Impacts of Extreme Space Weather

on GB Electricity Network

Space Weather and Finance Sector Symposium



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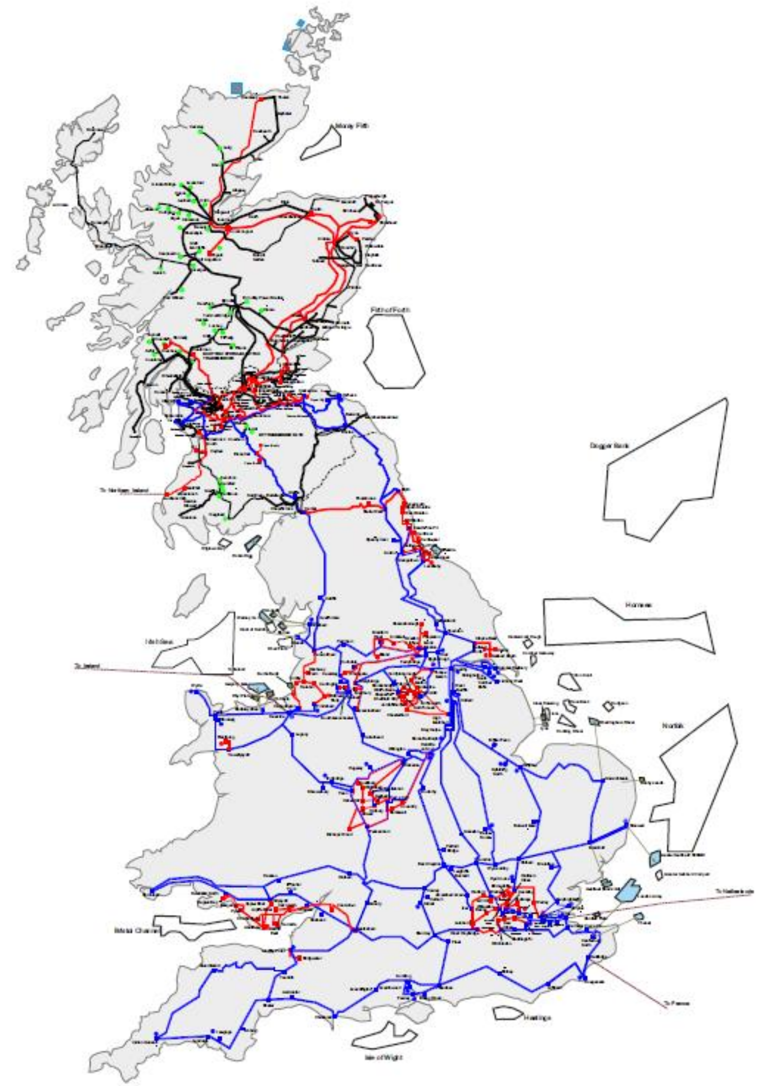
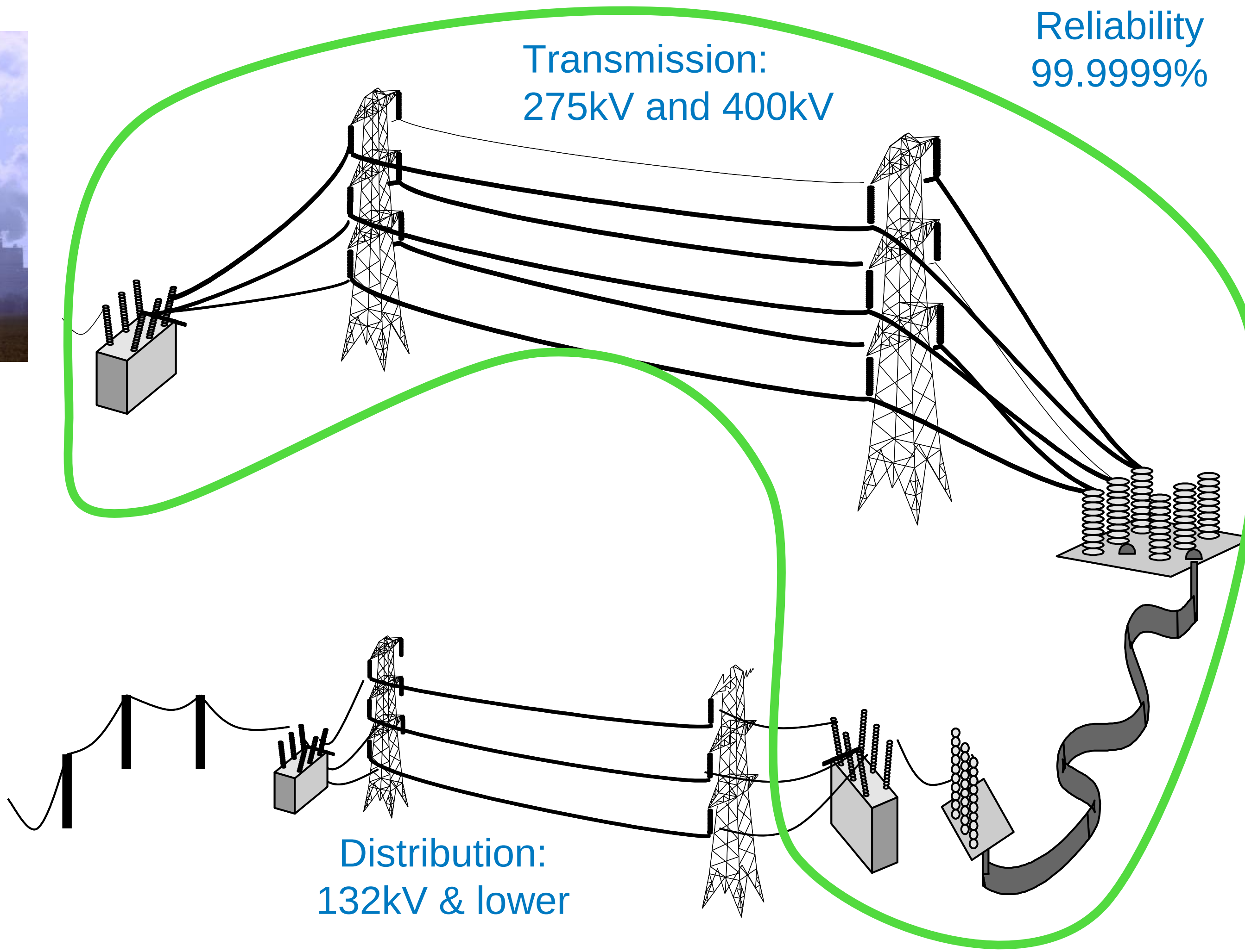
National Grid

- Own the high voltage network in England and Wales
- Operates the high voltage network in England, Wales and Scotland
- Almost 8000 km of transmission line and cable



Transmission and Distribution

Generation



Supply

Space Weather in National Risk Register

Figure 1: Risks of terrorist and other malicious attacks

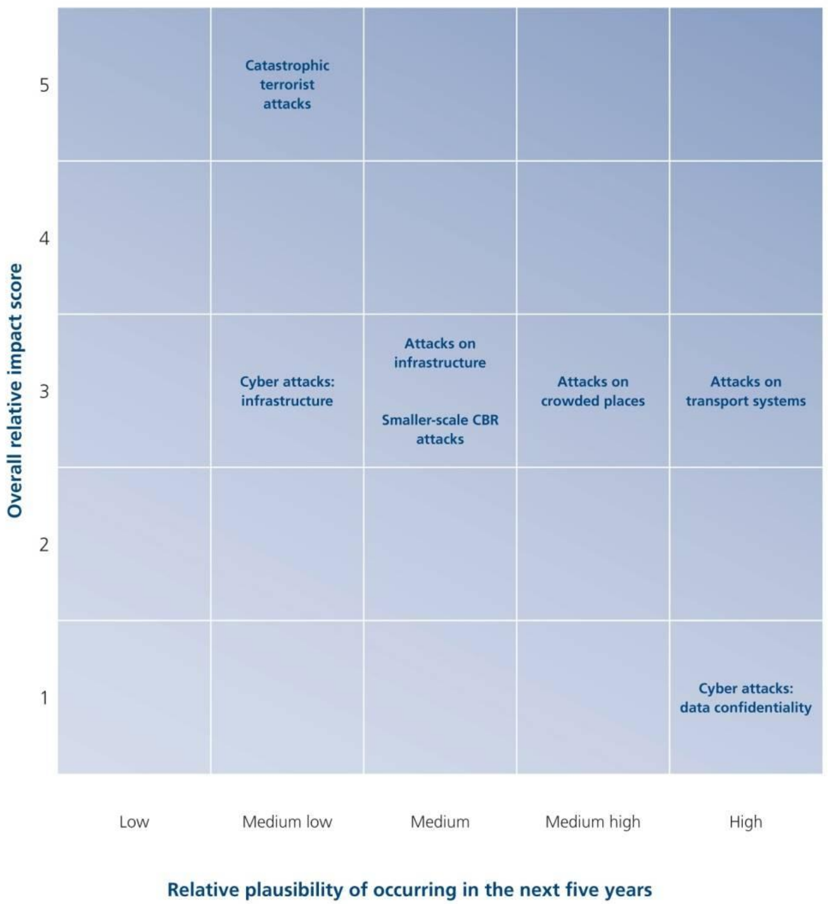


Figure 2: Other risks

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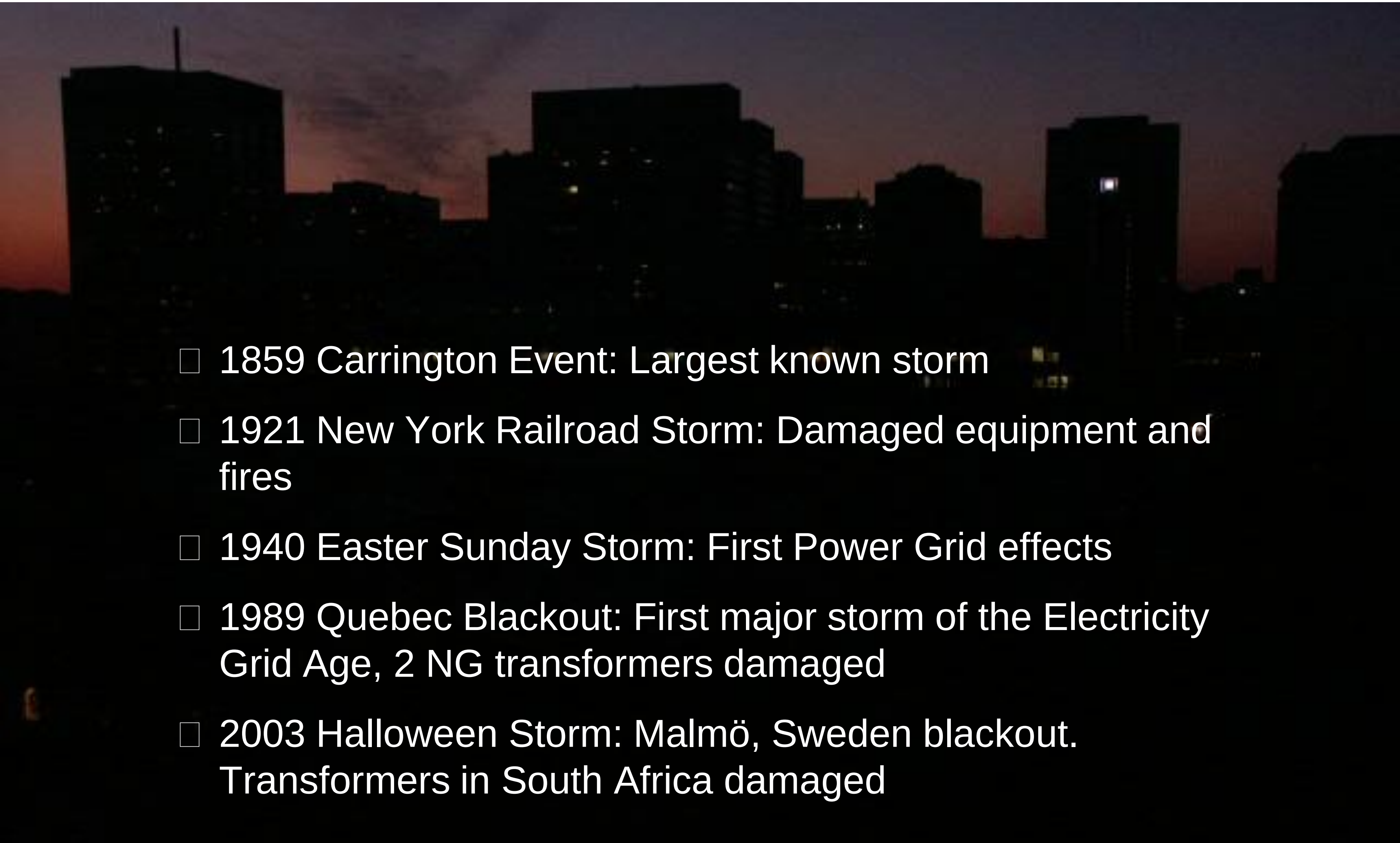
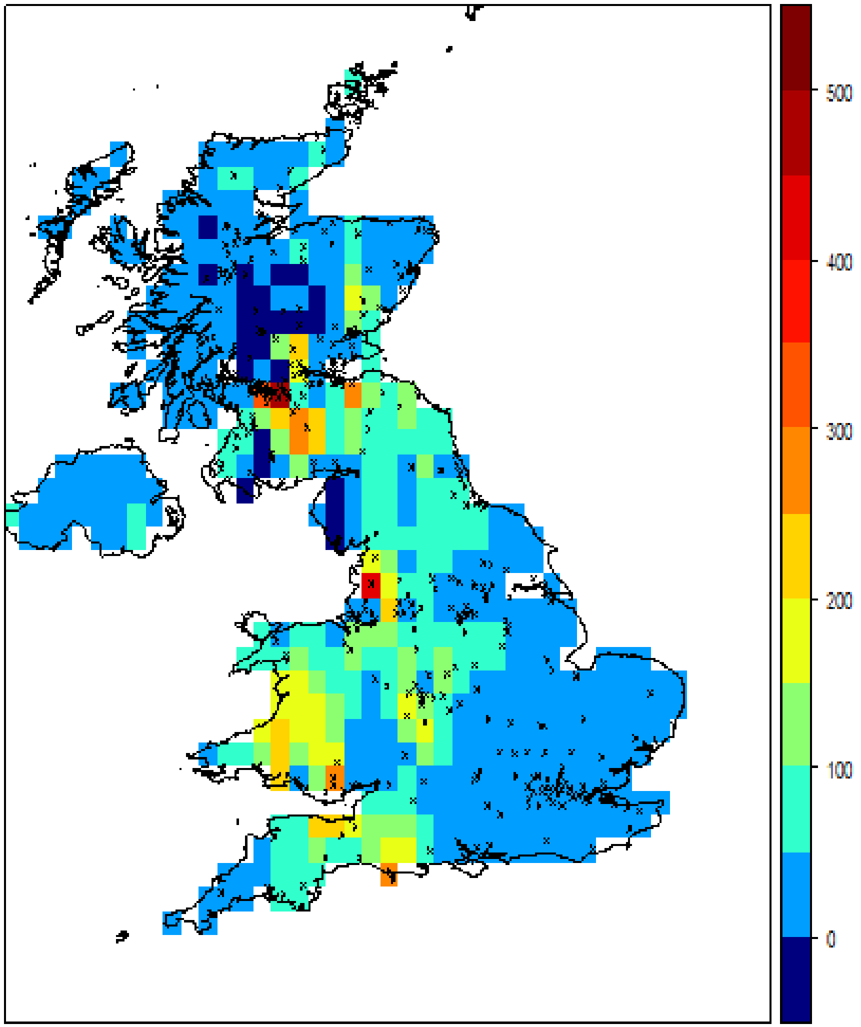
Key Historic Evidence



- 1859 Carrington Event: Largest known storm
- 1921 New York Railroad Storm: Damaged equipment and fires
- 1940 Easter Sunday Storm: First Power Grid effects
- 1989 Quebec Blackout: First major storm of the Electricity Grid Age, 2 NG transformers damaged
- 2003 Halloween Storm: Malmö, Sweden blackout. Transformers in South Africa damaged

Risk Factors

- Geographic Location
  - Further north
  - Geological structure – down to 800km
  - Coastal effects
  - Edge of system
- Length of lines
- Higher voltage
- Network topology
- Transformer design
- Backup transformers (redundancy)



National Grid: GIC estimate for one extreme scenario

Risk Levels of Possible Effects

from Severe Space Weather Event

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- Widespread damage/destruction of high voltage transformers
  - Major disruption to electricity network
  - Recovery time of years

Effectively zero chance

- Damage small number of transformers
  - Approx 13 transformers, 6 in E+W, 7 in Scotland
  - High financial impact on NG
  - Little impact on end customers
  - Replacement time: months

1 in 100 years

- Voltage and Harmonic effects
  - Local voltage collapse
  - High financial impact on local areas
  - Recovery time: 12 hours – 2 days

1 in 30 years

- Low level degradation of transformers
  - Increased failure rate

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Potential effects of space weather

- No propagation of GIC into distribution networks
- Any effects on distribution network
  - equivalent to power outage from any other cause
- Worst case scenario
  - mean of 13 supergrid transformers damaged
  - Roughly equal split between E+W and Scotland
- Possible prolonged loss of supply to 2 small substations
- UK seems more resilient than many systems at equivalent latitude


(Credit: K. Turnbull / J. Wild / ESA)

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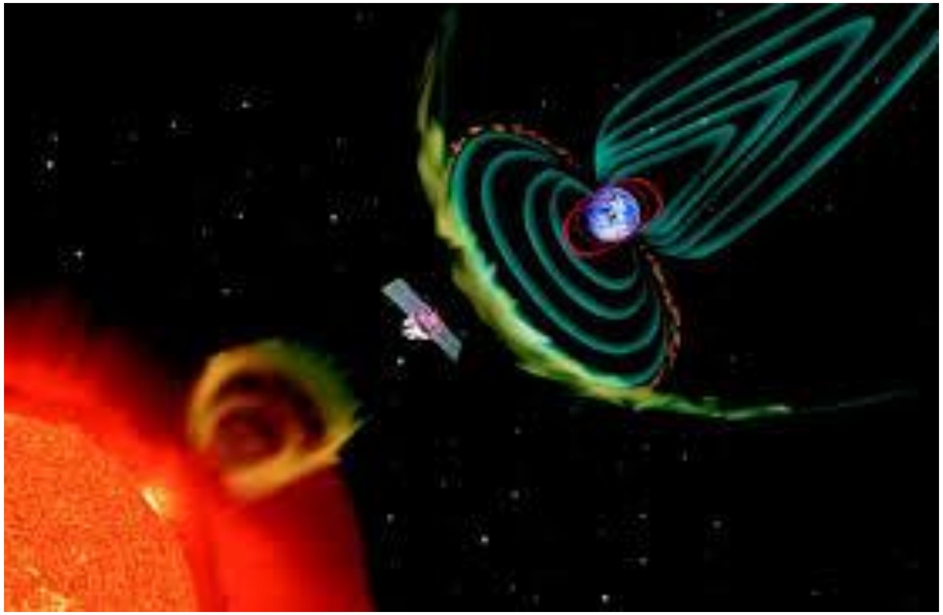
Mitigation Timescales

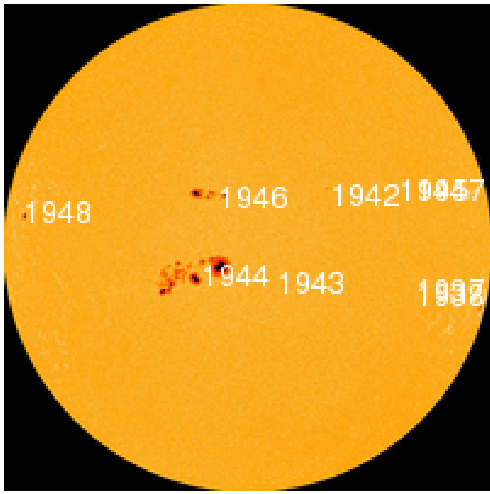
- National Grid requires 4 days to take its mitigating actions
- Space Weather Forecasting gives
  - Best case 24 hours notice
  - Worst case 10 hours notice
- National Grid has to take action before any actual warning from Space Weather Forecasters



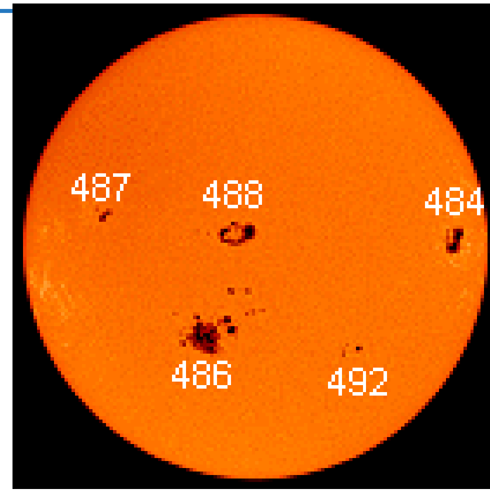
Build up to event and Warning schedule

- Day -5 onward
  - Observation of active sunspot group
    - Monitor all available space weather sources carefully
    - Initiate Silver Command structure
    - Issue Notification of Preparation for Geomagnetic Disturbance
      - Government, DNOs, Generators
    - Assess state of transmission system
      - Take any necessary early actions: recall circuits / halt outages
- Day -1
  - Observe CME
  - Issue Notification of Possible Geomagnetic Disturbance
  - Activate strategic mitigation plans
- T -15 minutes
  - Observe south-oriented Bz at ACE
  - Issue Notification of Expected Geomagnetic Disturbance and warning of system disturbance

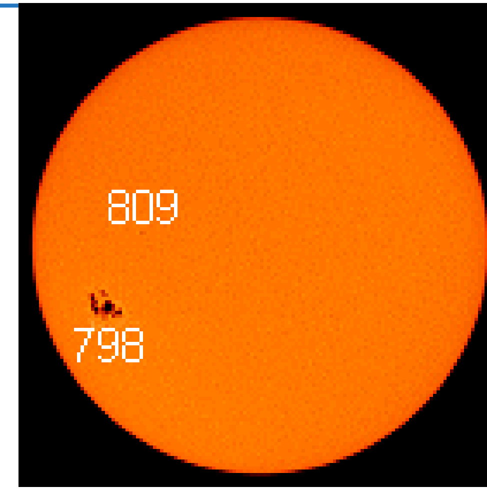
Sunspot Size



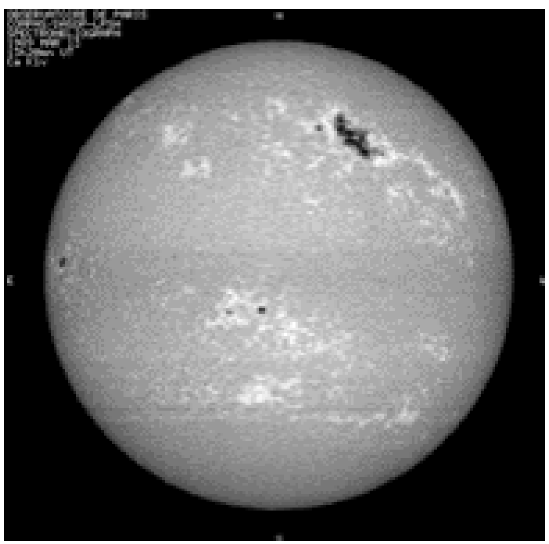
X1: 7 Jan 2014



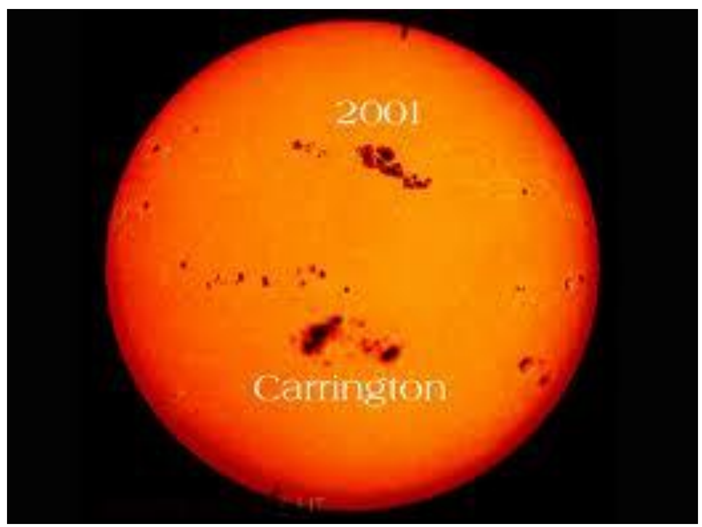
X17: 29 Oct 2003



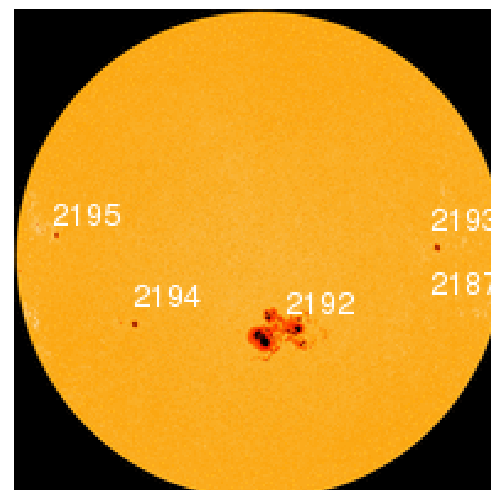
X17: 9 Sept 2005



X15: 12 Mar 1989



X1: 29 Mar 2001 and X28+ 29 Aug 1859



Many X1 – X3 flares: 18-28 Oct 2014

Categorisation of Disturbances

Category	Frequency	Description	Action
Category 1	4 or 5 per 11 year cycle	Media Interest. No effects on system	None
Category 2	2 or 3 per 11 year cycle	Minor Disturbance. Small voltage fluctuations seen on system.	MAGIC deployed. Heightened Awareness. Within NG normal working parameters
Category 3	1 per 11 year cycle	Storm. Voltage disturbances needing to be managed.	MAGIC deployed. Notice of system disturbance issued. Extra reactive power support. All transformers at high risk substations swithched in.
Category 4	1 in 30 year event	Major Storm. Very high reactice power demands. Likelihood of high voltage disturbance. Possibility of Bucholtz alarms on a few high risk transformers	DECC informed. Silver Command convened. All-in procedure. Circuits returned to service. All transformers connected. Extra generation synchronised. Extra reactive support. Interconnectors set to float.
Category 5	1 in 100 year event	Extreme storm. Carrington-like. Very high reactice power demands. Possibility of local voltage collapse. Likelihood of thermal damage to 10 - 20 transformers..	DECC informed. Silver Command convened. All-in procedure. Circuits returned to service. All transformers connected. Extra generation synchronised. Extra reactive support. Interconnectors set to float.

Space Weather Scale Comparisons

<table>
<tr><th>Kp Scale</th><th>NOAA G-Scale</th><th>National Grid Scale</th></tr>
<tr><td rowspan="4">Kp 9</td><td rowspan="4">G5</td><td>Category 5</td></tr>
<tr><td>Category 4</td></tr>
<tr><td>Category 3</td></tr>
<tr><td>Category 2</td></tr>
<tr><td>Kp 8 to 9-</td><td>G4</td><td rowspan="5">Category 1</td></tr>
<tr><td>Kp 7</td><td>G3</td></tr>
<tr><td>Kp 6</td><td>G2</td></tr>
<tr><td>Kp 5</td><td>G1</td></tr>
<tr><td>Kp < 5</td><td></td></tr>
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Any Questions