



# A Solar Superstorm – What If?

EDTAS 2015  
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# Risk Frontiers



An independent R&D not-for-profit company based at Macquarie University, located in Sydney and Melbourne. Created in 1994 to

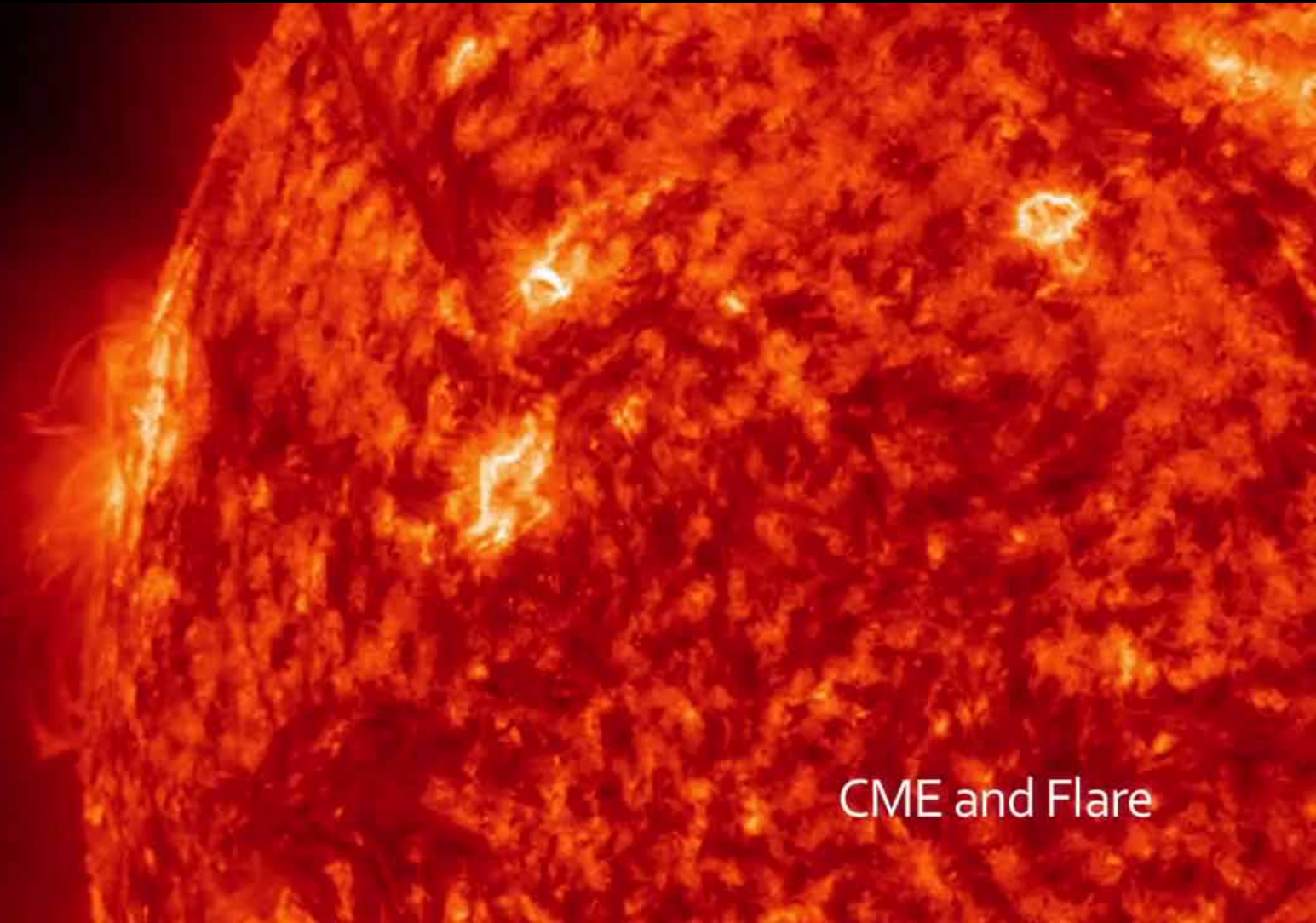
- undertake research and consultancy projects to understand disaster risks and their impacts on property and people
- develop Catastrophe loss models to improve the pricing of impacts of natural hazards for re/insurance
- improve decision making and policy in respect to the management of disaster risks through social and disaster management research

# Dirty Grey Swans?



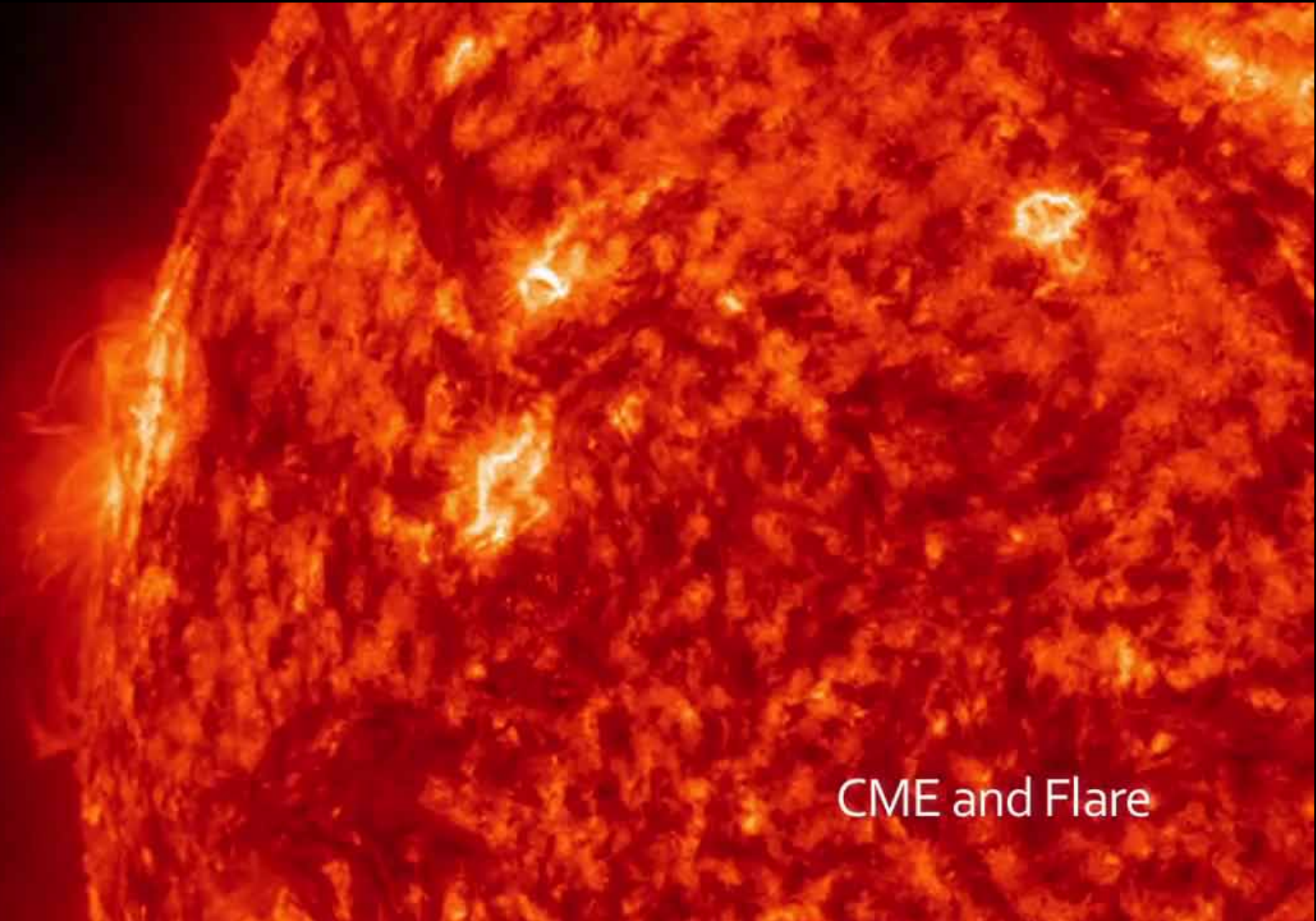
- Wild Cards?
- Future Shocks?
- Black Elephants?
- Pear Shaped Phenomena?

# The Sun



CME and Flare

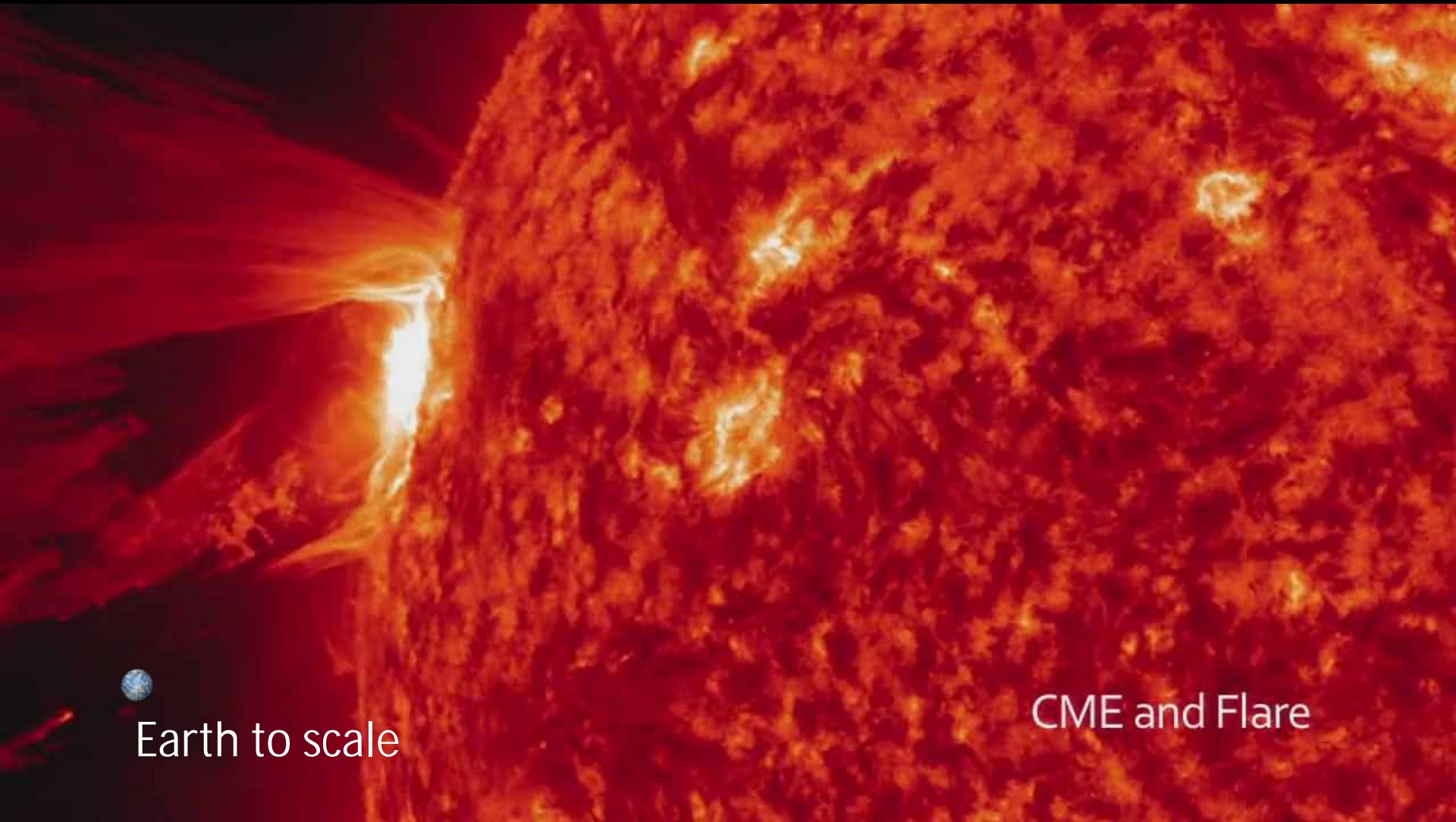
# The Sun



CME and Flare



# The Sun



Earth to scale

CME and Flare

# Effects at Earth



- Different variations in the solar wind have different effects at Earth

## NOAA Space Weather Scales

Solar Radiation	Radio	Geomagnetic
S5	R5	G5
S4	R4	G4
S3	R3	G3
S2	R2	G2
S1	R1	G1

Extreme

Severe

Strong

Moderate

Minor

Flare



SEPs



CME



# Effects on Us



- Unusual natural hazard – mostly direct effects on our Technology only



- Effects on power, aviation, satellites, communications,...



- This is a serious risk in our ever more connected society





# Timeline



Solar Flare(s)

CME arrives at earth - geomagnetic effects

SEPs protons and ions - radiation effects

X-Rays

Earth's radiation belt effects

0  
15 minutes

15 hours

1 day

2 days

3 days

Loss of signal, less frequencies, more interference



SEUs, radiation, surface charging



Dose, disruption



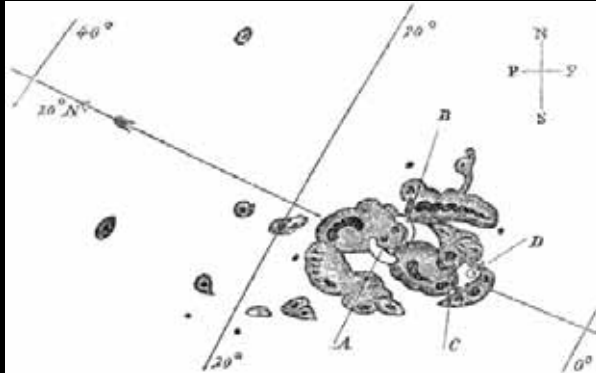
Loss of lock, reduced accuracy



Transformer heating, voltage instability



# It's happened before...



1859 - The Carrington Event

1921 - The New York Railroad storm

**SUNSPOT CREDITED  
WITH RAIL TIE-UP**  
*New York Central Signal System  
Put Out of Service by Play  
of Northern Lights.*

The sunspot which caused the bril-



1989 - The Quebec Blackout

2003 - The Halloween Storm

# What are the chances?

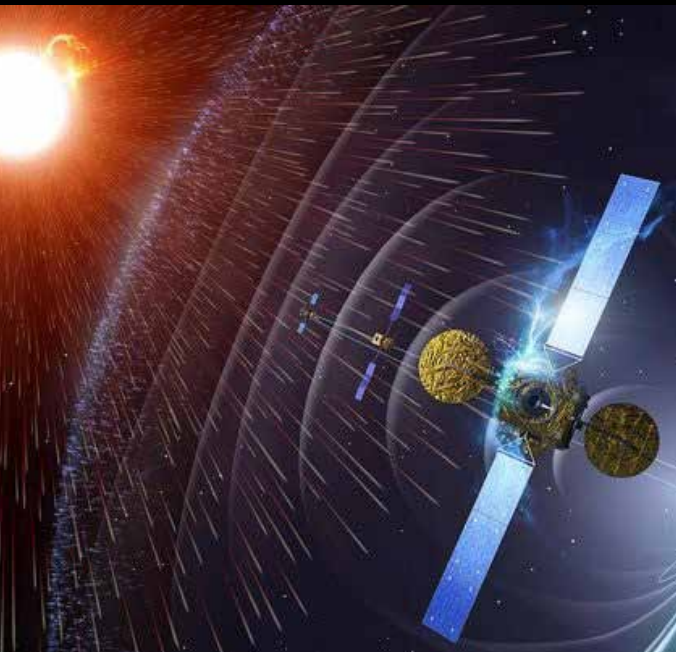


- How likely is a Carrington-class event?
- Riley 2012 – 12% in a decade
- Love 2012 – 6% in a decade
- UK Risk Register 1-in 100 to 1-in-200 year event
  
- Not 'if' but 'when'

# Technology Effects



- HF communications inoperable
- L-band satellite communications unavailable or poor quality
- Aviation, Shipping affected

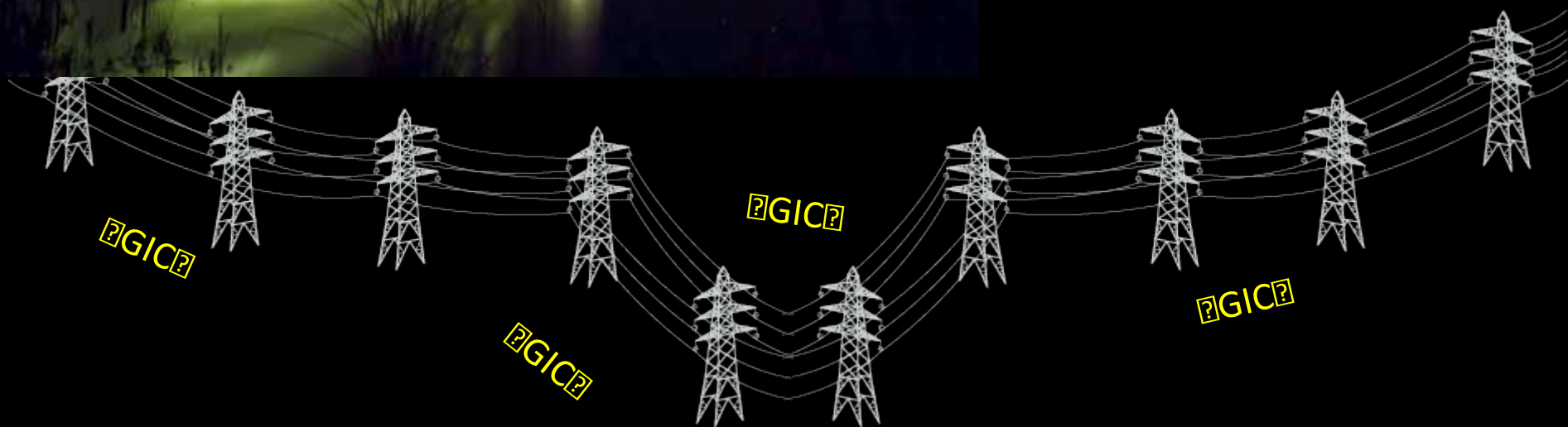


- Expected that 10% of satellites will have outages of hours to days
- GPS outages and position errors
- Users of GPS timing signal affected – banking, trading, network sync.

# Effects on Power



Power Transformers

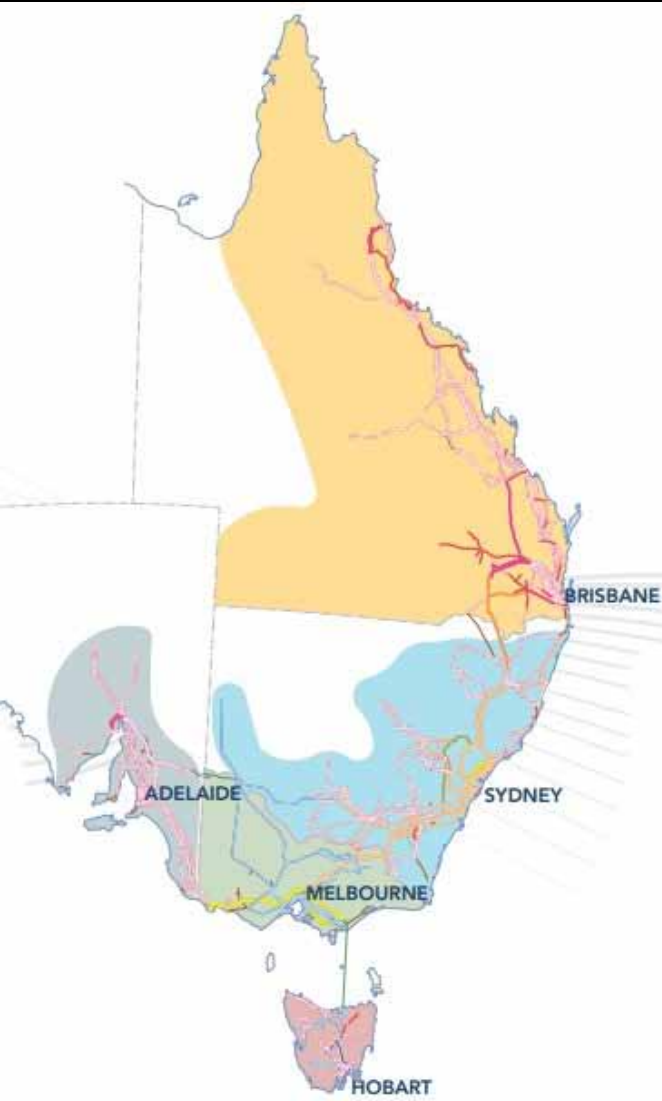




# Transformer Damage?

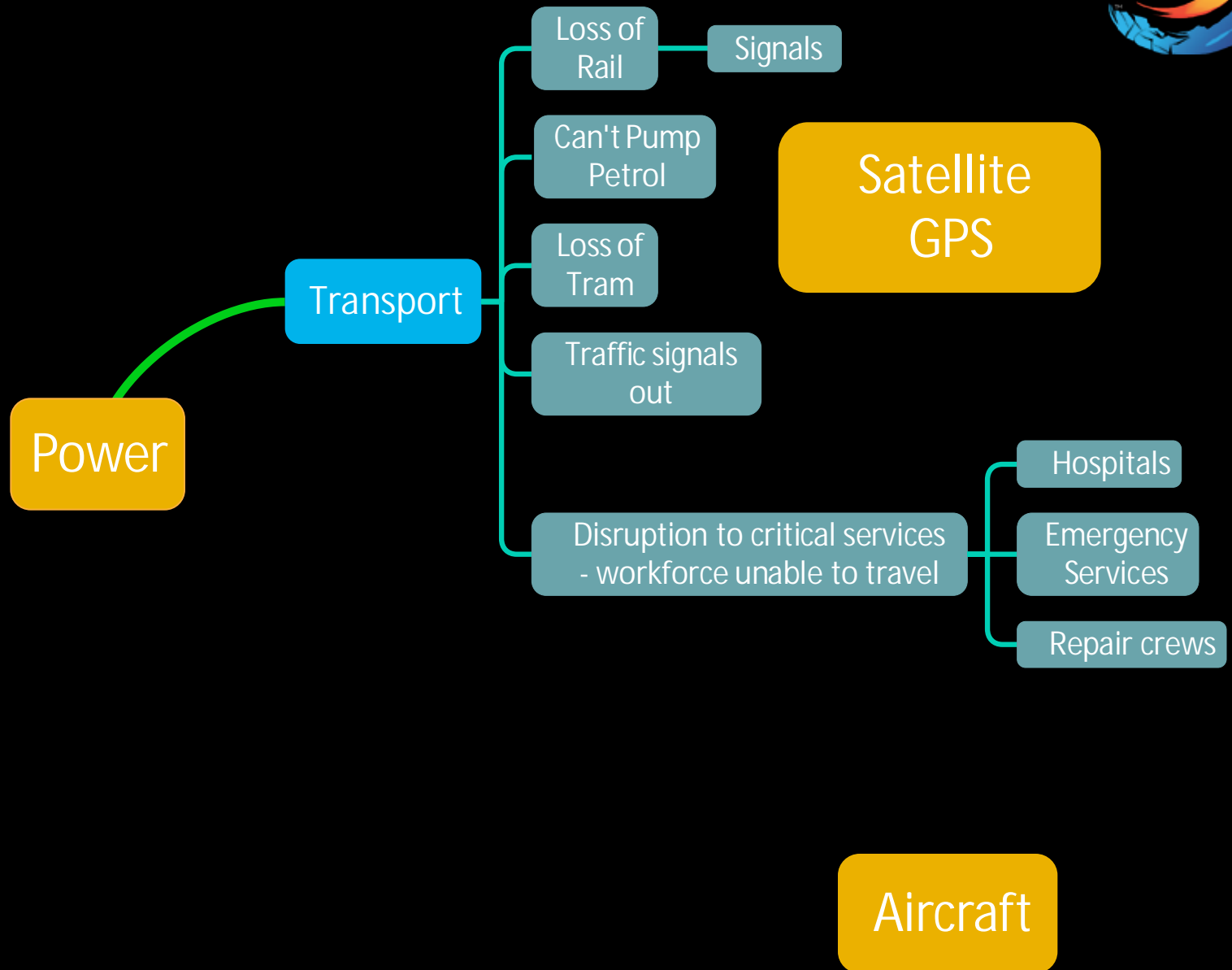


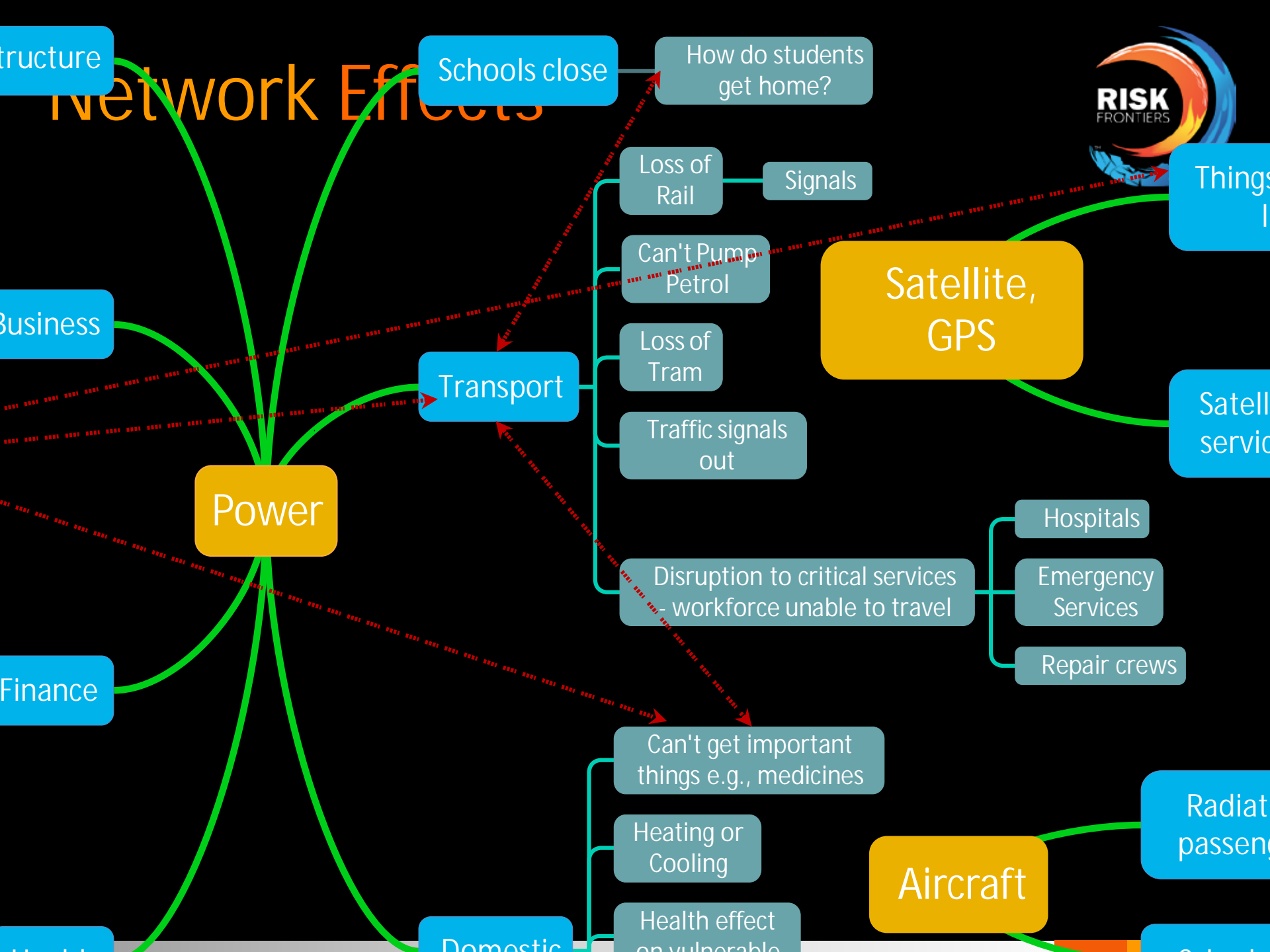
# Energy Market



- Local Grids joined together in a National Energy Market
- ...creating even longer conductors susceptible to GICs
- AEMO to instruct component grids in case of extreme events
  
- Outages at grid "weak spots" likely
- Metropolitan outage unlikely but not impossible
- Total grid collapse highly unlikely

# Network Effects





# Network Effects

Power

Structure

Business

Finance

Health

Schools close

How do students get home?

Loss of Rail

Signals

Can't Pump Petrol

Loss of Tram

Traffic signals out

Transport

Disruption to critical services - workforce unable to travel

Hospitals

Emergency Services

Repair crews

Can't get important things e.g., medicines

Heating or Cooling

Health effect on vulnerable

Domestic

Satellite, GPS

Things...

Satellite service

Aircraft

Radiat...  
passeng...

Other...



# Costs?



- US National Academy of Sciences Report 2008  
\$1-2 trillion USD
- Lloyd's of London report 2013  
\$0.6-2.6 trillion USD
- What would be the cost to Australia?



# Understanding the risk



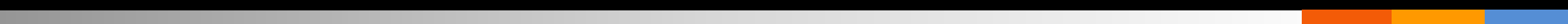
- What are the services that are most critical to the functioning of the community?
- Do the services have adequate plans for interruption?
- How would these critical services be coordinated, prioritised and warned of an impending incident?
- How would scarce resources to support critical services, such as fuel and power be coordinated?
- What is the public communication strategy?
- What is the strategy for vulnerable People?

Global Consequences → “Everyone for themselves”

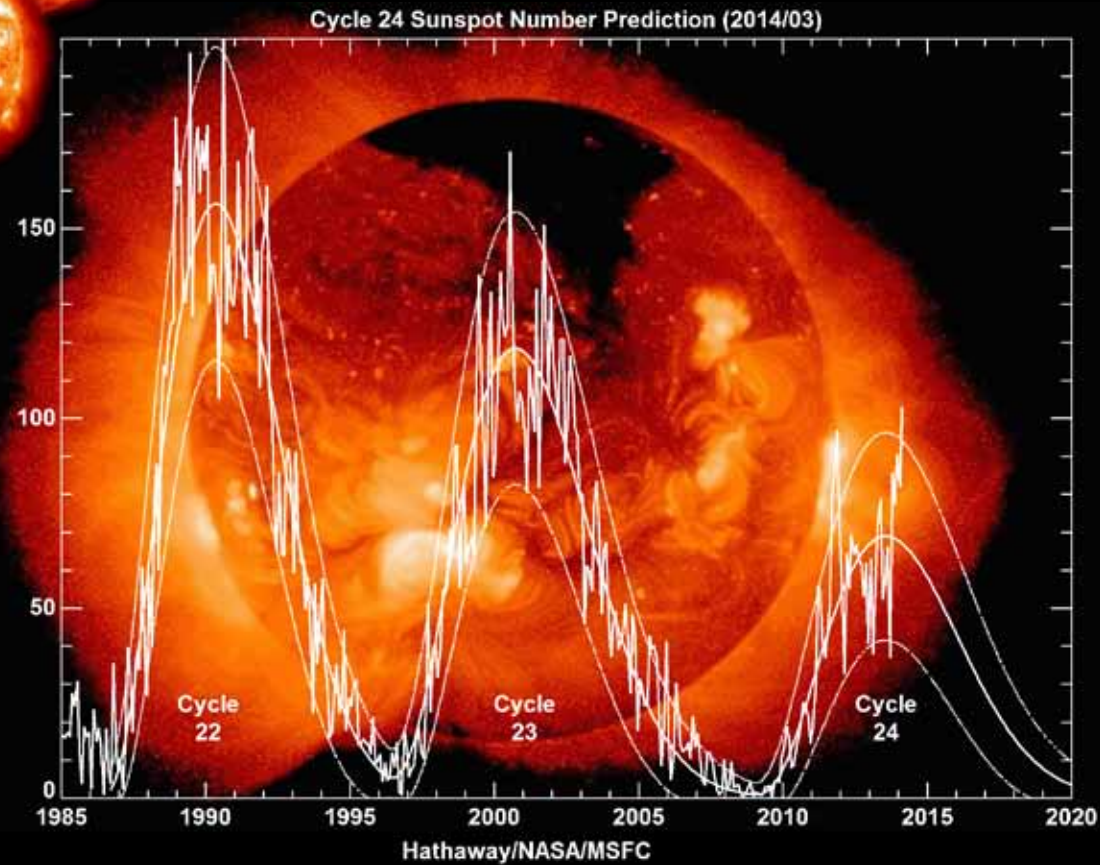
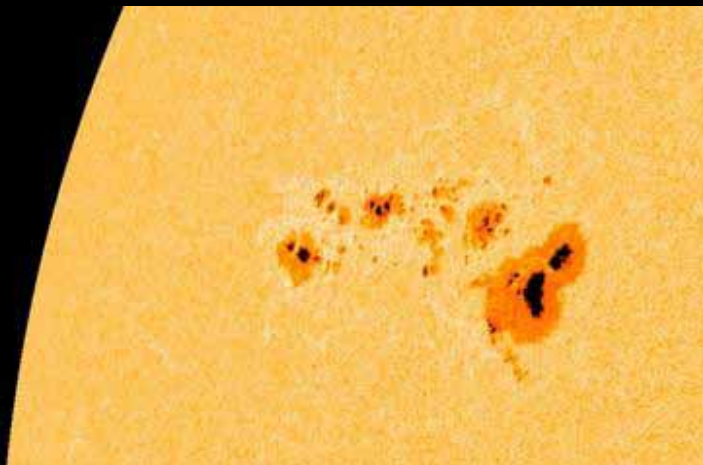
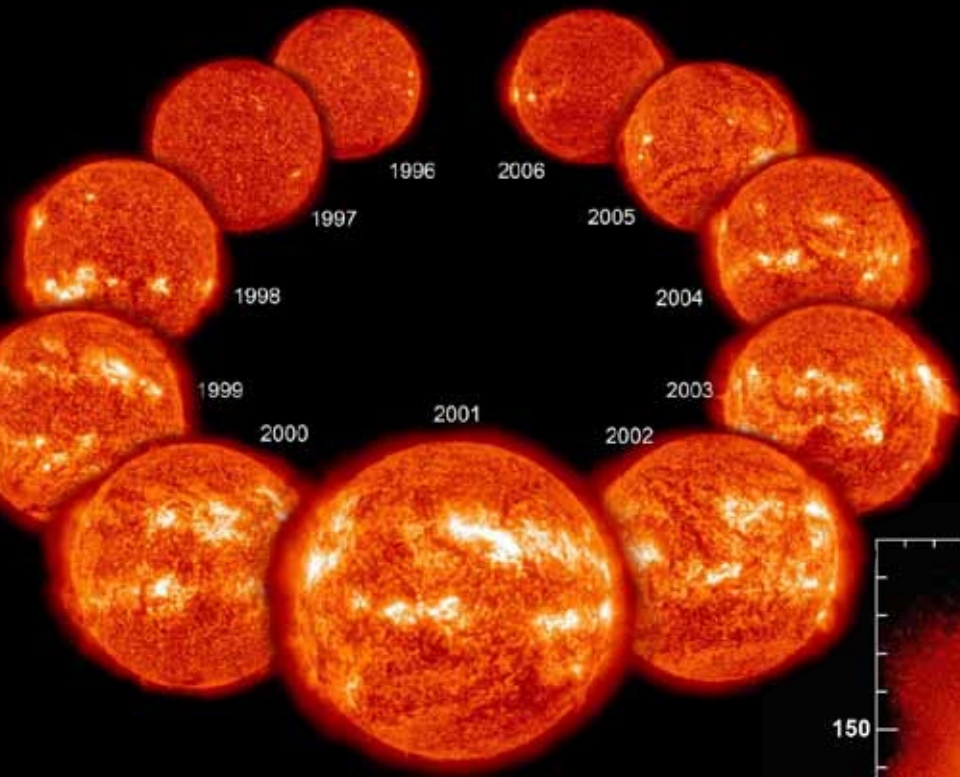
# Summary



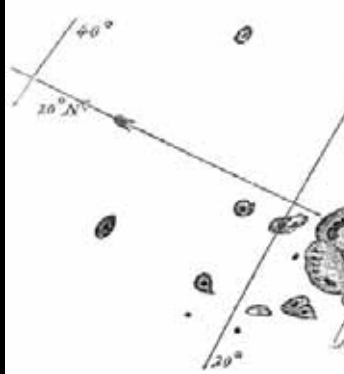
- A Solar Superstorm would have severe effects on our Technology
- Risk increases with technology dependence
- They have happened in the past
- They should not go unanticipated
- Policy and planning should be developed



# Solar Cycle



It's happen



Carrington



The Carrington Event

SUNSPOT CREDITED WITH RAIL TIE-UP

New York Central Signal System Put Out of Service by Play of Northern Lights.

The sunspot which caused the bril-



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WAKEDRAMA / ZONINGMEDIA PRESENTS THE CARRINGTON EVENT DIRECTED BY ROB UNDERHILL

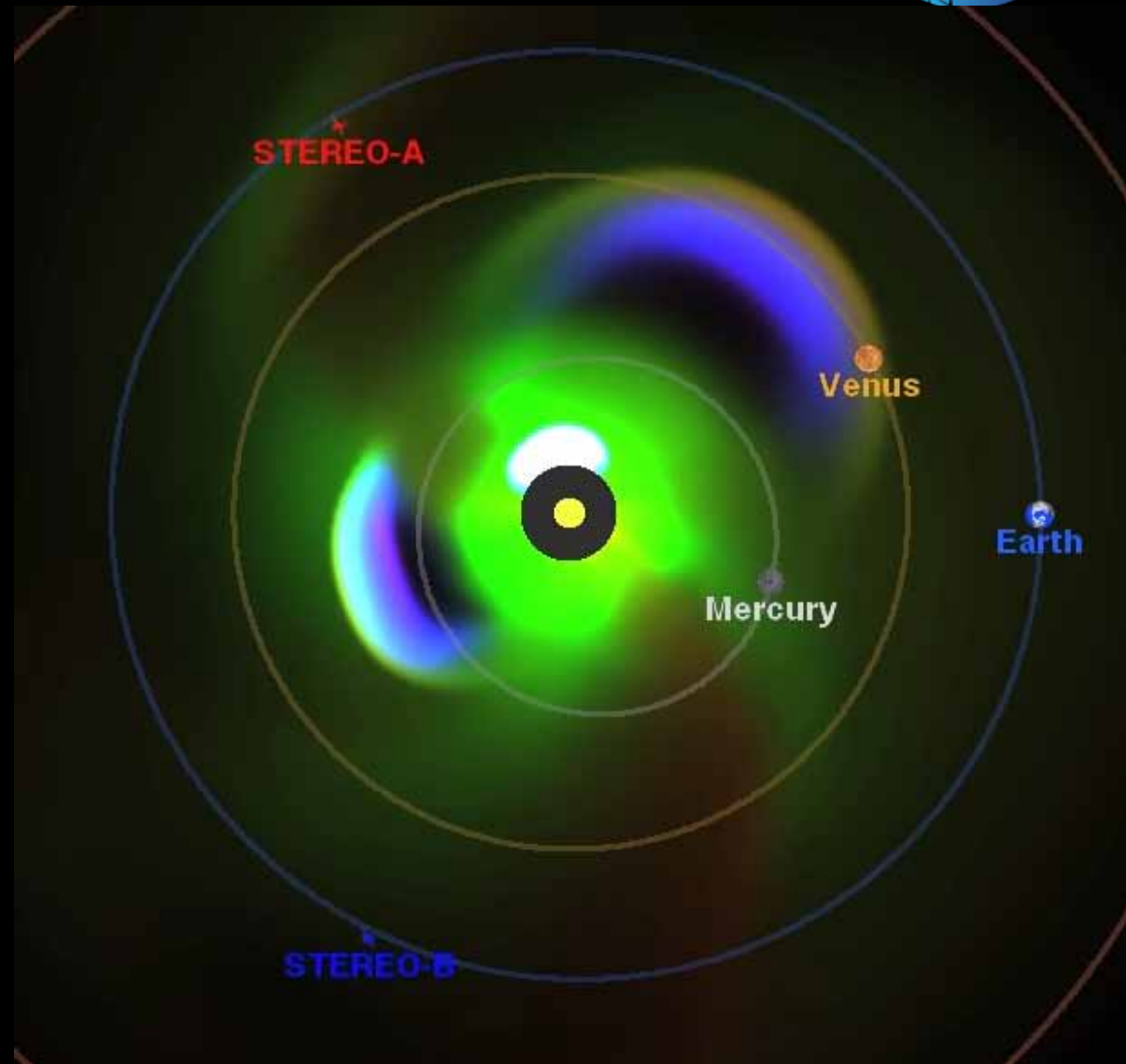
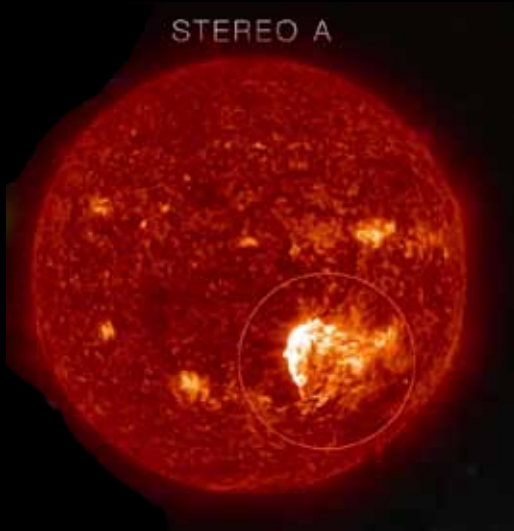
WWW.THECARRINGTONEVENT.COM

en Storm



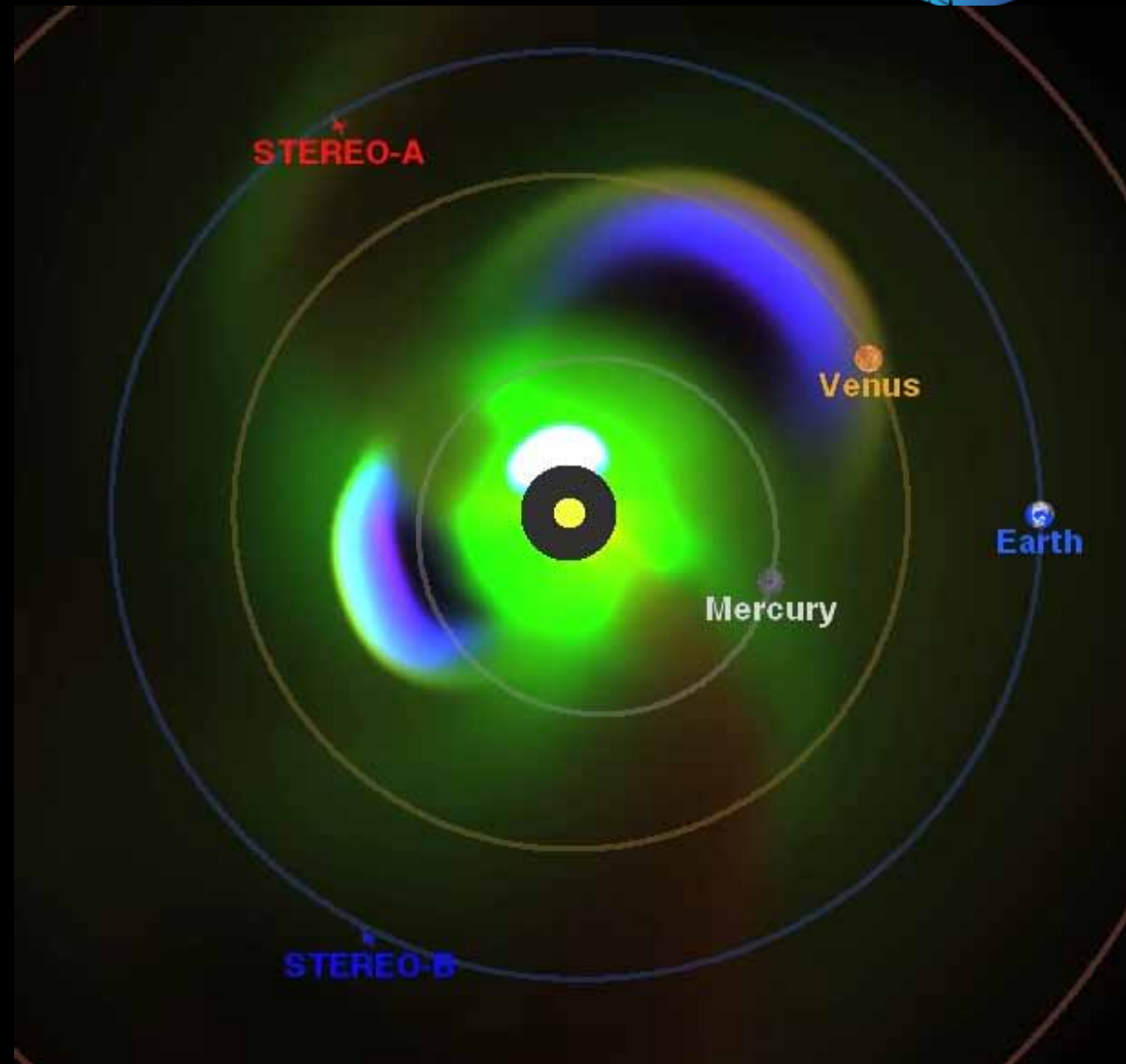
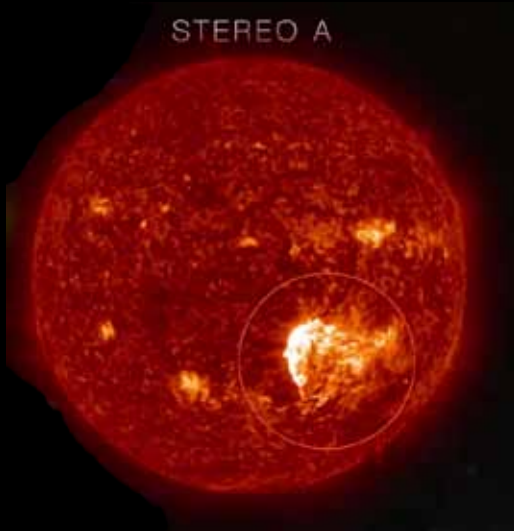
# Near miss

July 2012



# Near miss

July 2012

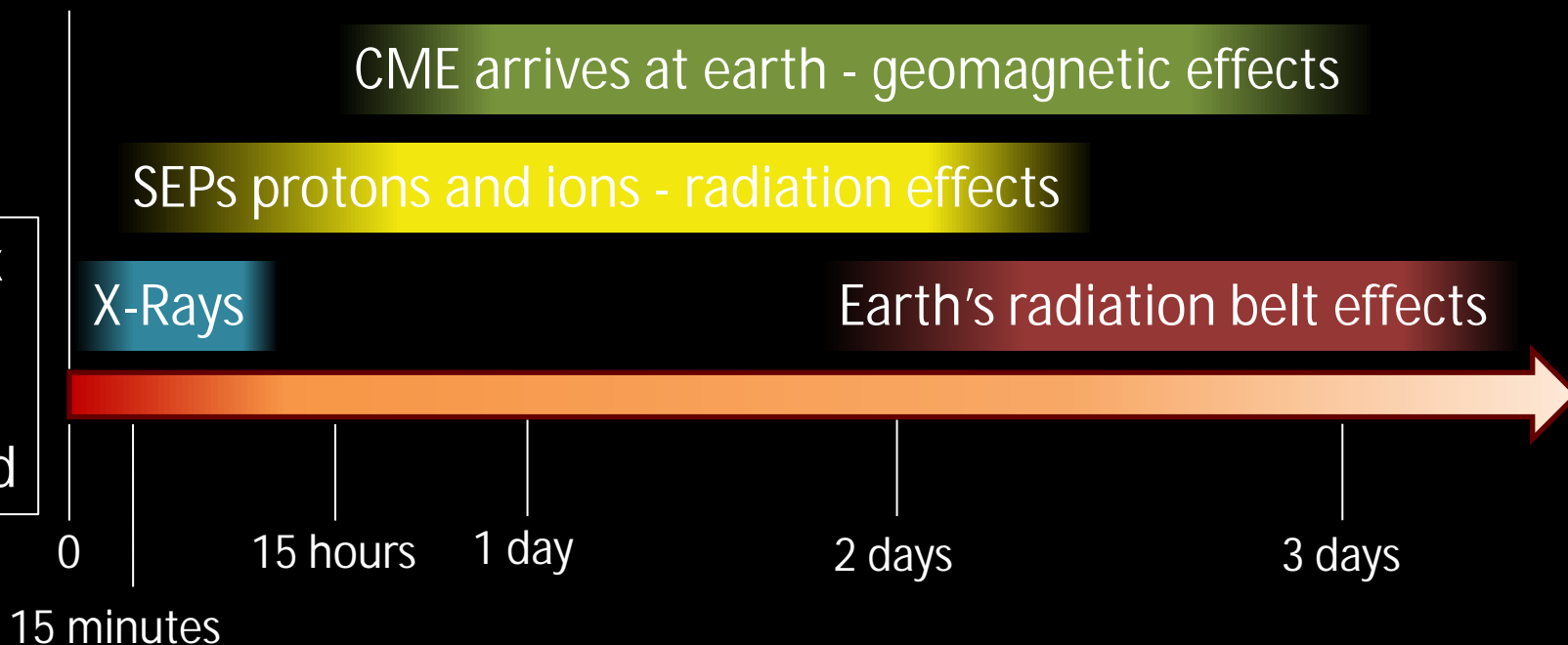


# Timeline



Solar Flare(s)

Complex sunspot groups observed



# Effects on Communication



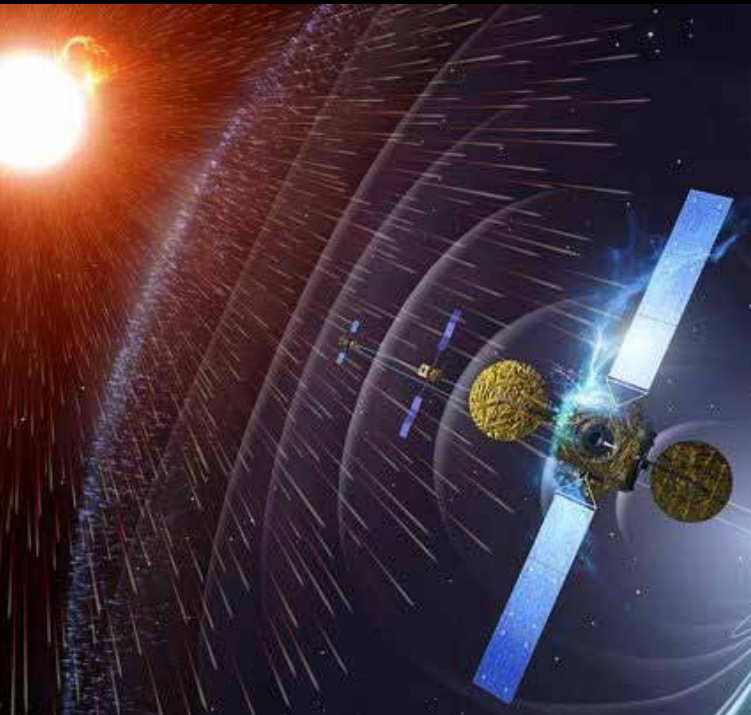
- HF communications (shortwave) likely to be inoperable for several days
- L-band satellite communications (satellite phones) might be unavailable or provide poor quality

Communications affected for:

- Aviation
- Shipping



# Effects on Satellites

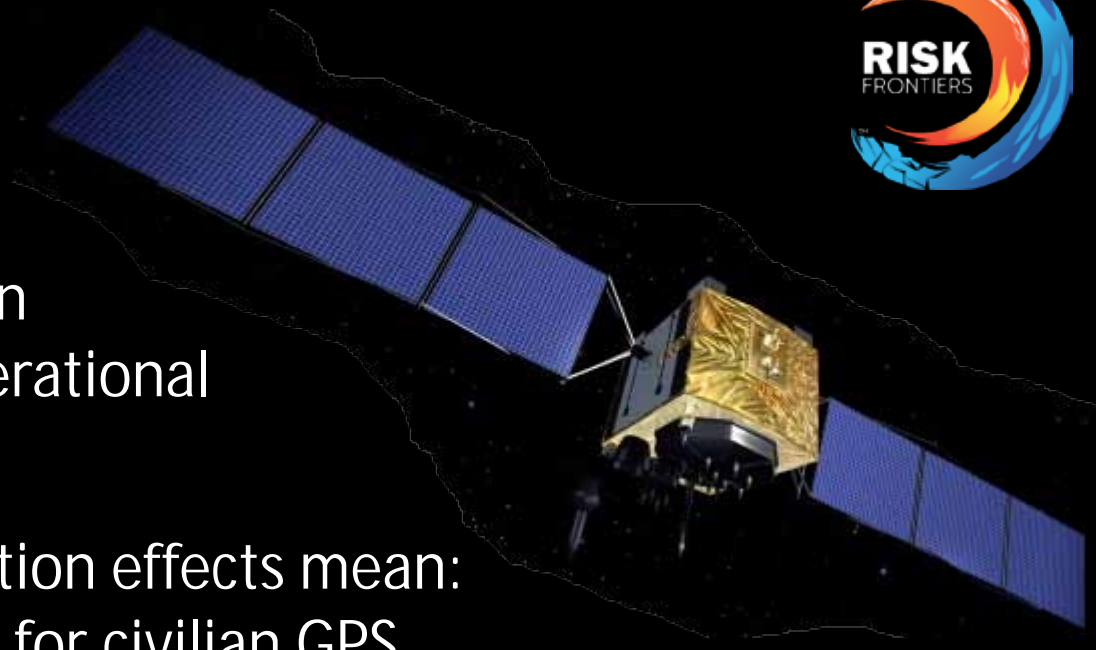


- Single Event Upsets from SEPs
- Surface Charging
- Orbital decay especially for LEOs
- Satellites switching to 'Safe Mode'

Expected that 10% of satellites will have outages of hours to days



# Effects on GPS



- Likely enough satellites in constellation remain operational
- Ionospheric and scintillation effects mean:
  - Loss of lock or errors for civilian GPS
  - Loss of service for commercial precision GPS
- Implications for:
  - Aviation, shipping,...
  - Users of timing services: banking, trading, network sync,...

# Effects on Aviation



- Possible loss of communications – satellite and HF
  - Possible loss of precision navigation – GPS
  - Trans-polar routes diverted
  - Major schedule disruption expected
- 
- Increased radiation dose to passengers and crew
  - Community concern post event



# Monitoring and Forecasting



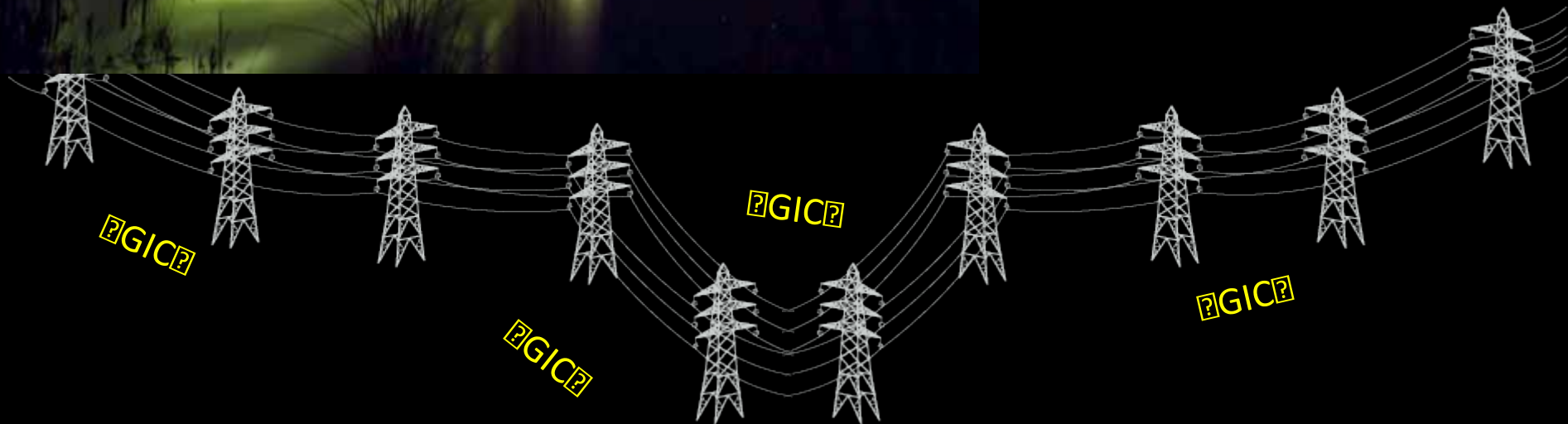
- Many ground based observatories
- ACE and DSCOVR craft



# Effects on Power



Faraday's law



# Effects on Power



GICs cause Power Transformers to operate anomalously.

This causes:

- Rapid core heating, shut down, permanent damage
- Grid voltage instability → voltage collapse → blackout
- AC waveform distortion → shuts down voltage support equipment → collapse more likely



Power Transformers



SVARs