UNIVERSITY OF LEICESTER

Institute for Policy

Space Weather

Operational preparedness to protect our assets

Key Policy Recommendation

Create the **UK's first research centre** dedicated to focusing on the **risk to spacecraft and associated services posed by space weather events**.

This research centre would bring together world-leading expertise from across the country, crossing disciplinary boundaries to address:

- Fundamental space plasma physics.
- Space weather impacts on satellites, instrumentation and space-based services.
- Risk to critical UK infrastructure, supporting forecasting efforts.

The impact of Space Weather

Space weather has the potential to affect satellites in low earth orbit, causing them to lose altitude, and even burn up in the atmosphere. **Almost 10,000 satellites currently orbit the Earth; 84% are in Low Earth Orbit (LEO)**.

- **The majority of these satellites are commercial**, including rapidly-growing constellations such as SpaceX, with ~6000 satellites (as of April 2024).
- Examples of existing commercial services provided by these satellites include **communication, navigation, imaging, defense, and remote sensing**.
- Upcoming space-based services may include **quantum key encryption, satellite banking/payments systems, asset/disaster management and IoT**.

Examples of risk to services and ground-based assets include:

1. **Interruption to satellite services** through ionospheric scintillation, such as GPS (marine, road transport, rail, but also drones).
2. **Damage to national and international energy infrastructure**, caused by geomagnetically induced currents.
3. **Disruption to high frequency communication systems**, impacting high latitude airline routes.
4. **Higher radiation doses** for airline passengers and astronauts.

The time window for potential migitative action prior to the impact of a severe space weather event is of the order of hours, and therefore rapid action would be required to manage ground-based, orbital and potentially lunar assets.

The case for further research

1. More accurate forecasting
Current geomagnetic forecast data frequently relies on global activity indices, which have a one hour temporal resolution, and no spatial information at all. A single geomagnetic storm may span several days, but the risk to ground-based assets is much more temporally variable and spatially constrained. Furthermore, the risk to space-based assets varies by storm intensity and phase, and could extend beyond the indication that is currently given by this index.
Enhanced spatial and temporal forecasts would both reduce risk of damage and minimise disruption to operations requiring satellite services.

2. Reliance on satellite services
It is expected that ~58,000 satellites will be launched by 2030 (US GOA). Increasingly the satellites launched are ever smaller (cubesats and nanosats), compromising their ability to respond to an event that threatens their orbital stability, and increasing their probability of atmospheric burnup. A significant space weather event could severely impact upon the space-based services that we are increasingly dependent on.

3. Rapid response
The UK Severe Space Weather Strategy (2021) outlined the importance of ensuring that our response is 'continually updated as space weather science continues to evolve'. A better understanding of the space weather impacts and their associated timescales would support the Met Office Space Weather Operations Centre in their critical role of alerting key stakeholders. A research centre with a formal responsibility to liaise with the operations team would strengthen links between academia and the MET Office, and ensure an ongoing programme of space weather research focussed on UK assets, infrastructure and risk.

Evidence base

The impact of recent space weather events can be seen through recent case studies:

Case Study: Solar Storm Feb 2022
Starlink launches 49 satellites, as part of their mega-constellation, into a space weather event. 38 satellites are lost. Subsequent launches are delayed by forecasts, as solar activity ramps up.

Case study: Solar Storm Feb 2023
A space weather event delayed the launch of 21 Starlink satellites from Florida, and disrupted drilling at an oil drilling rig in Saskatchewan, Canada, due to uncertainty in drill location and orientation.

In their detailed 2023 report on operational resilience, the Institute of Engineering made a series of recommendations which would require coordination through a national research centre of this nature. In particular, they noted that:

'Extreme storm risks to space systems critical to social and economic cohesion of the country should be assessed in greater depth' and that ***'research should be actively pursued to better define the extreme storm environments for satellites and consequential events'.***

The recent £20 million Space Weather Instrumentation, Measurement, Modelling and Risk programme produced valuable work, but the grant was finite and has now concluded. A national space weather research centre would provide the key long-term scientific research to underpin the work of the MET Office.

Implementation

A first-of-its kind national space weather research centre would bring together academic expertise from across the UK to complement and underpin the work of our space weather forecasters. Enhanced research programmes would enable the development of more accurate and more targeted warning systems.

The specific focus of the centre would be on collaborative studies between academia/the Met Office and industrial partners including satellite operations and service providers, downstream service and data users, UK national infrastructure operators and government departments.

"The UK is home to world leading experts in academia who are crucial for deepening our understanding of space weather"

(UK Severe Space Weather Preparedness Strategy (2021)

The work of the centre would also enable the following:

- More accurate predictions of satellite drag impact, minimising disruption to launches.
- Targeted shutdown of assets where required.
- An accurate predictive capability associated with the interruption of satellite services (including GPS).
- Examination of future technology risk mitigation (e.g. space-based quantum encryption).
- Development of higher resolution spatial and temporal space weather risk assessments to enable optimal risk management.

Research centres of this nature have developed virtual and physical infrastructure models. SWIMMR was an academic collabortion with a total cost of £5 million averaged out over the course of the four-year programme. In contrast, The Higgs Centre for Innovation established at the University of Edinburgh in 2018 consisted of a research facility funded by HM Treasury, incurring an upfront capital cost of £10.7 million, with £2 million additional cost over the subsequent 5 years.

The costs incurred by research centres such as these is dwarfed by the potential financial impact of severe space weather events.

In 2008 US National Academies estimated the cost of outages caused by severe space storms at between $1 trillion and $2 trillion for the first year alone, with recovery times of 4 to 10 years. This has been corroborated by the University of Cambridge in their 2017 study, which found daily economic costs stretching into the tens of billions of dollars, owing to previous underreporting of indirect impacts.

This policy briefing paper was produced by:
- Prof. Suzie Imber (Professor of Planetary Science) with the support of the University of Leicester Institute for Policy.

References

National Research Council of the National Academies, 'Severe space weather events – understanding societal and economic impacts: A workshop report', *Committee on the Societal and Economic Impacts of Severe Space Weather Events: A Workshop* (Washington D.C., 2008), pp. 1 – 16.

Schulte in den Bäumen. H, Moran. D, Lenzen. D, Cairns. I, and Steenge. A, 'How severe space weather can disrupt global supply chains', *Natural Hazards and Earth System Sciences* (2014), pp. 2750-59.

Oughton. E. J , Skelton. A, Horne. R. B, Thomson. A. W. P, and Gaunt. C. T, 'Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure', *Space Weather* Vol. 15 (2016), pp. 65-83.

University of Leicester
University Road
Leicester, LE1 7RH, UK

e: instituteforpolicy@leicester.ac.uk
w: www.le.ac.uk/research/institutes/policy