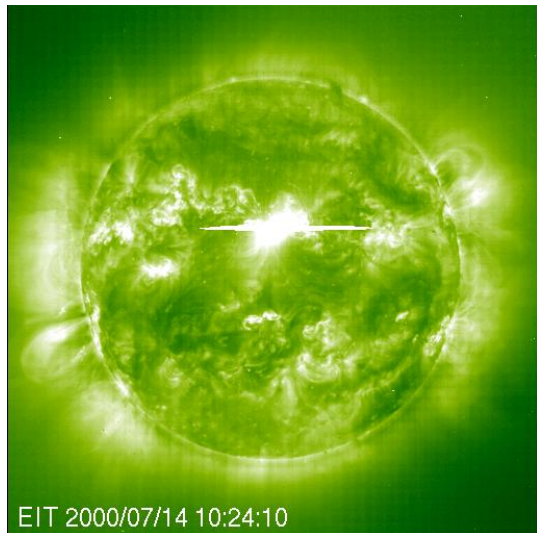




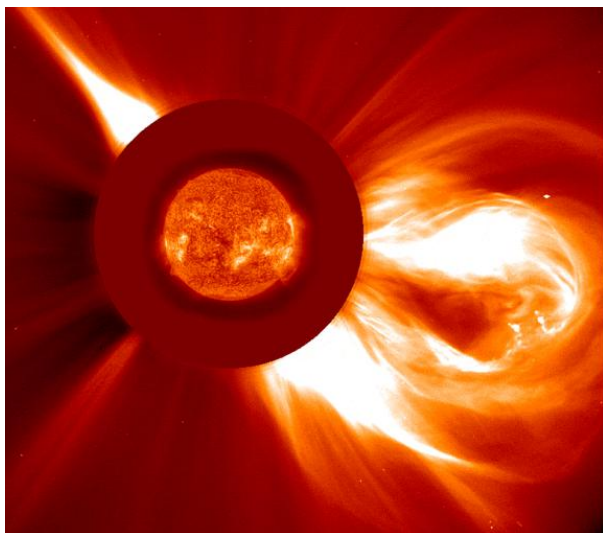
# Impact on Aviation: Severe Space Weather and EMP

Captain Bryn Jones  
CEO SolarMetrics Limited  
[bryn.jones@solarmetrics.com](mailto:bryn.jones@solarmetrics.com)

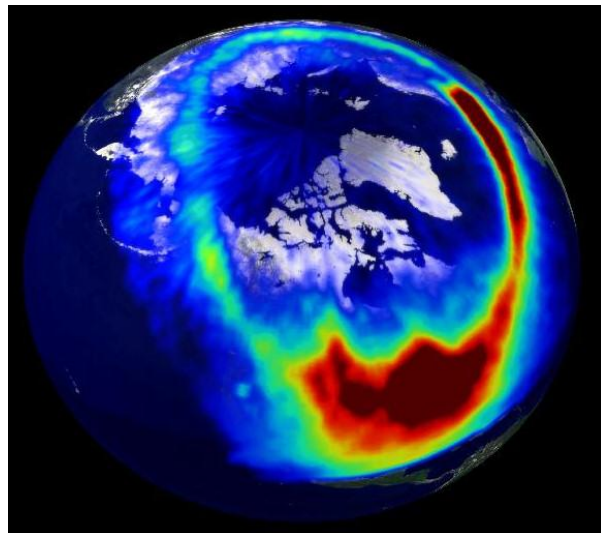
# Solar Storms: Space Weather Hazards



Solar Flares



Coronal Mass Ejections  
(CMEs)



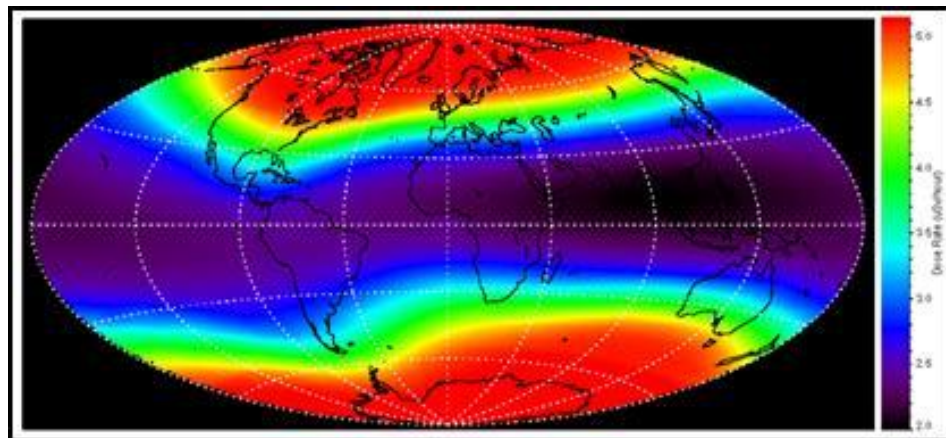
Geomagnetic Storms

Interested in....

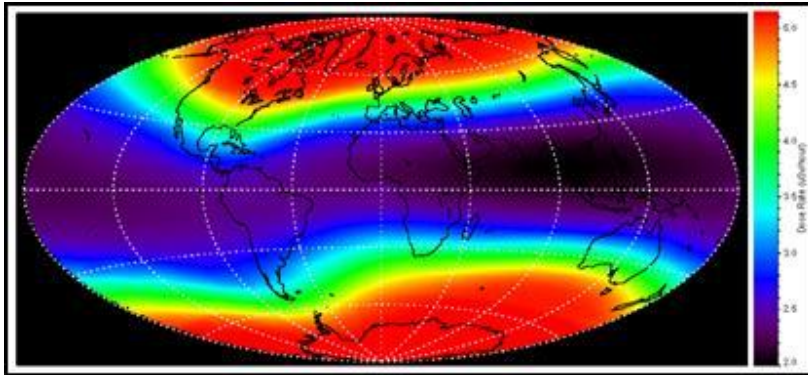
- High energy solar outputs
- Magnetic orientation

& effect upon....

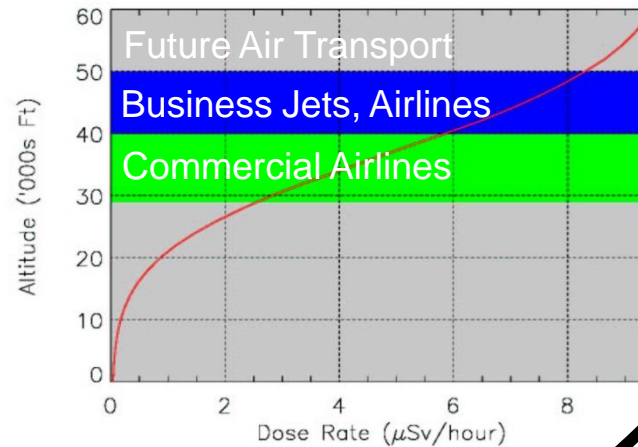
- Radiation environment
- Technology & operations



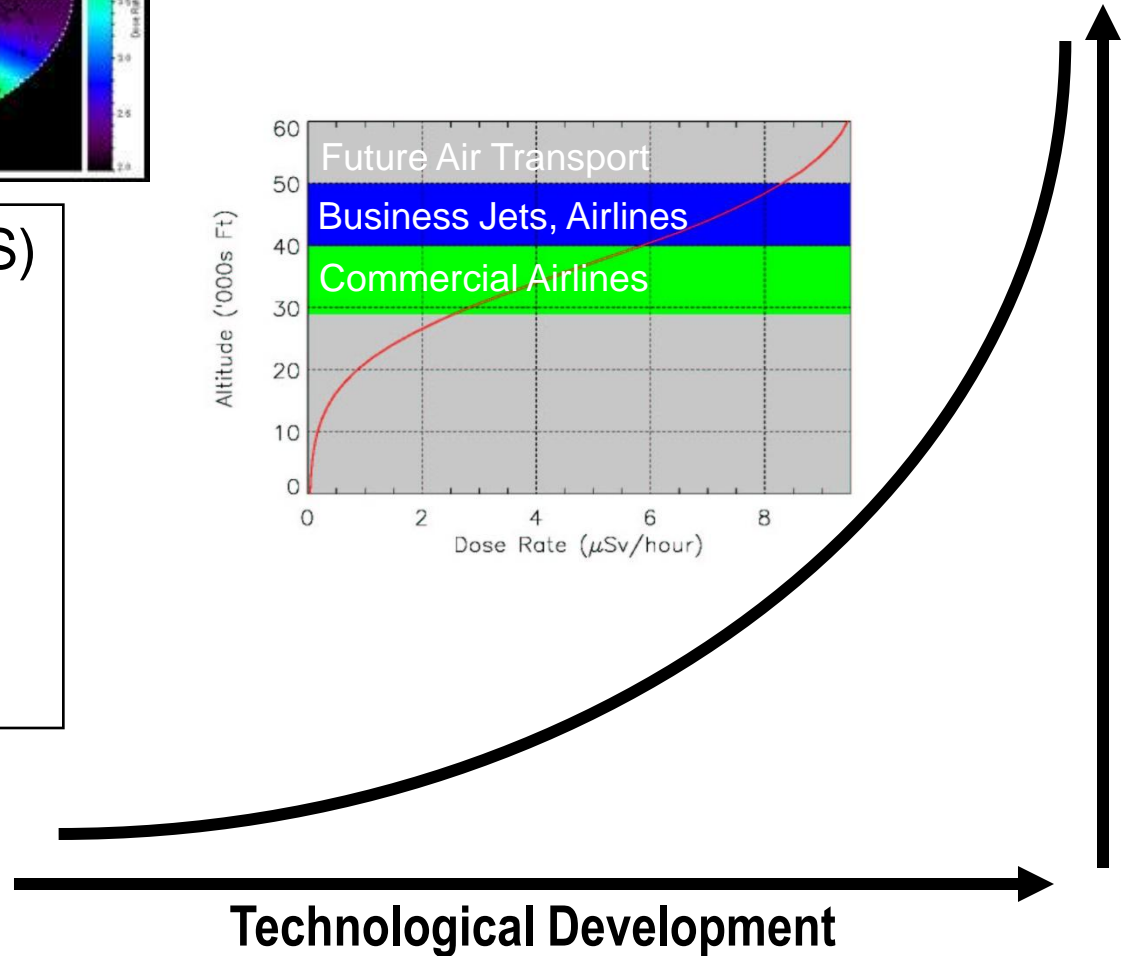
Dose rate @35,000ft from background cosmic radiation



- Satellite navigation (GPS)
  - Position errors
  - System availability
- Communications loss
- Avionics upsets/failures
- Human exposure



Vulnerability



Technological Development



## WAAS Outage

Oct 2003

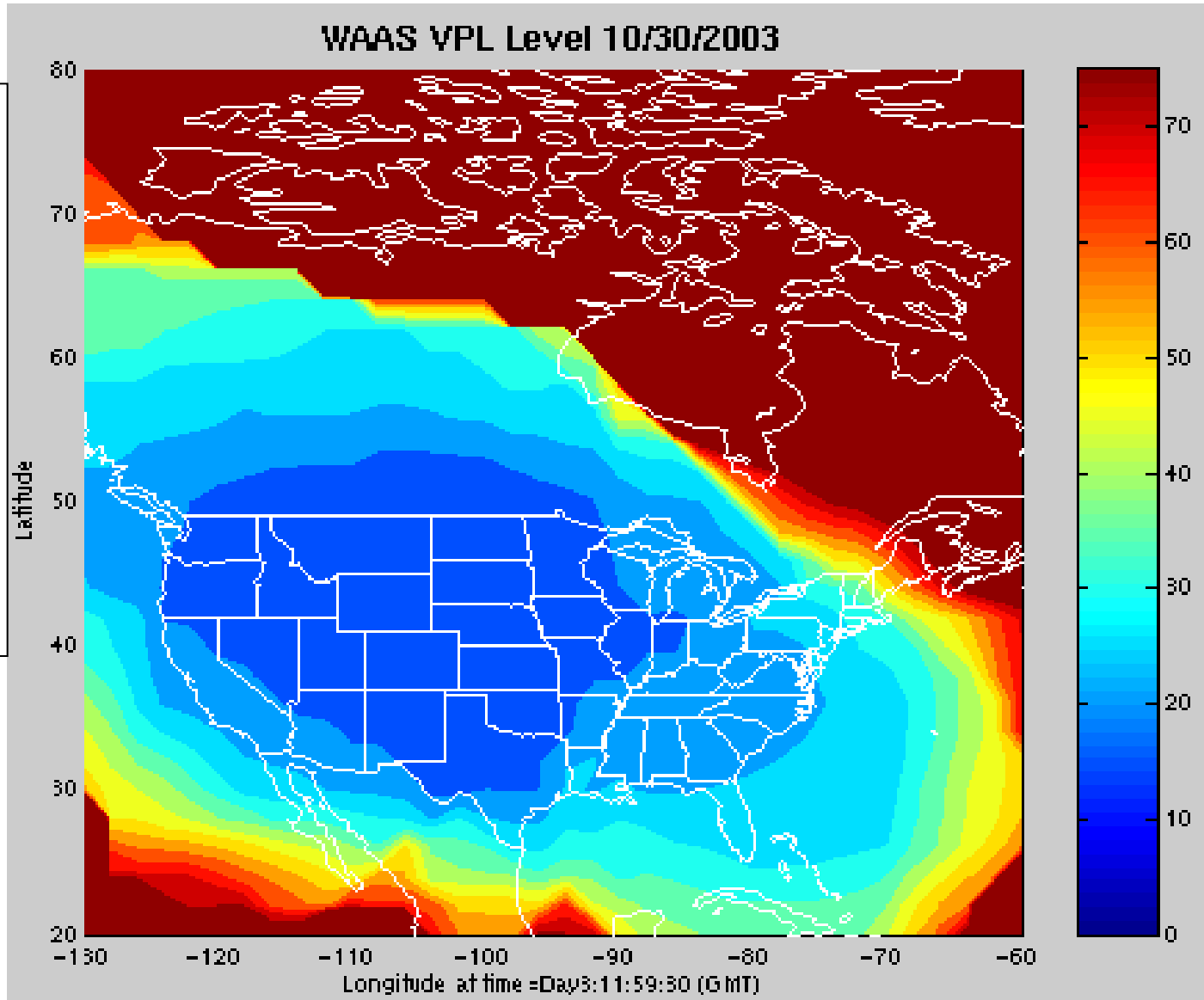
- 15 hours

Nov 2003

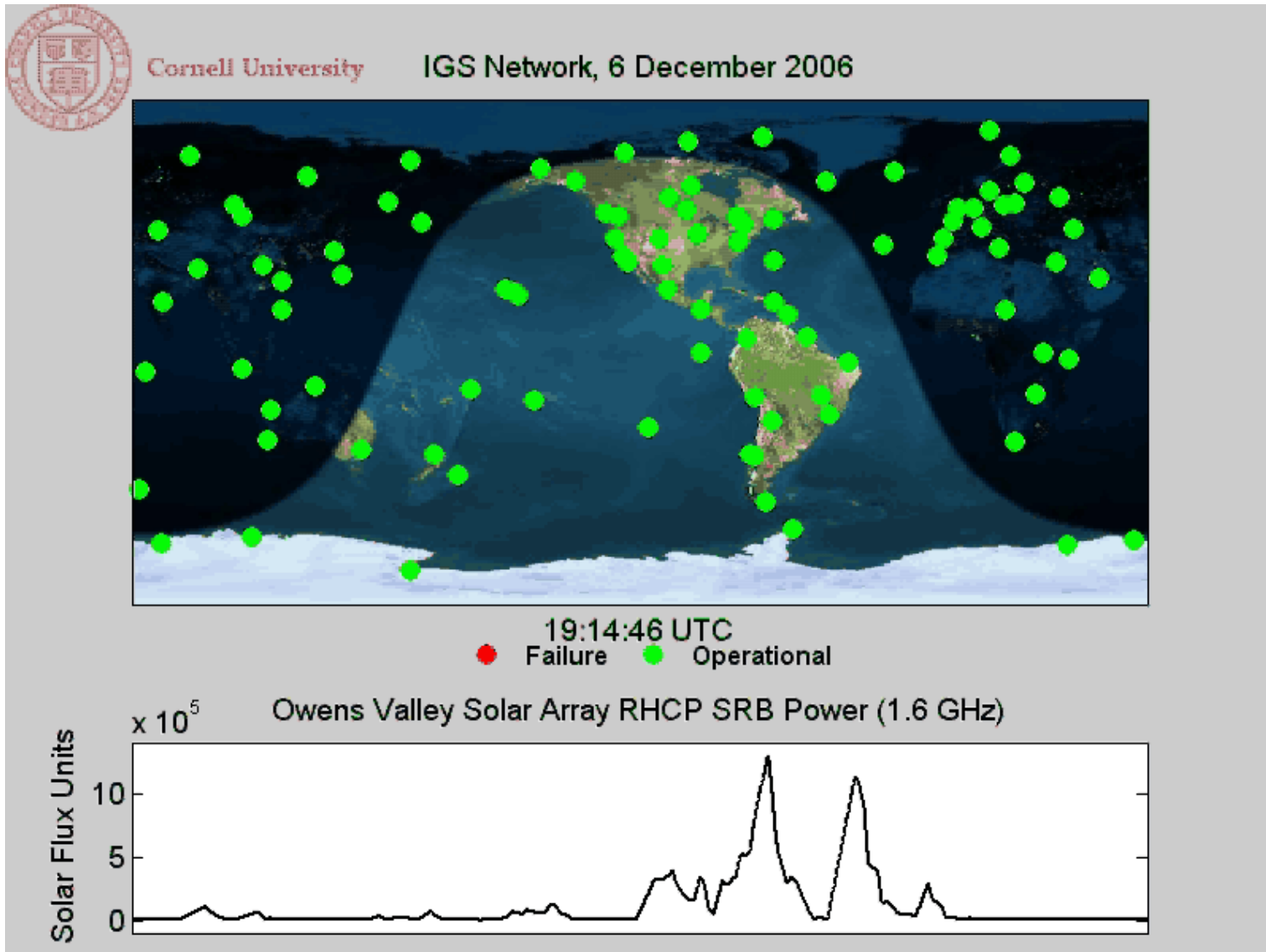
- 10 hours

Apr 2010

- Galaxy 15 lost



# Impact on Aviation: GPS outage

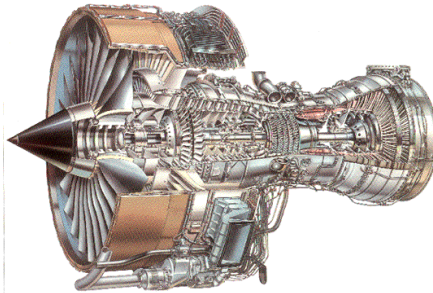


# Impact on Aviation: Avionics



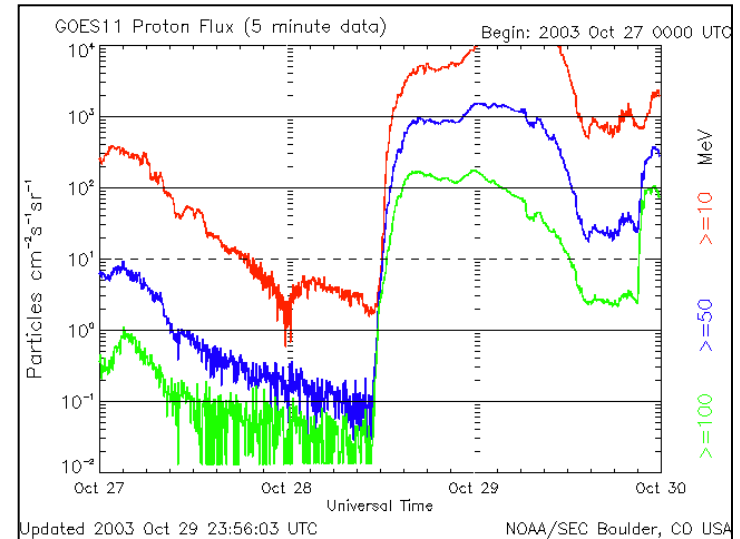
## Avionic upsets, failures

- Fewer radhard components
- More advanced electronics = more susceptibility



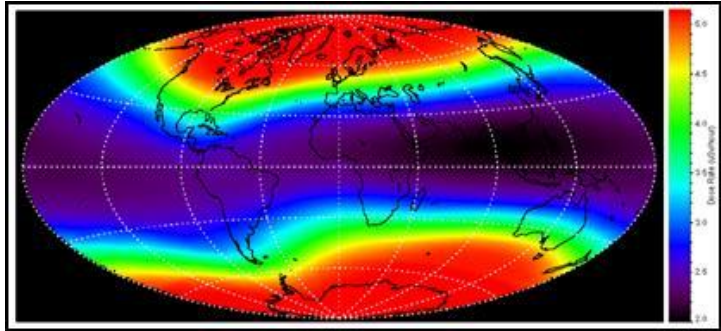
## Upset rate/hr in memory chip (avg 2.5/hr) (Dyer et al)

- Sep 1989 – 84.7/hr
- Feb 1956 – 493/hr
- Sep 1859 – ?





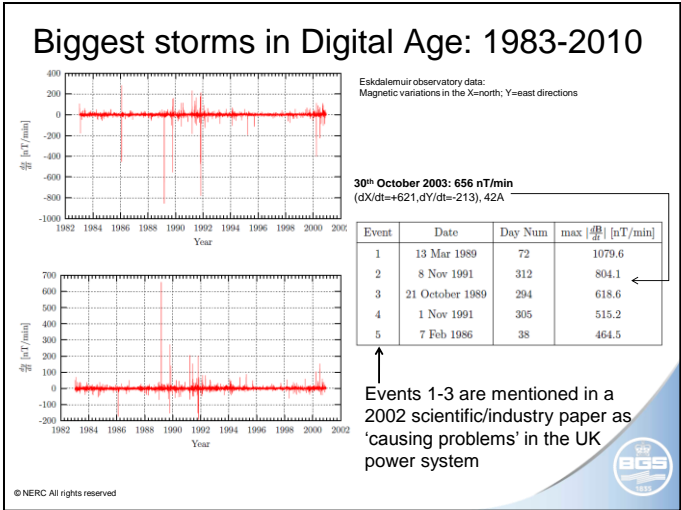
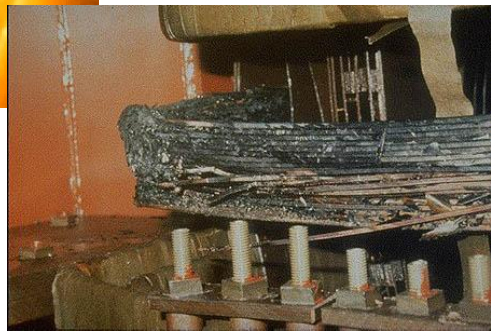
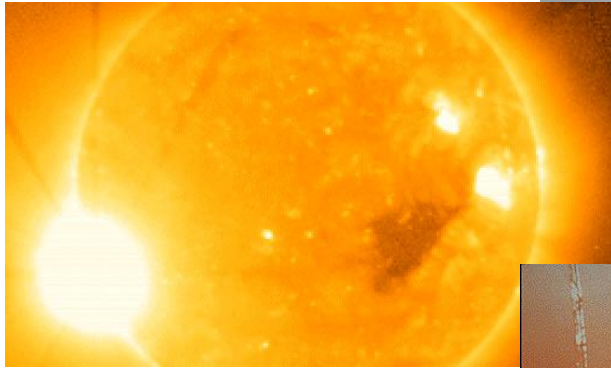
# Impact on Aviation: Ordinary v Severe Doses



Calm(!) radiation environment  
London – Los Angeles 0.065mSv



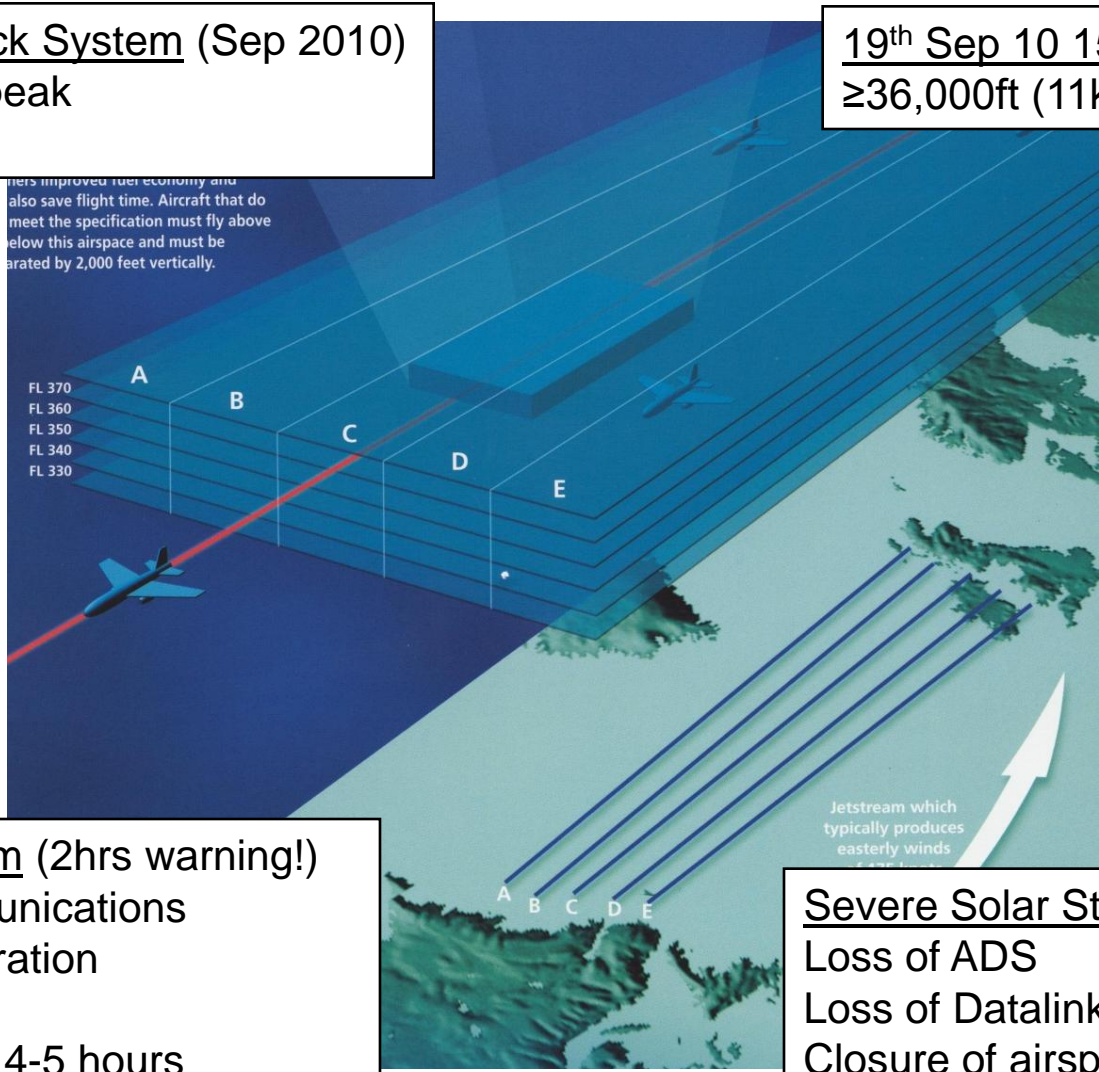
Solar Storm Doses (Dyer et al.)  
Jul 2000 – 0.031mSv  
Oct 1989 – 0.25mSv  
Sep 1989 – 1.33mSv  
Feb 1956 – 2.27mSv  
Sep 1859 – ?



# Impact on Aviation: Operations, Safety

North Atlantic Track System (Sep 2010)  
 110 aircraft/hour peak  
 1200 aircraft/day

19<sup>th</sup> Sep 10 15:30  
 ≥36,000ft (11km) - 41 aircraft



Strong Solar Storm (2hrs warning!)  
 Loss of HF communications  
 Double time separation  
 ~ 40 aircraft/hour  
 Severe disruption 4-5 hours

Severe Solar Storm  
 Loss of ADS  
 Loss of Datalink communications  
 Closure of airspace

## Polar Routes – Economic Drivers

Polar 3 (Flight time: 14:32)  
316 Pax  
2200kg (5000 lbs) Cargo

Russia (15:41)  
246 Pax  
No Cargo

NOPAC (17:18)  
No Pax  
No Cargo



2005 - \$186M extra fuel used due space weather

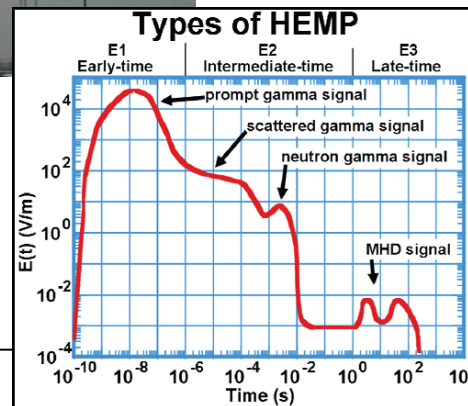
# Impact on Aviation: EMP

Most electronic reliant transport



## Safety-of-Flight electronics

- Non-hostile/natural EM
- Significant redundancy (4 levels)



## EMP vulnerability

- All aircraft at significant risk
- ATC systems, radars at risk
- Months or greater to restore

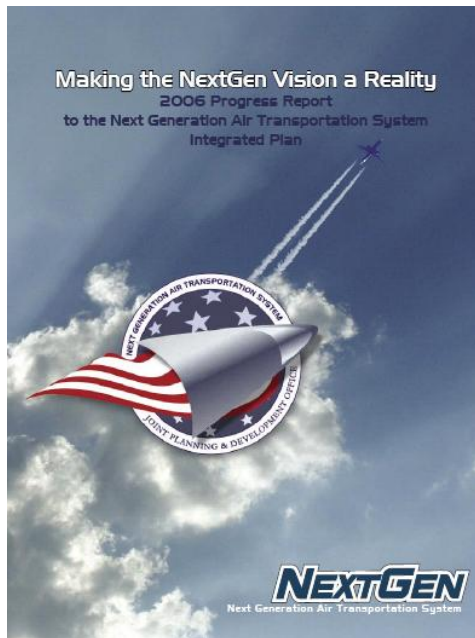


# Mitigation: International Coordination

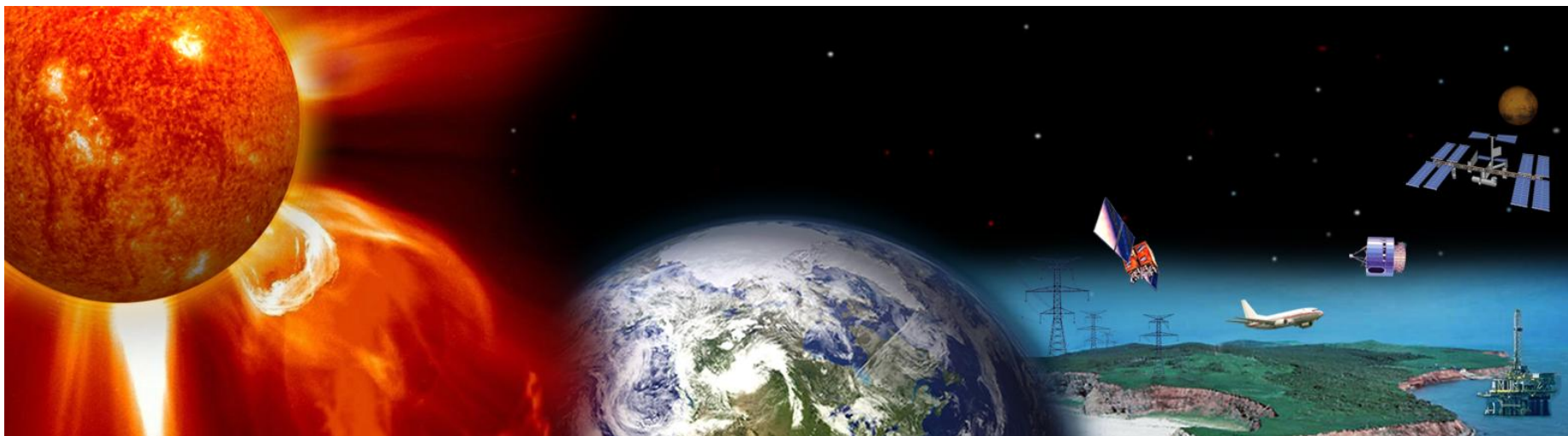
International Civil Aviation Organization (ICAO)



World Meteorological Organization (WMO)



# Summary



- Space weather impacts current global operations and safety
- Severe solar storms could curtail or shutdown operations
- All commercial aircraft and ATC systems prone to EMP effects
- Advancing technology = increasing vulnerability to space weather

International coordination in progress, more required