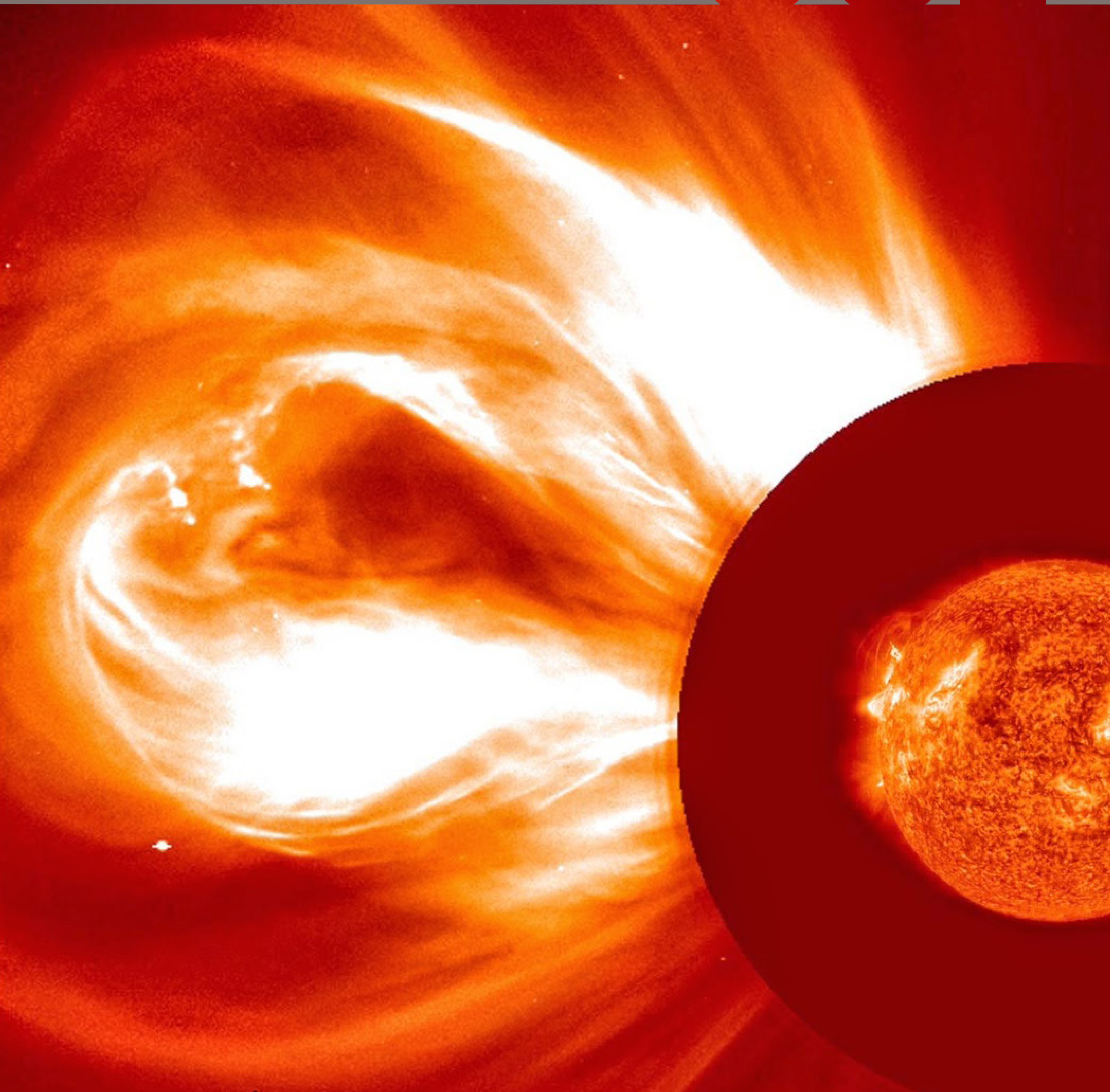
CASCADING DISASTERS RESEARCH GROUP
INSTITUTE FOR RISK AND DISASTER REDUCTION

UCL



ORGANISATIONAL RESILIENCE FOR SEVERE SPACE WEATHER

Wicks, R. T., Pescaroli, G., Green, L.M., and Turner, S.

ORGANISATIONAL RESILIENCE FOR SEVERE SPACE WEATHER

A checklist for continuity management

R. T. Wicks, G. Pescaroli, L.M. Green, and S. Turner.

Please cite this work as:

Wicks, R.T., Pescaroli, G., Green, L.M., and Turner, S., Organisational Resilience for Severe Space Weather, UCL IRDR and Mullard Space Science Laboratory Special Report 2019-01. DOI: 10.14324/000.rp.10076567

Acknowledgements

This report was produced by a collaboration supported by a UCL Knowledge Exchange Award.

Disclaimer

This report contains guidelines written for non-academic audiences, which summarize our scientific research in order to support the work of end users. It is not a substitute for technical advice or consultation of the full papers quoted in the references. These guidelines may not be resold or used for any commercial purpose.

Cover Image: Composite image of a Coronal Mass Ejection leaving the Sun as seen by the SOHO spacecraft, credit: ESA/NASA.

Executive summary

This special report is the result of a collaboration between academics and practitioners. It aims to assess and identify organisational mitigation strategies to respond to space weather events and any associated technological disruptions. The format aims to provide an overview in order to facilitate reading in conditions of limited time availability. The following topics are addressed:

- An introduction to severe space weather events and their possible impacts.
- A risk assessment process and discussion of vulnerabilities that are common with other threats.
- Illustrative examples.
- An operational checklist for continuity planning and management.
- Basic actions to increase organisational and operational resilience.
- Resources for training and essential references.

What is severe space weather?

Space Weather is a catchall term used to describe conditions in the space environment around the Earth. Space weather is driven by the activity of the Sun such as explosions known as solar flares (that release UV and X-ray radiation into the Solar System) and eruptions known as coronal mass ejections (CMEs, that release magnetic field and hot gas, also known as plasma, into the Solar System).

As well as these dramatic and rapid dynamic events, the Sun is also the source of a continual but highly variable outflow of plasma. These flows are collectively called the solar wind. The speed, pressure and magnetic field of the solar wind can change rapidly depending on solar activity.

The Earth and its magnetic field respond to the prevailing conditions. Although the magnetic field can protect the Earth by deflecting incoming solar wind and CMEs it can also exacerbate hazardous conditions by trapping radiation and creating electric currents in the atmosphere, the ground and in our technological infrastructure. When the Earth's magnetic field is highly disturbed a 'geomagnetic storm' ensues, during which time the aurora expands from inside the arctic circles to lower latitudes, radiation levels in the regions where satellites orbit become highly variable, and electrical currents travelling through the upper atmosphere and on the ground increase suddenly in localised areas.

Just as with terrestrial weather, periods of severe conditions can be experienced. Severe space weather can be considered as comprising large solar flares, fast coronal mass ejections, and large geomagnetic storms that produce levels of radiation, UV light and X-rays high enough to pose a risk to modern technology, services, and even life in very severe cases. The Sun has an activity cycle that waxes and wanes roughly every eleven years but severe space weather can occur at any point in this cycle.

Severe space weather is unique among natural hazards, in that its impact can be experienced simultaneously around the globe. The three primary hazards posed by severe space weather are:

1. X-rays and other radiation emitted by solar flares hits the atmosphere on the side of the Earth facing the Sun (in daylight) changing the ionosphere, disrupting radio signals and communication between satellites and the ground.

2. Radiation storms caused by CMEs and geomagnetic storms increase the dose of particle radiation absorbed by satellites, disorienting automatic pointing systems, disrupting on-board computers and causing electrostatic discharges that may damage electronic components.

3. Geomagnetic storms create additional electrical currents in the atmosphere that in turn create currents at ground level. These currents flow through technological infrastructure such as high-voltage power lines, pipes, and railway infrastructure, causing the tripping of safety features, which can lead to disruption of service and even unintended damage.

A more detailed introduction to space weather and its impacts can be found in reports issued by UCL, The Royal Academy of Engineering, Lloyds, and the European Commission. See the 'Further Reading' section at the end of this document.

Possible impacts

The impacts of space weather can be categorised into three main types depending on their cause:

1. Blocking of radio signals (both ground-based and satellite).

2. Radiation dose increase to satellites and aircraft.

3. Generation of electrical currents in conducting materials.

Thus, the expected direct impact of severe space weather is based around disruptions to technological systems:

- Communications (HF radio and satellite services).
- Transport (especially Aviation).
- Mapping and timing (GNSS).
- Power (electrical disruption).

The UK Space Weather Preparedness Strategy defines a reasonable worst-case scenario for the UK as having a 1% probability in any given year with likely impacts being:

- Localised power outages;
- Disruption of satellite operations, including to Global Navigation Satellite System outages (GNSS) and SATCOM disturbances;
- Disruption to high frequency radio communications;
- Increased radiation to aircrew and passengers in flight, particularly over polar regions; and
- Further disturbances to micro-electronic systems.

Power outages would be likely to last only a few hours to a day and are more likely at the end points of the distribution system. All of these effects may occur during intervals lasting anywhere from hours up to two weeks.

The rapid pace of technological change, the uptake of new technology into essential services and the often hidden dependency on systems such as GNSS makes assessing the impact of severe space weather particularly difficult. In particular, the interconnected and inter-reliant nature of modern technology makes 'cascading disasters' possible. This is where one or more triggers is able to cause multiple different impacts, the effects of which travel through the interconnected systems that we have created to cause multiple different, and separate, disasters.

Severe space weather events can cause cascading effects through our connected technological infrastructure. For example, power distribution, satellite navigation, and telecommunications systems are all routinely used by most UK citizens and businesses on a daily basis. Therefore, disruptions in these areas could have far-reaching implications. The possible consequences of disruptions of significant magnitude include the creation and escalation of secondary emergencies, challenging the coordination of emergency relief and long-term recovery.

Do we have to prepare for severe space weather?

Estimates of the probability of severe space weather events puts the likelihood of both a severe radiation event that could disrupt satellite services and geomagnetic storm that can disrupt electricity supply at about one in twenty years. Radio communication blackouts are slightly more common, with radio disruption and satellite communications disruptions happening about one in every ten years. The reasonable worst-case scenario, which is large enough to cause complex and compounding disruptions, may be as frequent as one in two hundred years.

In the reasonable worst-case scenario, it is thought that power outages would be localised and short, however other impacts of space weather can occur around the globe and last for several days. Different impacts are likely to occur simultaneously with each other, and potentially with other hazards.

To help prepare for severe space weather, the UK government created the Met Office Space Weather Operations Centre in 2014, which provides a 24/7 space weather forecast.

Assessing cascading technological risk

There are many different aspects that determine societal resilience as a whole (Florin and Linkov 2016). Dependency on technology is a critical challenge to address in the near future because it orients how emergency management teams plan for, and respond to, possible crises. For example, as technology becomes more reliable, we become dependant on it, possibly to an extent that we do not plan for its failure.

It is clear that in recent decades the use of tools such laptops and GNSS services has changed considerably, creating new organisational processes and common routines that are rooted in the availability of interconnected services. For example, use of the Internet and smartphones has modified both working behaviours and management procedures. They are reliant on faster, networked, communications and data sharing methods that are completely different to those available even just a decade ago. Similarly, during mass emergencies social media now has a prominent role in the dissemination of information, and navigation systems become essential for the effective deployment of first responders, such as ambulances. A new challenge is emerging that relates to cloud working, as organisations outsource the backing up of information so that they can dispense with expensive servers.

When assessing risk, critical infrastructure (CI) must be considered as a source of major disruption that could inhibit communities' and organisation's capacity to cope. In other words, disasters nowadays may not only be associated with clear "life threatening" events such as fires or floods. They can also be associated with disruptions to critical services and technology. Hence, CI can be viewed as the physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society" (UNISDR Glossary 2017).

The failure of CI can create cascading effects if complex, non-linear sequences of events evolve. This can escalate the impact of the primary emergency (Pescaroli and Alexander 2015, 2016). In practical terms, cascades may not just be associated with the magnitude of a severe space weather event: instead, they are rooted in the vulnerabilities that have not been addressed in the socio-organisational domains, such as the management capacity (see Pescaroli and Alexander, 2016). For example, an inadequate understanding of early warning systems or the absence of a well-designed checklist that should be undertaken in the advent of a geomagnetic storm. It is key to get the right procedures in place.

Impact pathways can be understood and assessed through scenario building (Pescaroli and Alexander, 2016). Many of the potential vulnerabilities and sources of escalation that affect the same CI can have common triggers. For example, different triggers such as severe space weather or cybersecurity can have the same process of escalation that leads to GNSS failures (Pescaroli et al., 2018). It is possible then to develop space weather scenarios using existing material.

However, tools should be grounded in the specifics of the regions considered in the planning process. For example, remote industries that are highly dependent on positioning data versus urban areas with the capability to have back-up systems in place. One of the challenges in developing these scenarios is to be aware of CI interdependencies associated with a lack of information sharing among stakeholders. London Resilience created a generic and replicable model called ANYTOWN to support this process (Hogan, 2013).

A checklist for continuity management

The following table proposes a quick assessment list that could help to improve business continuity management for severe space weather events and technological disruptions. It has been derived using the format proposed by London Resilience, integrated with the resources proposed in the references. The list has been cross-checked in an operational workshop with non-academic stakeholders. Please note that the list does not intend to be exhaustive, but focuses on key generic actions that could help maintain an organisational and operational lifeline in case of technology disruption. An in-depth assessment undertaken at a tactical and strategic level may be beneficial.

Please note that an operational focus on the cascading effects of GNSS failures has been included in our complementary report *Cascading Impacts of Global Navigation Satellite Systems Failures,* Pescaroli et al. (2019)

Recommendations for improving resilience to severe space weather

It is possible to define some basic steps that could improve organisational resilience to severe space weather and to technological failures at large. They are:

- Undertake a review of your critical and core processes and procedures to understand the impact on the organisation of a space weather event.

- Command and control, ensure key decision makers and tactical responders have been briefed and the understand procedures to follow in the event of a space weather event.

- Ensure notification and activation procedures are not reliant on technology that may be impacted by a space weather event.

- Define an operational procedure to be activated in case of telecommunication failure and/or blackout, such as defining a meeting point and key actions to be addressed.

- Ensure that key personnel have instructions of what to do in case of public transport disruption.

- Exercise scenarios of technological disruptions with your colleagues to define what vital procedures could be compromised and which are resilient.

- Maintain a safe (not VOIP) landline for assuring vital telecommunication.

- Create a paper-based vault of key documents and procedures.

- Define energy conservation procedures to undertake in case of an emergency.

- Procure a minimum amount of multifunctional emergency hand crank radios and chargers.

- Keep extra batteries available and safe.

- In case of a warning of severe electrical disruption, verify if it’s recommended to disconnect electrical appliances.

- Overall, review and update your business continuity plan. Assess the needs and the actions already undertaken in your organisation.

General assessment for technological failures

Do you have a Business continuity plan? Is it regularly reviewed and updated?

List your critical services/departments and the technology they are reliant on

What technological systems are likely to cause knock-on effects or affect multiple users or departments if disrupted?

What are the knock-on effects of technological failures in your business? At what point will your business continuity arrangements be activated?

0 – 12 hours loss:

12 – 24 hours loss:

24 – 48 hours loss:

48 hours to 1 week loss:

Have you assessed the capacity of your organisation to remain operational during an extended technological failure?

How do you communicate with your colleagues or employees in case of loss of telecommunications?

Do you have HR procedures or polices in place to address technological failure, that is, if you have home-workers or lone workers are they aware of the processes to be enacted in the event of a technological failure?

Are your key personnel aware of what to do in case of loss of telecommunication? (e.g. meeting points)

Are your backup systems available, maintained and operational? (Including generators)

What are the supply lifelines your organisation cannot afford to lose in a worst-case scenario?

What measures can be taken to improve each individual's resilience in case of technological failures? (e.g. cash, hand crank chargers)

Do you have a paper-based backup of key contacts and documentation? Are they the most update versions and is there a process in place to replace them as documents get revised?

Severe space weather events (SSW)

Is your organisation aware of the likelihood of SSW and its possible impacts?

Do you know how to receive and react to a warning of an SSW? For example, have you signed up for space weather information from the Met Office Space Weather Operations Centre?

Have you ever exercised a scenario of an SSW?

What are the key uncertainties that you could face in case of SSW and how will you tackle them?

What are the key actions needed to protect your equipment from SSW?

Do you have energy conservation procedures that could be activated in case of SSW?

Do you have an emergency generator? Is it operational and have personnel been trained to use it? Does it cover all critical systems or locations?

How is your organisation dependent on GNSS?

What consequences will your business suffer during a GNSS disruption?

How can you mitigate GNSS disruption to your business?

Essential references and further reading

The following list summarises the open access literature that has been considered for this report. For further details, please contact the authors for more detail.

- Cannon, P.S., et al., 2013, *Extreme space weather: impacts on engineered systems and infrastructure.* Royal Academy of Engineering, UK, ISBN 1-903496-95-0, www.raeng.org.uk/spaceweather

- Department for Business, Innovation and Skills, UK, *Space Weather Preparedness Strategy*, www.gov.uk/government/publications/space-weather-preparedness-strategy

- Florin, M., and Linkov, I. (Eds), 2016. *IRGC resource guide on resilience. International Risk Governance Council*, www.irgc.org

- Government Office for Science, 2018. *Satellite derived time and position: a study of critical dependencies.* www.gov.uk/government/publications/satellite-derived-time-and-position-blackett-review

- Green, L.M., et al., 2016. *Building Space Weather Resilience in the Finance Sector,* UCL Department of Space and Climate Physics Report. www.luciegreen.com/wp-content/uploads/2016/08/space_weather_and_finance.pdf

- Hapgood, M., and Thomson, A., 2010. *Lloyd's 360° Risk Insight Space weather: it's impact on Earth and implications for business,* www.lloyds.com/~/media/lloyds/reports/360/360%20space%20weather/7311_lloyds_360_space%20weather_03.pdf

- Hogan, M., 2013. Anytown : *Final Report.* London Resilience, London. www.londonprepared.gov.uk

- Krausmann, E., et al., 2014. *Space Weather and Financial Systems: Findings and Outlook*, DOI 10.2788/18855

- Krausmann, E., et al., 2015. *Space Weather and Rail: Findings and Outlook,* European Commission, Publications Office of the European Union, EUR 27523 EN, Scientific and Technical Research series, doi:10.2788/211456

- London Resilience Partnership, 2017. *London Risk Register V. 6.0,* www.londonprepared.gov.uk

- Met Office Space Weather Operations Centre, www.metoffice.gov.uk/publicsector/emergencies/space-weather

- Pescaroli, G., and Alexander, D.E., 2015. *A definition of cascading disasters and cascading effects: Going beyond the "toppling dominos" metaphor, Planet@Risk,* Global Forum Davos, 3(1), pp. 58–67

- Pescaroli, G., et al., 2017. *Cascading Impacts and Escalations in Wide-Area Power Failures.* UCL IRDR and London Resilience Special Report 2017-01, Institute for Risk and Disaster Reduction, University College London. www.ucl.ac.uk/rdr/cascading/resources/reports-guidelines/Report_Power_Failures

- Sadlier, G., et al., 2017. *The economic impact on the UK of a disruption to GNSS.* London Economics www.gov.uk/government/publications/the-economic-impact-on-the-uk-of-a-disruption-to-gnss

- UK Cabinet Office, 2016. *National risk register of civil emergencies - 2015.*

Department of Space and Climate Physics

UCL's Department of Space and Climate Physics, (Mullard Space Science Laboratory - MSSL), is a world-leading research organisation and is the UK's largest university-based space research group. MSSL delivers a broad, cutting-edge science programme, underpinned by a strong capability in space science instrumentation, space-domain engineering, space medicine, systems engineering and project management.

Cascading Disasters Research Group

Our mission is to promote a cross-disciplinary approach to the emerging topic of cascading risk, involving the public sector, private enterprises and communities in impact-oriented collaborations.

Become a Member of The IRDR

The IRDR aims to bring together the expertise available at University College London in terms of research, teaching and knowledge exchange to overcome the barriers to understanding risk and reducing the impact of disasters.

IRDR

Cascading Disasters Research Group

www.ucl.ac.uk/rdr/cascading