The Hazards To Space Systems

Solar Activity

Space Debris
The Threat From The Sun

- Major solar events, (Solar Flares and Coronal Mass Ejections) have the potential to generate significant effects on satellites, in the Earth’s atmosphere, and on the ground.
- Variations in levels of solar radiation affect the Earth’s upper atmosphere and the Van Allen belts, causing perturbations to satellite orbits that change over time.

- An improved understanding of the behaviour of the sun would enable:
  - Improved protection of astronauts and satellite systems.
  - Better forward-prediction of satellite and space debris orbits.
Potential Hazards

- Satellites could be temporarily disrupted or permanently damaged
- The atmosphere could be significantly disturbed
- Terrestrial power systems could be overloaded
The Carrington Event

- On September 1, 1859 Richard Carrington recorded a sunspot group which led to a massive solar eruption

- A major electromagnetic disturbance subsequently affected the Earth on the following day, with huge auroral displays

- A similar event would lead to far greater disruption today
Is Carrington The Worst The Sun Can Do?

• Disappointingly, the answer appears to be “No”.

• In 774 AD, a major solar event is thought to have occurred.

• Tree ring data and measurements of isotopes in ice cores suggest that a major, short-lived event occurred in this year.

• There are also references in the Anglo Saxon chronicles to a “red crucifix” that was seen in the sky in this year. This has been interpreted as a low-latitude auroral display associated with this solar activity.

• Estimates suggest a magnitude 10 times greater than Carrington.
Solar Monitoring Mission Concept

- A comprehensive monitoring capability requires satellites stationed (approximately) at the L1, L4, and L5 Lagrange Points.

- The Sun rotates anticlockwise, so an L5 mission would provide initial warning an additional 4 days’ warning ahead of an impending solar-induced event.

- An L1 mission would provide about 90 minutes’ warning of the magnetic polarity of the plasma and the potential coupling into the Earth’s magnetosphere.

- An L4 mission would provide better viewing geometry of the events that actually affect the Earth.

- An operational system would ideally involve multiple satellites at each location to provide high system availability.

Graphics courtesy of Dr Ruth Bamford
The First Orbital Space Debris

Anatoly Zak’s illustration of the Sputnik launch
The Problem With Space Debris

• At Low Earth Orbit velocities (7.5 km/s) an object the size of a sugar cube (1cm) has the equivalent energy of a hand grenade

• When such an object hits a satellite, it goes straight through.....

• This is part of the International Space Station’s solar arrays
The Growth Of Space Debris Over Time

- Total mass of debris in Earth orbit is currently \(~6,800\) tonnes
- There are >20,000 debris objects larger than 10 cm in Earth orbit
- Satellites should deorbit within 25 years, but is that long enough?
Where Is All This Junk?
Debris Evolution

- **This** plot shows the predicted evolution of the debris in low Earth orbit (LEO) making assumptions about differing levels of Post-Mission Disposal.

- Note the “ripple” that assumes some “clearing-out” of LEO debris objects caused by solar induced drag.

- Debris-on-Debris collisions could lead to the “Kessler syndrome”, so a debris removal capability is needed.
Debris Removal

- A variety of technologies, including Mass drivers; Adhesives; Harpoons; Lasers; Tethers; Nets; Grapplers; Propulsion plumes; Slingsats; Branes; De-orbit sails; and Electrostatic tractors have been suggested to remove large, long-lived debris objects.

- All these concepts are technically immature and look like anti-satellite weapons in the wrong hands. It’s unclear how these concepts would be financed, and the politics is hard too.

![Debris Removal Concepts](https://via.placeholder.com/150)
Even Dilbert Is Worried...

- This is not the future we want
A “Perfect Storm”?  
- A major solar eruption occurs  
- Various satellites experience anomalies, and some fail  
  - Some ground stations lose power  
  - Communications to all satellites are affected by ionospheric scintillation  
  - All LEO objects have their orbits perturbed by increased atmospheric drag  
  - Increased risk of collision due to tracking uncertainties  
- Radars struggle to reacquire objects due to scintillation  
- Optical tracking facilities are hampered by auroras  
- Sick satellites are lost due to communications delays  
  - Society is affected for decades
Thank You

Space Traffic Control Now!