Why does space weather matter?

Severe space weather is a risk that brings the potential to damage infrastructure and cause disruption, say **Emmelie Andersson** and **Chris Felton**, who describe Swedish and British national programmes to address the threat

Our Sun is an active star, with continuous eruptions of radiation and plasma generated by the processes within its core and a changing magnetic field. Space weather describes the whole range of events resulting from the eruptions of the sun and their interactions with the Earth. Occasionally, there are massive eruptions of X-rays and gamma rays (solar flares), proton bursts (proton events/radiation storms) and/or magnetised plasma clouds (coronal mass ejections or CMEs).

These eruptions are associated with so-called sunspots, active areas on the sun's surface. This activity varies over the solar cycle, a period of approximately 11 years. The peak of the current solar cycle was in 2013. However, extreme events, which can cause widespread disturbances of the technology society depends upon, might happen at any time.

The most significant recorded incident was the Carrington Event on September 2, 1859 when telegraph operators received electric shocks when they touched their teletypes as electricity surged through the lines. Astronomer Richard Carrington witnessed the solar flare that caused the event, which was subsequently named after him.

The impact of that storm was limited to the telegraph system. But as our reliance on technology has increased, so has our vulnerability. Other more recent severe storms have caused disruption in several countries. The effects of a storm in 1921 in several countries included significant disruption to the New York Railroad and the telephone network in Sweden. The 2003 Halloween Storms similarly had global impact. There have also been numerous other storms that have caused more regional effects. Storms greater than the Carrington Event are possible.

From a crisis management perspective, severe space weather presents particular challenges.

As we have seen, it can affect critical infrastructure in several countries at the same time. CMEs can penetrate Earth's magnetic field at the poles, generating geomagnetic storms – a disturbance in the magnetic field. As well as causing the Aurora Borealis and Aurora Australis (the Northern and Southern Lights), this can induce an electric field in the Earth's crust and electric currents through the ground. These can disrupt or damage power grids, pipelines, telecommunications and railways.

Solar flares and charged particles can ionise the ionosphere, disrupting satellite signals (eg Global Navigation Satellite Systems – GNSS) for days at a time; they can also damage satellites and put them out of service, sometimes permanently, affect electronic systems in aircraft, and increase radiation for aircraft passengers and crew. The impact from disruption to GNSS signals such as the Global Positioning System (GPS) might be widespread, owing to the range of sectors relying on this technology for positioning or timing purposes.

Effective engagement

Today's society is interconnected; disturbances to infrastructure in one country from severe space weather can affect other countries. These might be economic impacts, disruption to transport, and delays in delivering goods or services. Several countries might simultaneously need to replace infrastructure damaged by the solar storm, for example if several power transformers were damaged during a solar activity. Transformers are manufactured in a few places in the world and it can take up to one year from order to delivery. This can seriously affect each country's ability to recover and highlights the need for effective engagement between countries in preparing for this risk.

The UK has experienced the effects of past events – for example two transformers were damaged in the 1989 storm. This risk, based upon a 'reasonable worst case scenario' of the 1859 Carrington Event, was added to the UK's *National Risk Assessment* in 2011 and subsequently appeared in the 2012 version of the public *National Risk Register.*

Since then, there has been considerable work to increase our understanding of the risk faced by the UK and its infrastructure from solar storms and to increase the ability to forecast and mitigate its impacts. Publication of a Royal Academy of Engineers report in 2013 was critical and allowed the UK, led by a full time project manager in the Civil Contingencies Secretariat, to take an informed and proportionate approach. This fits with the UK's wider strategy of using existing capabilities to build resilience and building new capability only where necessary.

One new capability underpinning the UK approach to space weather is a forecasting centre, based at the UK's Met Office, which

moves to 24/7 operations this year. This is only the second round-the-clock space weather forecasting centre of its type in the world, the other being the US's Space Weather Prediction Center in Boulder, Colorado.

The National Grid in the UK has also increased its ability to withstand solar events through the installation of more resilient transformers since 2003, increasing stocks of transformers, and development of operational response plans. This mitigation is being enhanced by the provision of UK specific alerts from the Met Office Space Weather Operations Centre. Work is also being undertaken with a wide range of other sectors, some of which have not previously been aware of their vulnerability to this risk.

Another critical element of the UK approach is to make local responders, such as the emergency services and local government, aware of the risk and their role in a response. This focuses on the need to be resilient to the effects of solar storms (loss of power, loss of GNSS services, transport disruption) rather than being overly concerned about their cause. This is also at the heart of plans to communicate with the public before and during an event.

The final element of the UK approach is to work closely with our international partners, such as Sweden and the US, to develop a consistent approach, while recognising that infrastructure in each country will not necessarily be affected in the same way. ▶

Sweden experiences geomagnetic-induced currents more often than many other countries, owing to its geographical location in the north. This has provided for a relatively high degree of awareness of space weather and its effects among owners and operators of certain infrastructures, such as the power grid. However, within the wider crisis management community and among the public at large, the awareness of the space weather phenomenon remains limited, as it does in the UK.

Measures have been taken over the years to protect critical parts of the national infrastructure. The electric power system's ability to withstand geomagnetic disturbances has improved over the decades. There is some consistency in the approach with that of the UK. Among other things, the step-up transformers are gradually being replaced with models that are constructed according to the design that is most resistant to geomagnetic-induced currents. The Swedish National Grid has also had operational response plans in place since the 1980s, which have been updated continuously.

The Swedish Civil Contingencies Agency (MSB) has been tasked to develop society's capacity to prevent and cope with accidents and emergencies. This includes a wide spectrum of risks and disruptive events, ranging from more frequent emergencies to so-called high impact and low probability events (HILP).

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Extreme space weather is seen as a good example of a possible HILP event. The risk from extreme space weather was added to the Swedish National Risk and Capability Assessment (NRCA) in 2011 and is being analysed with the support of Swedish experts, scientists and emergency management stakeholders.

Since 2012, MSB has had a Space Weather Co-ordinator working full time on co-ordinating space weather-related projects and facilitating collaboration with international partners, raising awareness and supporting private and public stakeholders at all levels.

MSB's operational mission includes a responsibility to enable and support co-ordination between relevant stakeholders in an emergency. During a space weather event, rapid and effective co-ordination and communication to the public is critical. MSB Duty Officers have thus been trained in the basics of the phenomenon, including the meaning of various terms that they may encounter. Having 'broker functions' in place that are able to interpret the content and meaning of early warnings and who may convey relevant information to stakeholders in society, is a vital part of the system for emergency preparedness.

Inspired by our UK colleagues, Sweden and MSB are also in the process of developing a national space weather warning system, together with the Swedish Meteorological and Hydrological Institute (SMHI). The institute will be responsible for distributing space weather forecasts and alerting stakeholders, but will not monitor solar activity and make forecasts (like its UK counterpart), rather it will draw on already established space weather forecasting centres.

Although the nature of the space weather risk is more exotic than some of the other threats we face, there are nonetheless flexible and cost effective ways to make ourselves more resilient. But we are unable to eliminate our vulnerability to space weather completely. The ability to respond relies on warnings that are as timely and accurate as possible, delivered speedily to stakeholders and tailored to their needs. The work of the UK Met Office and other forecasting centres aims to achieve this.

Ageing capability

But major challenges in providing alerts remain. The underpinning science is still developing. Satellite capability is in short supply and ageing. And when a large coronal mass ejection is earthbound, there will be only a 50/50 chance we will experience the effects on infrastructure until about 30 minutes before it reaches Earth. Added to this, there is very limited ability to forecast solar flares or proton events accurately.

All this demonstrates the need for work, in advance, to increase awareness among vulnerable sectors, responders and central government, to make infrastructure more resilient, and to improve readiness to respond to an event. This work needs to be underpinned as much as possible by tried and tested plans for responding to other emergencies.

Interpretation of warnings and assessment of how systems might be affected is challenging; this is a complex area, littered with scientific terms requiring prior knowledge of the subject. Scientists, forecasters and crisis managers need to work more closely together to bridge the gaps between them. Their joint work is the only way to develop user-friendly forecasts and early warnings. This will also be vital in providing effective communication to the public in an emergency.

The creation of more resilient emergency management requires collaboration across Europe and further afield to increase awareness of space weather and how vulnerabilities in international infrastructure can be reduced. Several countries and organisations have taken the initiative to organise forums for experts and scientists to share knowledge and build networks. It is vital to bring scientists, forecasters, industry and government together and to support an effective dialogue between them to assess the risk further and to develop mitigation.

We also need to increase our understanding of the science underpinning solar activity to be able to forecast these extreme events; this is best done on an international level. We must ensure that messages are co-ordinated internationally to avoid unnecessary alarm through confused communication to the public before and during an event.

Clearly, the common view of space weather that it is an exotic risk or a Black Swan should be challenged. This is also no Y2K. Severe space weather is a risk that brings the potential to damage infrastructure and cause disruption. Events have happened in the past and severe events could occur at any time.

It is also becoming increasingly clear that eruptions that lead to these major storms are relatively frequent – they become a concern for us when they head towards the Earth. We saw one in July 2012, which had the potential to lead to a Carrington scale event. Fortunately, it was heading in the opposite direction. Many of the mitigation measures needed are common to other risks. So we need to address this risk as an integral part of the broad spectrum of work we do on risk identification and resilience building and national exercise programmes, an approach being adopted in both Sweden and the UK. CRJ

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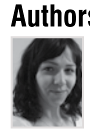

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Sources

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