space Weather

Coronal mass ejections & the threat from stars

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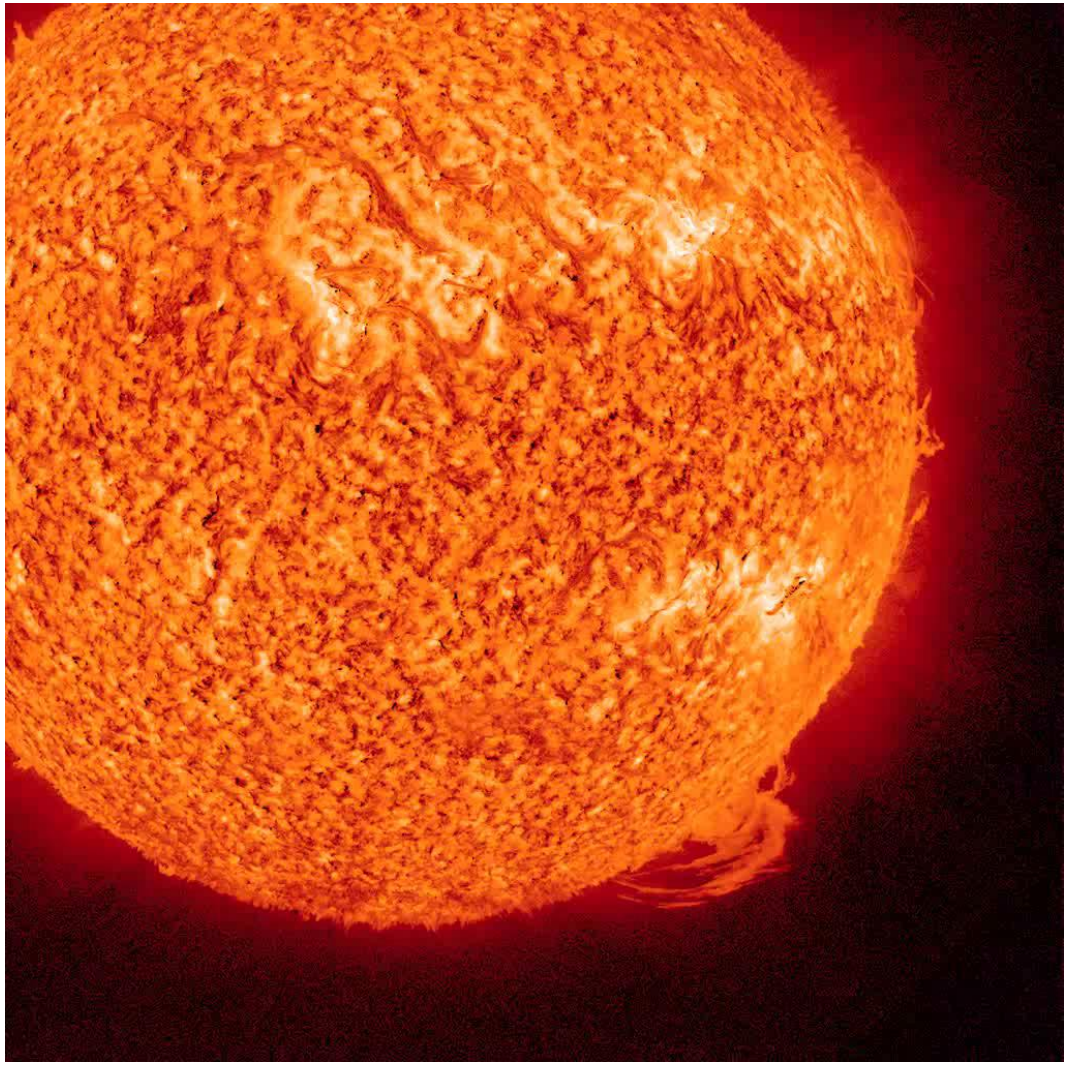
RAL Space

WHAT IS THE THREAT?

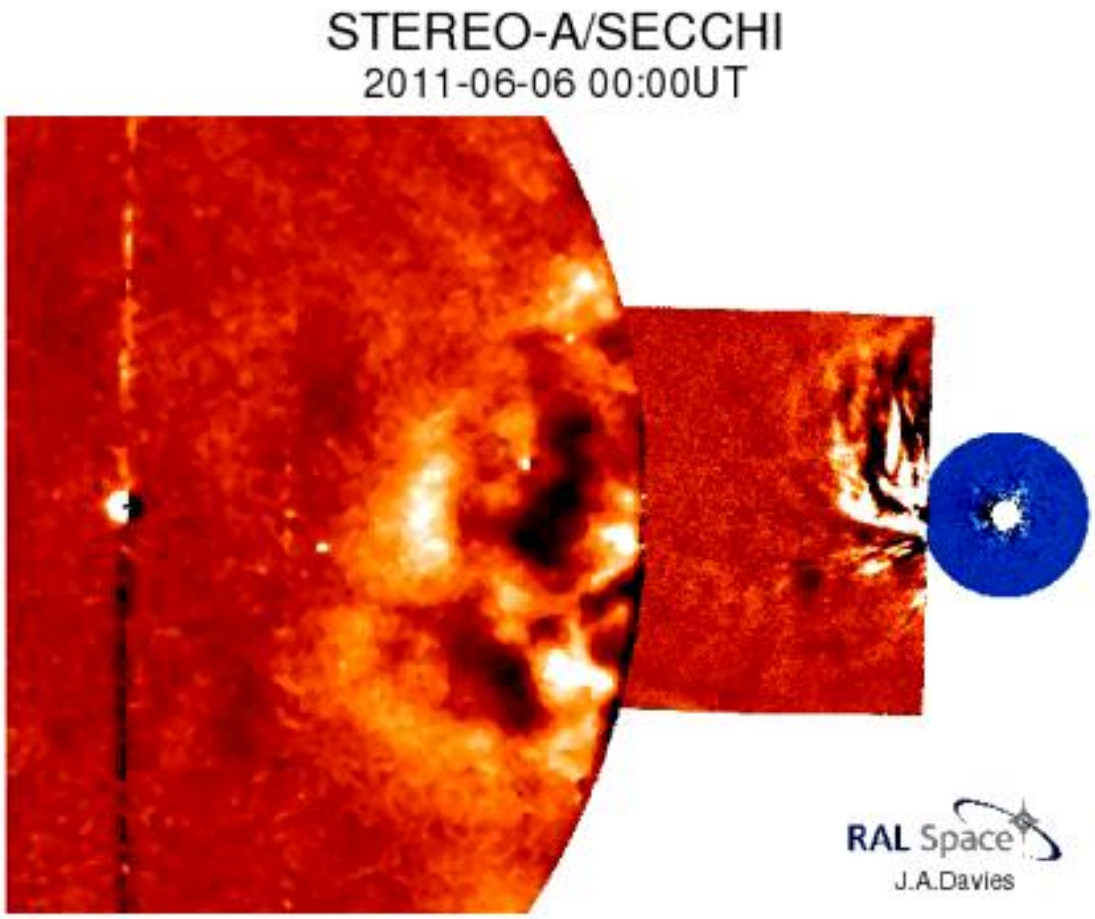


7 June 2011: a striking solar explosion

AIA on SDO gives clear view … for first time.

UK technology at core of instrument

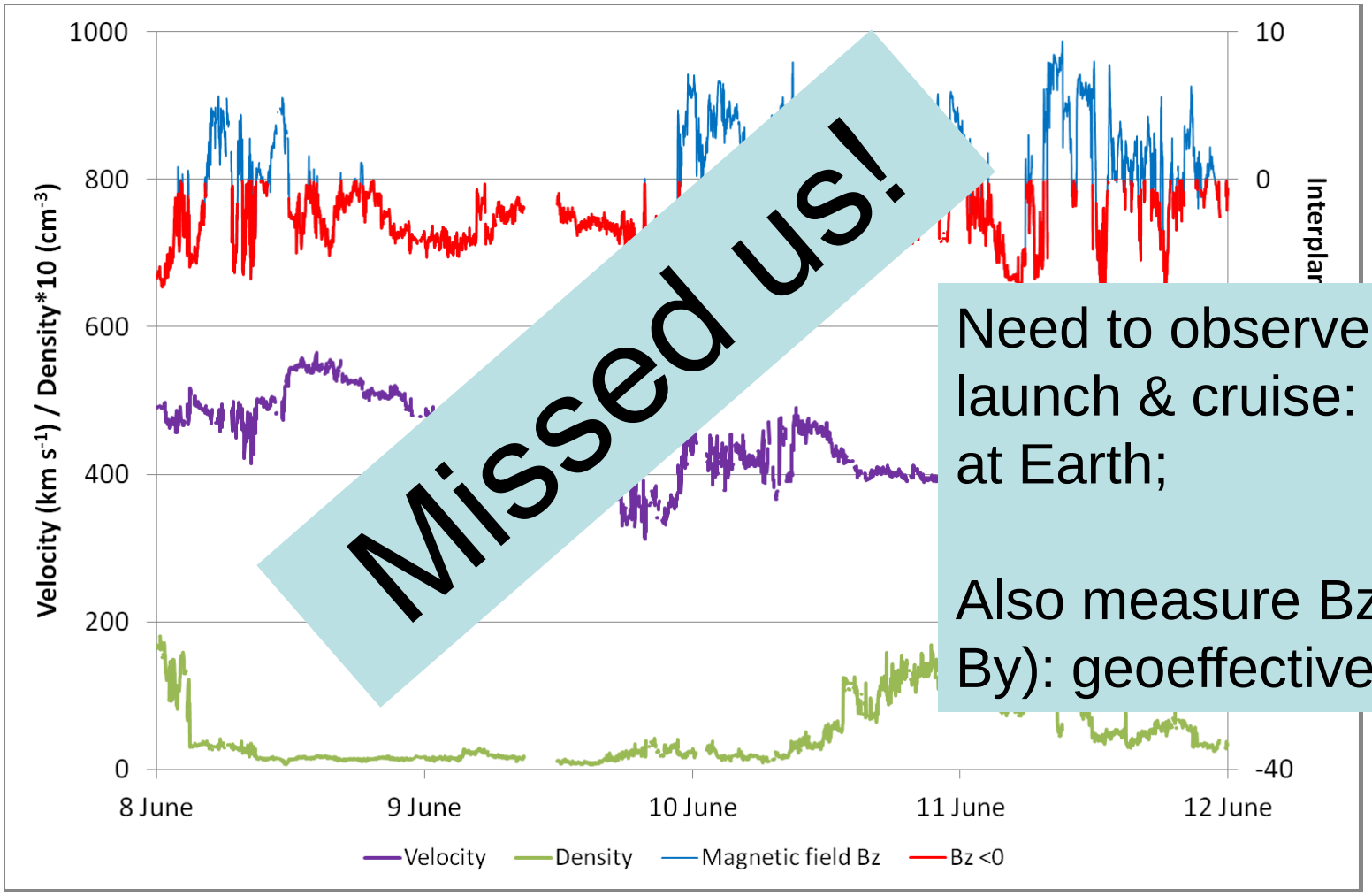
The view further out : tracking the CME



View from STEREO: *Coronagraph & Heliospheric Imager*

UK technology at core again

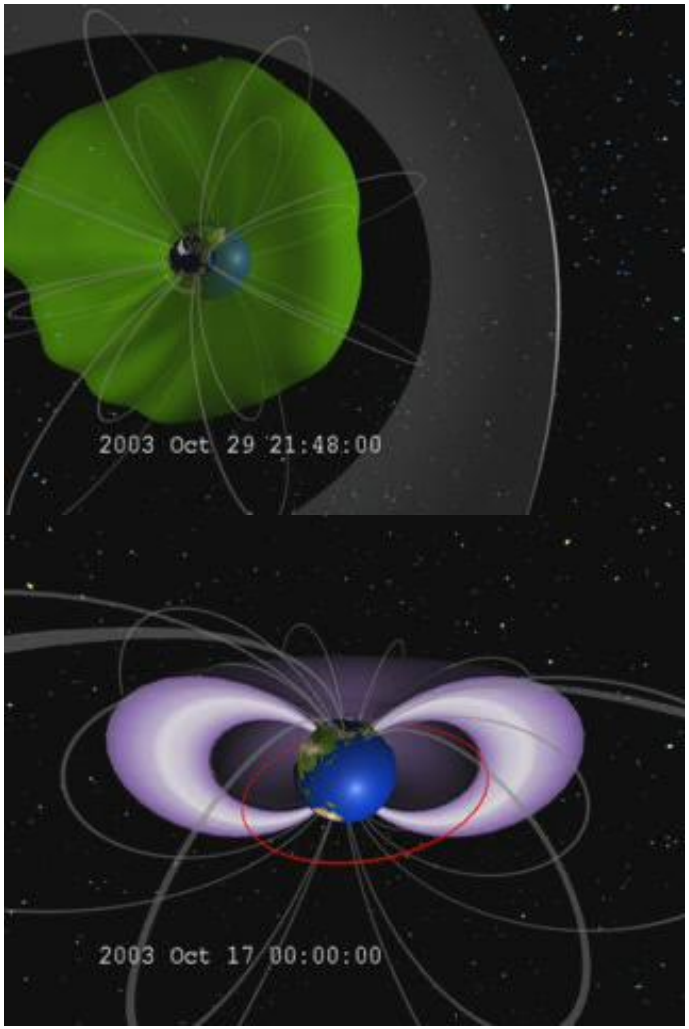
What arrived : view from ACE



Need to observe CME launch & cruise: arrival at Earth;

Also measure Bz (& By): geoeffectiveness

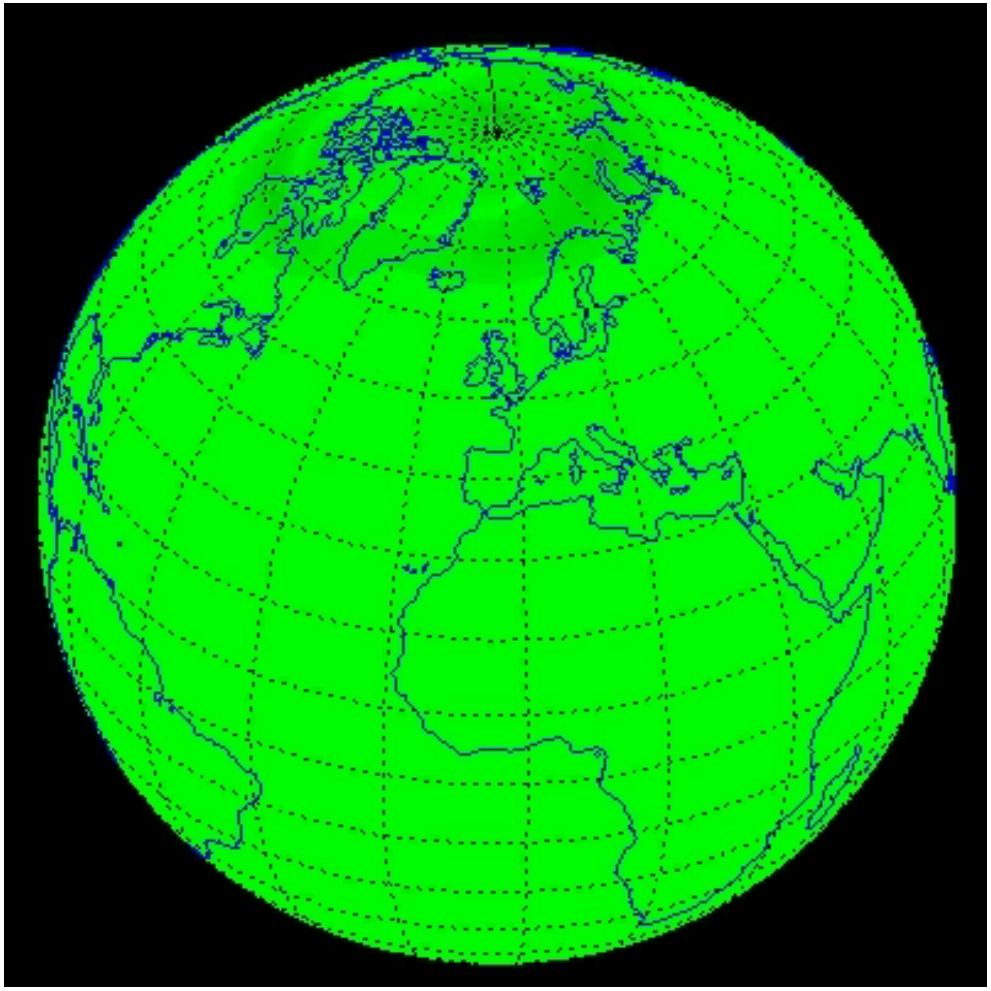
But if we get an geoeffective hit: Magnetospheric hazards



- Plasmasphere
  - GPS/Galileo
  - spacecraft tracking (ranging & radar)
- Outer radiation belt
  - Spacecraft charging: MEO & GEO
  - Also in LEO in severe events?
- Ring current
  - Low/mid latitude power grids (e.g. South Africa in 2003)

Courtesy NASA

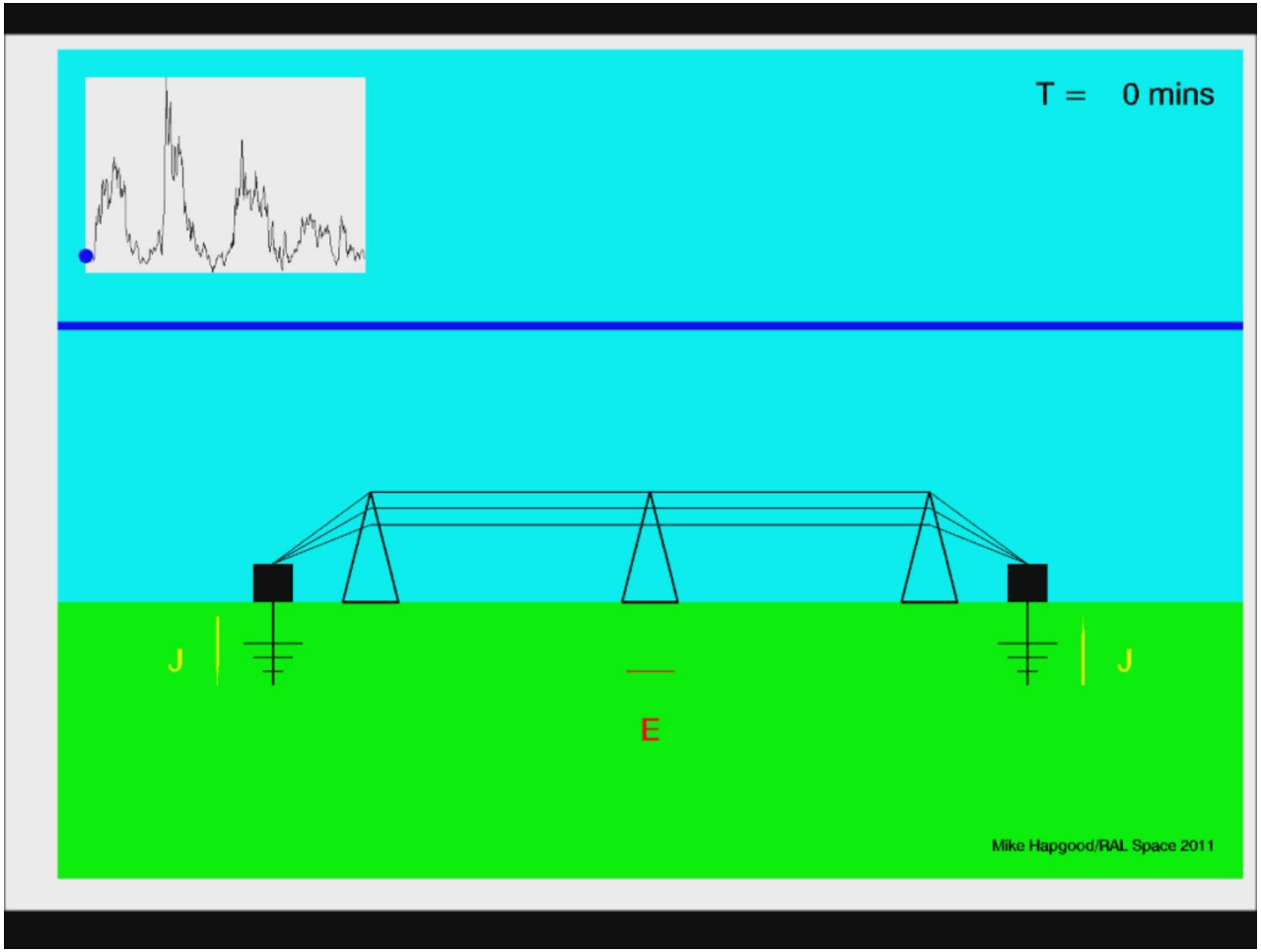
Stirring up the atmosphere



Courtesy UCL

- Bigger electric currents in upper atmosphere => aurora
  - High/mid latitude power grids, etc
  - s/c charging
- => Heating of polar upper atmosphere (winds, waves, turbulence, composition)
  - GPS/Galileo/etc
  - HF radio (e.g. aviation)
  - Space & ground surveillance
  - Spacecraft drag

SpW threat to power grids



- Space weather adds DC electric currents to grids
- Saturates transformers
- Heating, vibration, harmonics
- Risk of cascade failure in grid (92s in Quebec 1989 case)

IMPACT, MITIGATION & PLANNING

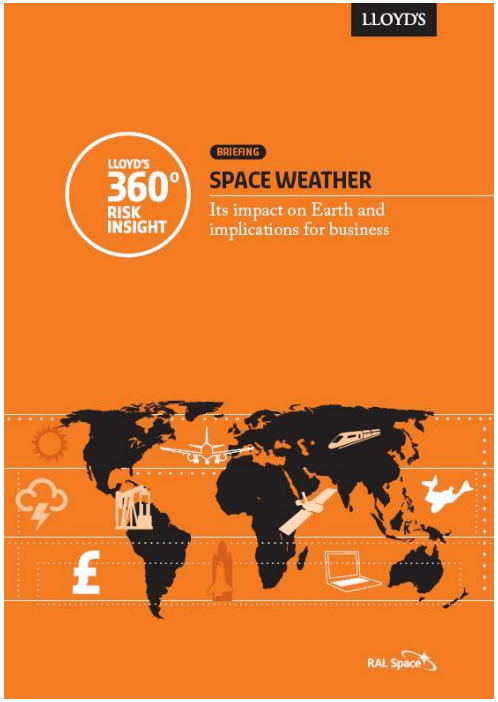
Real responses to SpW

Survive • design kit to cope • good spec	Assess • learn lessons, *liability* • nitoring/tools
Ad • re • goo	es, *market shock* ss and planning
Fix • alert/strengthen ops teams • good now-/fore-casts	Panic? • *media hype* • awareness and planning

Includes rapid assessment to support political/military decisions: is problem due to space weather or hostile human action?

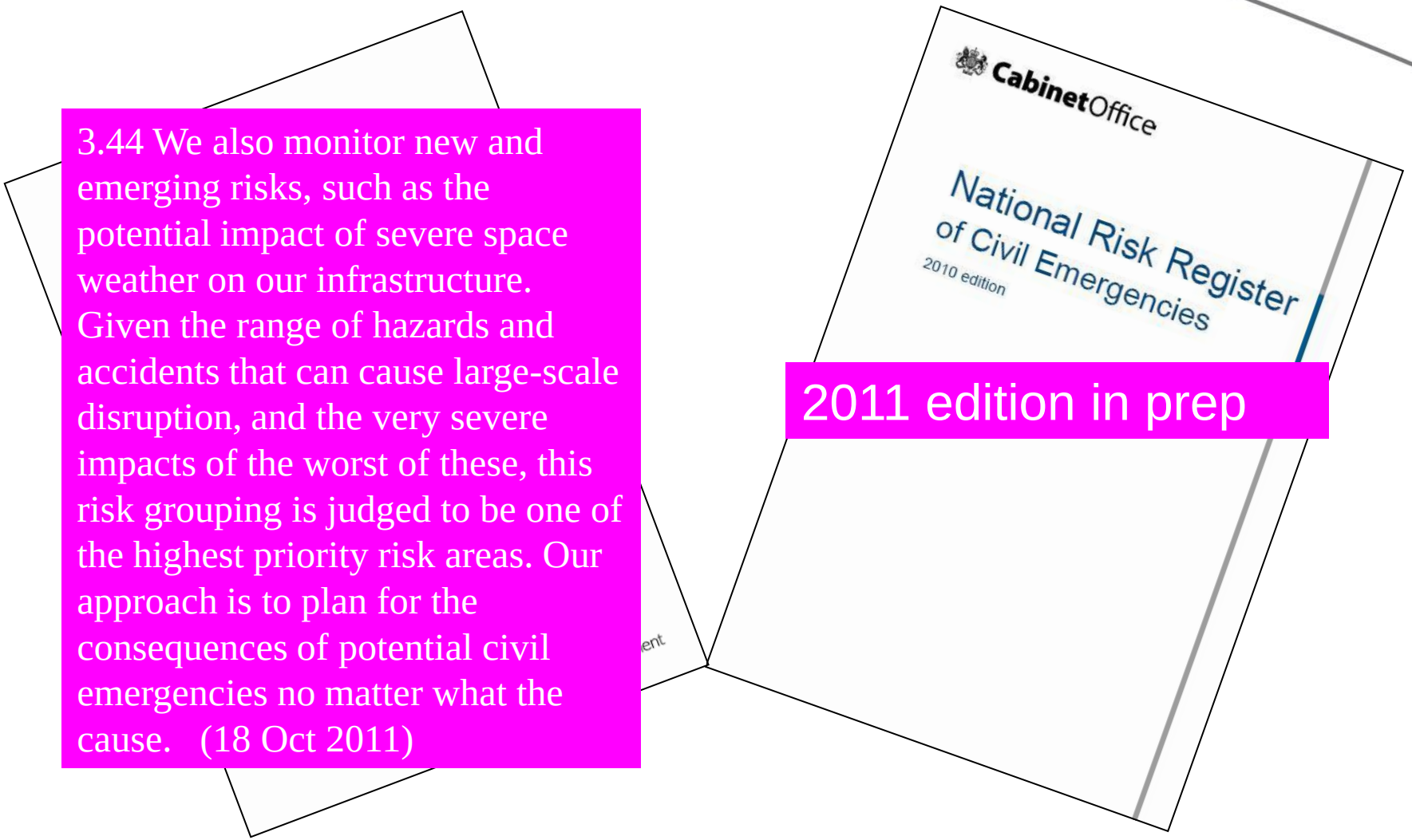
PART 3

BUSINESS RESPONSES



Government + risks

3.44 We also monitor new and emerging risks, such as the potential impact of severe space weather on our infrastructure. Given the range of hazards and accidents that can cause large-scale disruption, and the very severe impacts of the worst of these, this risk grouping is judged to be one of the highest priority risk areas. Our approach is to plan for the consequences of potential civil emergencies no matter what the cause. (18 Oct 2011)



2011 edition in prep

WHAT SCIENCE IS NEEDED?

Science challenges

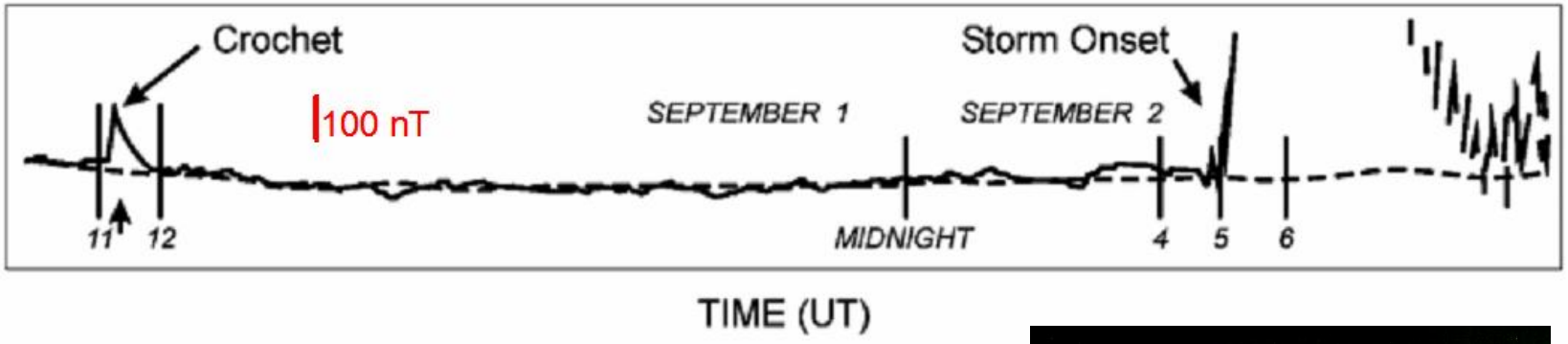
- What are the extremes?
  - Stats: extreme event methods, other stars, wait 400 years!
  - Physics: what applies in extremes, feed into modelling
- Modelling of space weather **environments**
  - Sun, solar wind, many terrestrial environments
  - Key science output to support services => engineering
  - Important to get physics detail right, dot some i's!!
- Monitoring - what are key observations?
  - To push the physics forward & to feed into operations
  - Well-studied, see WMO database (http://www.wmo-sat.info/db/)
  - Need space & ground observations: how to move to operations? Roles for ESA, EU, WMO, national programmes.

What to monitor?

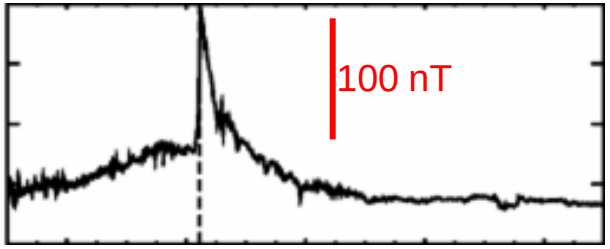
- Solar wind transients (CMEs & CIRs)
  - Direction & speed – launch & cruise phases
  - Magnetic field – strength and orientation!
  - (electric potential driving magstorms is ~ -Bz v L)
- Conditions at Earth
  - Critical to forecast because of **preconditioning**: response to solar input depends on current conditions
  - Rad belts (GEO & MEO), magnetosphere (sub-storms, ring current), plasmasphere, ionosphere, thermosphere, etc
  - Near real-time data also vital for nowcasting and post-event analysis (important for industry & security)
- Solar context
  - Active regions, flares, filaments, etc

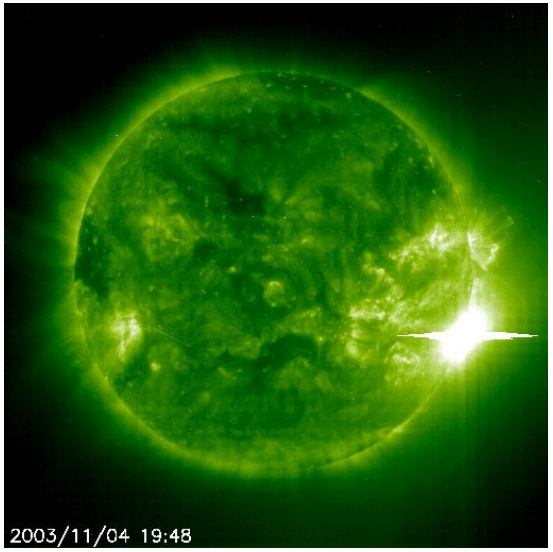
And finally a warning

Carrington event – flare EMP at Kew (London)



Halloween 2003 final event – flare + EMP at Newport, Washington (12 LT)





SPARES

Space Weather has range of impacts

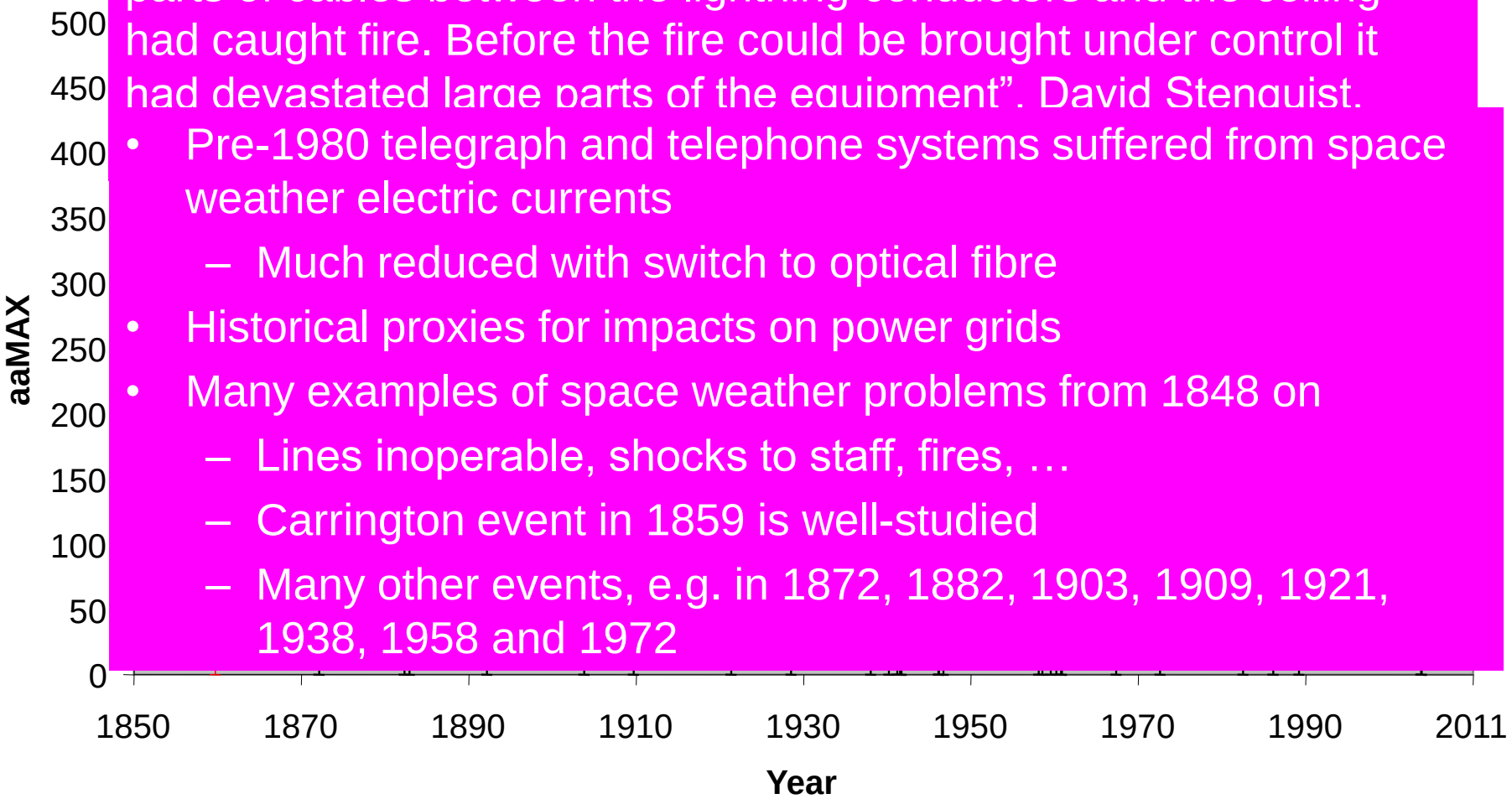
- Nuisance effects are common
  - For example power grid congestion (spot price > 24h-head price)
  - Businesses need awareness and mitigation (e.g. Lloyds report)
- But severe effects do happen
  - Examples exist at 10- & 100-yr timescales
  - Mar 1989 & Oct 2003 in modern era
  - Sep 1859 & May 1921 much studied, many other historical examples
  - Have potential for high impact on critical infrastructures: power, aviation, GNSS, ...
  - Focus for Government risk managers (National Risk Assessment)
- Media coverage conflates these extremes

1989: Aurora over Oxfordshire

Destruction of Karlstad telephone exchange, May 1921:

"…suddenly smoke issued from the test and change-over switch and the night trunk service positions. In the cross-connexion room, parts of cables between the lightning conductors and the ceiling had caught fire. Before the fire could be brought under control it had devastated large parts of the equipment". David Stenquist.

- Pre-1980 telegraph and telephone systems suffered from space weather electric currents
  - Much reduced with switch to optical fibre
- Historical proxies for impacts on power grids
- Many examples of space weather problems from 1848 on
  - Lines inoperable, shocks to staff, fires, …
  - Carrington event in 1859 is well-studied
  - Many other events, e.g. in 1872, 1882, 1903, 1909, 1921, 1938, 1958 and 1972



WHY NOW?

Space weather is as old as the Earth

Phenomena distant from the Earth (Sun + supernovae) create ***adverse environments for key technologies*** *operating in space, in the atmosphere and on the surface of the Earth.*

Limited sensitivities

No sensitivities

Comms, navigation, radiation, digital systems

Power & control

Examples of damage

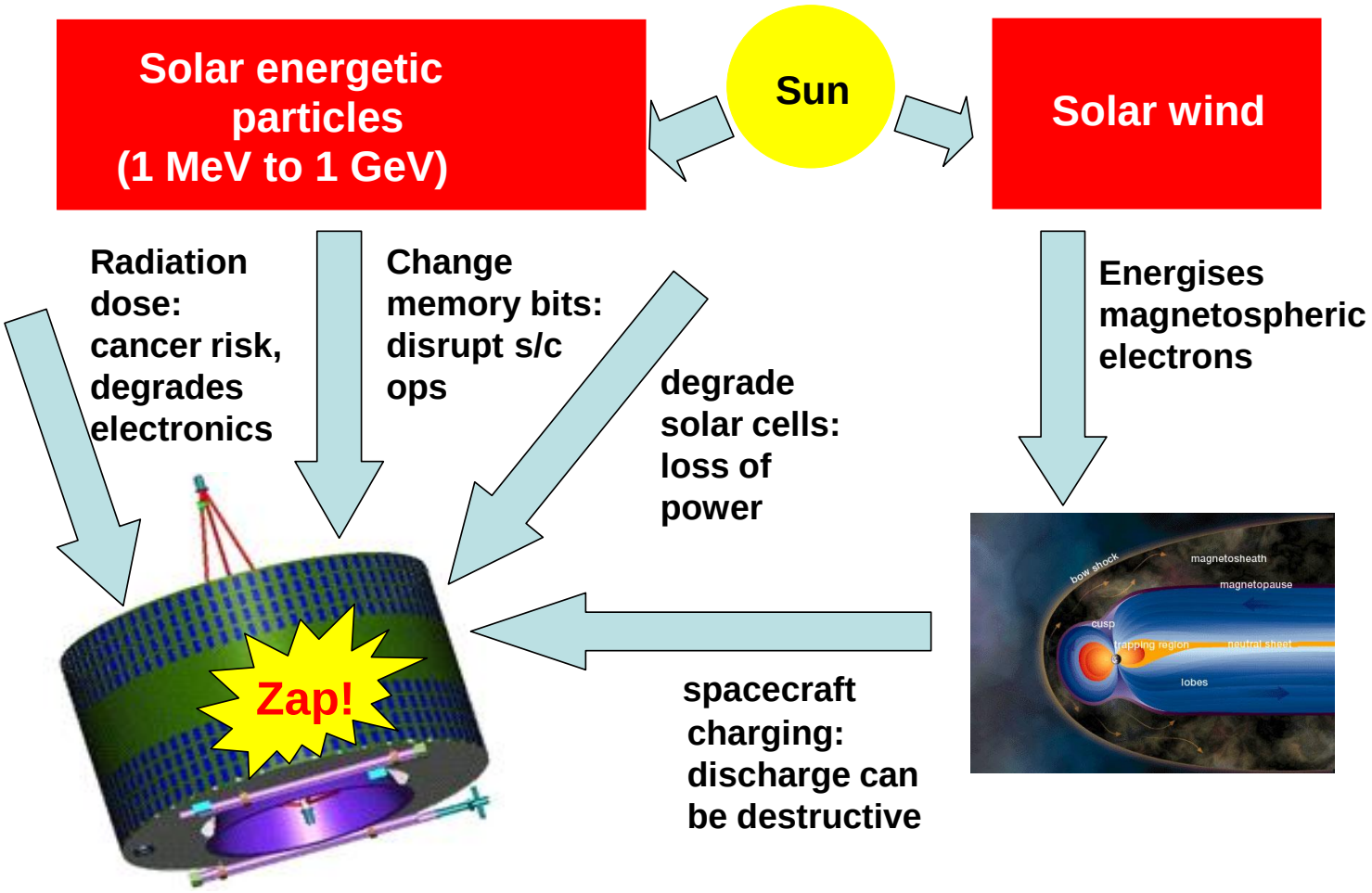
courtesy Metatech

New Jersey, March 1989.

Also major failure in Quebec, and transformer damage in UK

South Africa, Oct 2003

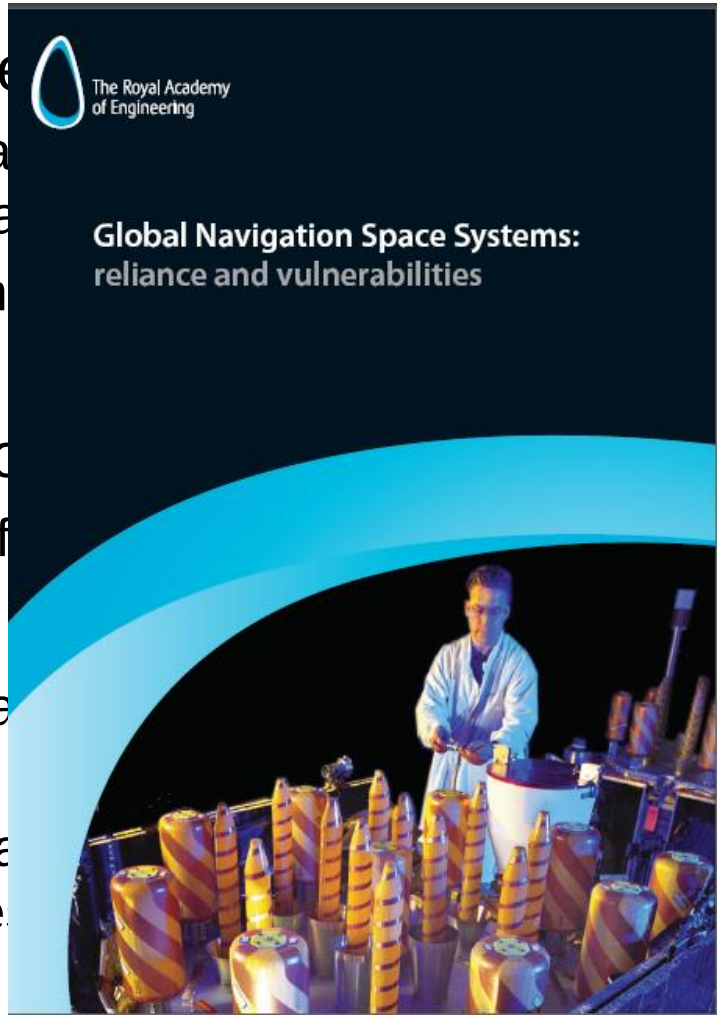
Space weather & spacecraft



Amplifying the threat - interconnectivity

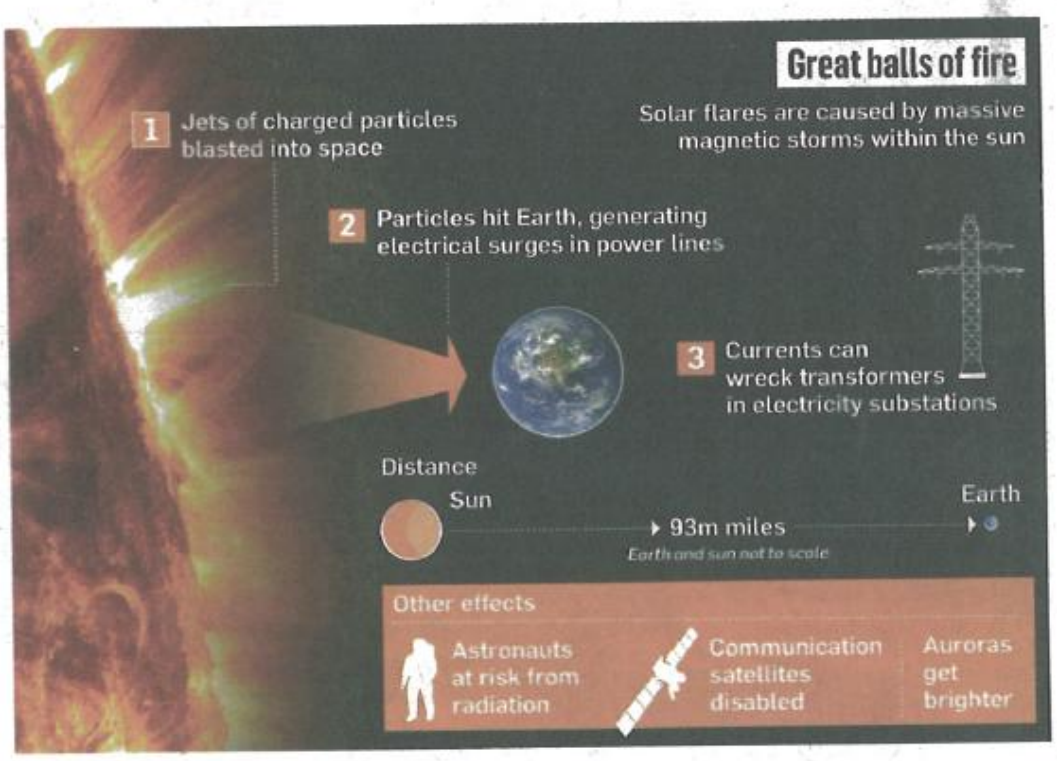
- Space weather affects ke
  - Power – THE fundamenta
    water/sewerage, retail fina
    im
- So huge potential for knc
  - e.g. 1989 Quebec power f
- Links into wider issue of
  - Our economic and societa
    interconnected
  - Growing attention to huma
    operation of infrastructure

e.g. RAoE report published 8 March



Blast from sun may shut down Britain

The national grid is being reinforced against a looming solar storm, writes **Marie Woolf**



MINISTERS are preparing to invoke emergency powers to turn off the nation's electricity in a bid to shield Britain from the worst effects of the biggest solar flare for 150 years.

They have been warned that a massive surge of energy from the sun could hit the Earth within the next 18 months. In a worst-case scenario, it could blow out the national grid and leave parts of the country without electricity for months.

The most extreme form of solar storm could knock out computers and the banking system, throw satellites off course and disrupt GPS technology.

Scientists have warned that

Huhne said: "The latest scientific research raises the possibility of a severe event with the potential to hit many parts of the grid simultaneously.

"That is why the Department of Energy and Climate Change is working with the national grid and experts from the UK

them at lower altitudes to reduce exposure to radiation.

The emission of billions of charged particles towards the Earth would also cause red, green and purple auroras — usually only seen at the Earth's poles — around the globe.

The first recorded solar flare,

spacecraft into different orbits, causing ground controllers at Nasa to lose contact with them.

Experts are issuing warnings about a class five storm, on a par with the 1859 event, may hit the Earth in 2012/13 as the sun reaches an active stage in its cycle.

Carrington event

1859 saw:

- Small EM pulse from flare X-rays
- Intense magnetic storm
  - Greenwich & Kew data off-scale
  - Extreme values at Rome & Mumbai
- Global aurorae, GIC in telegraph lines
  - strong electric currents in ionosphere, magnetosphere & crust
- Evidence for strong nitrate production
  - Intense radiation storm

- Carrington e
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  - No elect
- Repeat will
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  - Threat t
    and Nor
  - Also US
- US estimate
  - GIC: on
  - Space: 4
    dollars i
- Something t
- But also something that can inform us – needs more study alongside other historical events

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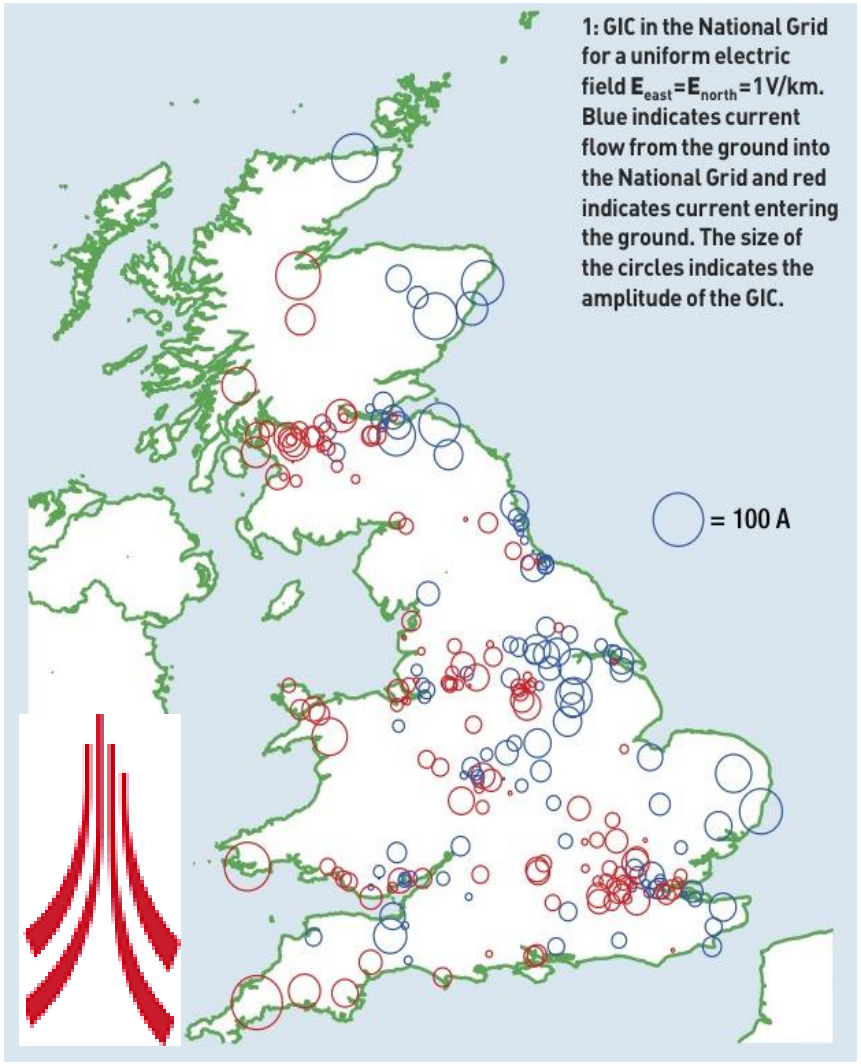
ver?)
billion

Modelling of risks



Example: model of *geomagnetically-induced currents* (GIC) in UK grids

- EPSRC-funded PhD project at Lancaster/BGS
- Geology matters
- Also detail of d**B**/dt (sub-storm effects)
- Note hot spots on coasts
- Focused workshop end-of-March

courtesy Lancaster University