

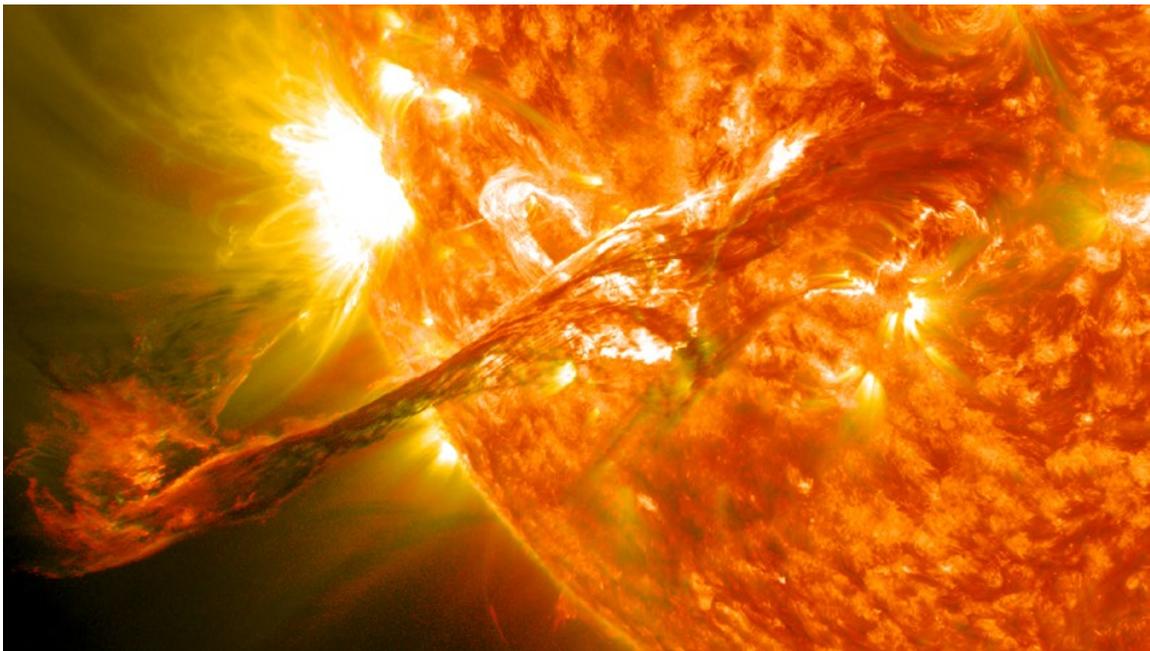
# Space Weather as a Threat to Critical Infrastructure

A. R. E. Taylor

Critical infrastructure protection is increasingly operating in a post-terrestrial space. Satellites and space stations are key enablers of a wide variety of navigational, communicational, security and scientific activity that is perceived as central to the continuity of industrialised societies. Now recognised as “critical space infrastructure” (Mureşan and Georgescu 2015), there is mounting interest and investment in ensuring their uninterrupted service provision in the face of a plurality of space risks. At the same time, as outer space becomes a new domain for infrastructure security, terrestrial infrastructures that once might not typically have been associated with outer space are also being brought into new threatening relationalities with the Solar System. Pipelines, telecommunication cables and electricity grids, among other ground-based infrastructures, have all been identified as vulnerable to “space weather.” This article explores how growing public and political awareness of the space weather threat is expanding what might count as “space” infrastructure, generating new imaginaries of planet Earth’s place in a dangerously energetic Solar System.

### Un-Earthing critical infrastructure protection

Since the mid-1990s, “critical infrastructure protection” has emerged as a key concept and priority target of national and international security regimes (Cavelty 2008; Collier and Lakoff 2008). For growing numbers of government officials and risk professionals, the industrialised societies of the global north are perceived to be increasingly vulnerable to catastrophic collapse due to their dependence on a complex network of interconnected and interdependent “vital systems” (Beck 1999; Collier and Lakoff 2015). In its various national articulations, critical infrastructure protection generally aims to manage the anticipated failure of infrastructure systems and govern the proliferating array of risks that might trigger large-scale infrastructure failure.

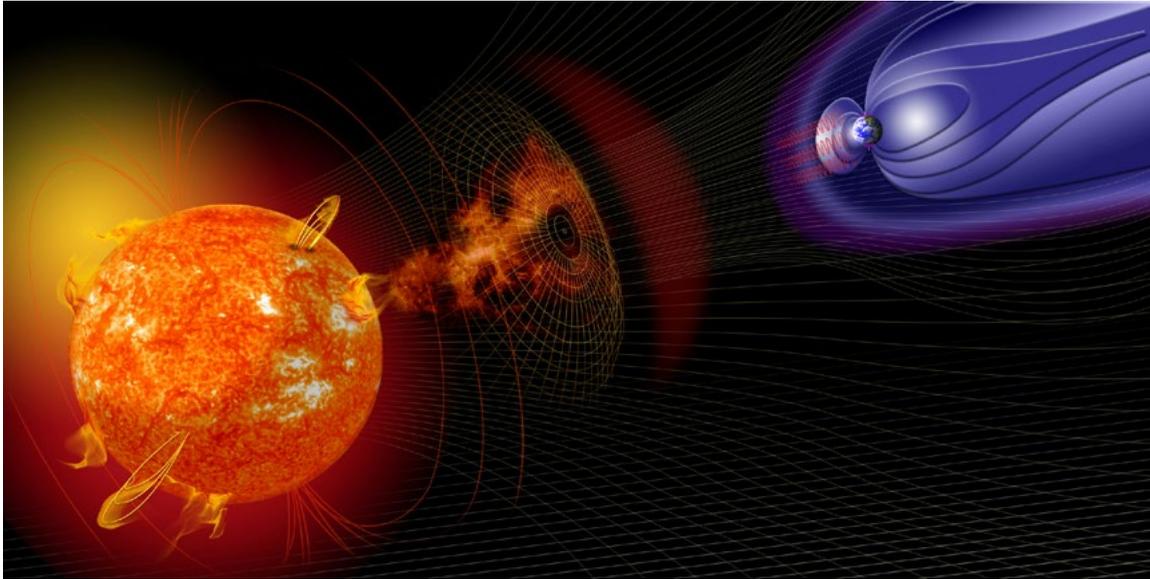


Since 2012, space weather has swiftly moved on to national security agendas across the global north as a key threat to critical infrastructure (Cabinet Office 2012, 2014; White House 2015a, 2015b; European Commission 2016). Space weather refers to a range of radiation events that occur in the near-Earth space environment, often originating from the Sun. During periods of intense magnetic activity, the Sun releases electrically charged plasma from its outer atmosphere, the solar corona. These solar events are known as coronal mass ejections (CMEs) and are often accompanied by explosive solar flares (Fig. 1). This high-energy solar radiation is capable of ionising the fragile microelectronics and memory circuits found in spaceborne infrastructure like satellites and spacecraft, potentially causing component failure and leading to loss of service (Horne et al. 2013).

Space weather not only poses a risk to infrastructure situated in outer space but also to terrestrial infrastructure. When these electrically charged solar particles interact with Earth’s magnetic field (Fig. 2) they can generate powerful currents that

*Figure 1: Extreme space weather events begin when plasma erupts from the Sun and streams towards Earth. This is an image of the Sun visualised in UV light by NASA’s Solar Dynamics Observatory (SDO). Credit: <https://www.nasa.gov>.*

flow into the earth. These earth currents can damage conducting material such as pipelines and they can induce high-voltage surges in power grids, computer chips and other electronic components of terrestrial critical infrastructure.



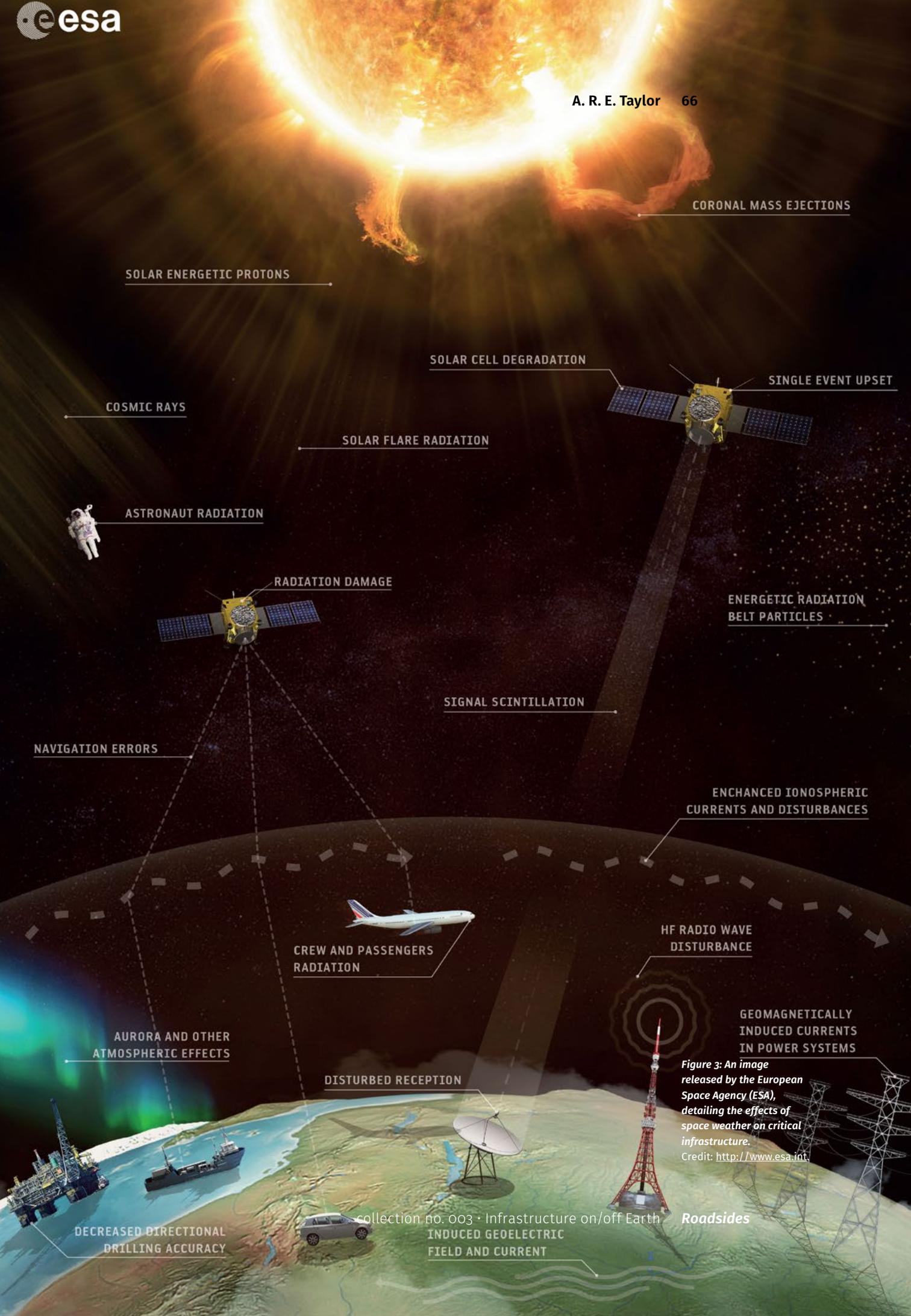
### The space-weathered world

A key visual tool that is widely utilised to communicate the space weather threat is a cross-sectional image of Earth and its space-based and ground-based critical infrastructures situated within the wider solar environment (Fig. 3). Variations of this illustration have been widely circulated in news articles and have become key images in the visual economy of space weather, released by a number of space agencies and scientific institutions (e.g. Fig. 4). Such visualisations serve to highlight the infrastructure and technology systems affected by space weather, inviting viewers to see outer space not as remote and detached from the everyday geographies of their lives but as deeply entangled with earthly “envirotechnical” landscapes (Pritchard 2011).

Jutting up from the surface of the Earth, the exaggerated scale of radio masts, satellite dishes, oil rigs and electricity pylons embeds these infrastructures in atmospheric space. Visually bridging the space between Earth and the upper atmosphere, the infrastructures pictured here draw attention to the relational “bridgework” (Howe et al. 2016: 549) that critical infrastructures (as conduits for electromagnetic currents and energies) facilitate between Earth and outer space. Rather than a picture of Earth safely nested within a protective atmospheric barrier, here, earthly infrastructure is not separate from the energetic fluxes and flows occurring in outer space but is presented as precariously immersed within them.

*Figure 2: NASA rendering of stellar magnetic fields. In this image, the blue lines represent Earth's magnetic field that is distorted by the “solar wind.”*

Credit: <https://www.nasa.gov>.



CORONAL MASS EJECTIONS

SOLAR ENERGETIC PROTONS

SOLAR CELL DEGRADATION

SINGLE EVENT UPSET

COSMIC RAYS

SOLAR FLARE RADIATION

ASTRONAUT RADIATION

RADIATION DAMAGE

ENERGETIC RADIATION BELT PARTICLES

SIGNAL SCINTILLATION

NAVIGATION ERRORS

ENHANCED IONOSPHERIC CURRENTS AND DISTURBANCES

CREW AND PASSENGERS RADIATION

HF RADIO WAVE DISTURBANCE

AURORA AND OTHER ATMOSPHERIC EFFECTS

GEOMAGNETICALLY INDUCED CURRENTS IN POWER SYSTEMS

DISTURBED RECEPTION

Figure 3: An image released by the European Space Agency (ESA), detailing the effects of space weather on critical infrastructure. Credit: <http://www.esa.int>

DECREASED DIRECTIONAL DRILLING ACCURACY

collection no. 003 • Infrastructure on/off Earth INDUCED GEOELECTRIC FIELD AND CURRENT

Roadsides

**Relation as threat**

Affecting infrastructure on and off Earth, space weather thus draws infrastructures into threatening relationality with the electromagnetic energy and matter of the Solar System. That infrastructures are not only material technological systems but also profoundly relational entities is one of the key insights to emerge from social studies of infrastructure (Star and Ruhleder 1996; Star 1999; Harvey 2010, 2012; Larkin 2013). During their planning, construction and disintegration, infrastructures produce and perturb relations in ways that are often unintended, sometimes generating unexpected relational configurations that can lead to powerful reorderings of social life. The cross-section image of the space-weathered world thus at once enacts and addresses a relationship of vulnerable permeability between the electromagnetic outer space environment and social life on Earth, communicating a new understanding of how

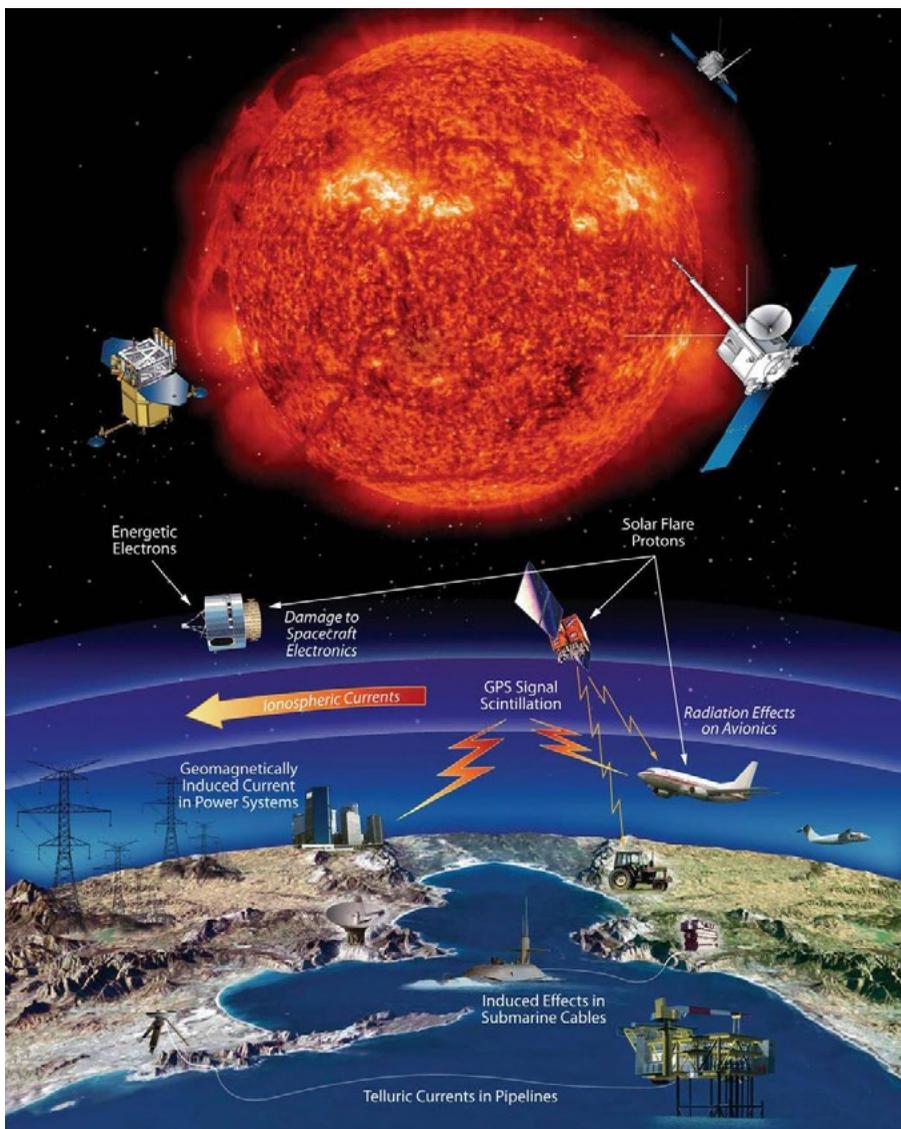


Figure 4: An image of the space-weathered world released by NASA. The caption that accompanies this image on NASA's website reads: "A web of inter-dependencies makes the modern economy especially sensitive to solar storms." Credit: <https://www.nasa.gov>.

technological infrastructure emplaces and re-scales the planet in (perilous) relation with the Sun. Newly configuring relations of connectivity and proximity between the Sun and Earth, security actors are rethinking the meaning of an infrastructured Earth's place in the cosmos.

### **Dystopian infrastructure futures**

While the development and installation of infrastructure often promises to concretise futures of modernity and progress (Edwards 2003; Harvey and Knox 2012, 2015; Hetherington 2014; Anand et al. 2018), the failure or breakdown of infrastructure can threaten to disrupt or even undo modernity. Severe space weather events are often represented in the mass media as entailing the prolonged loss of power grids, computer systems, satellites and other critical infrastructures, on a national, continental or even planetary scale.<sup>1</sup> The imagined technological and societal disruption is typically configured temporally as a violent return to a pre-modern evolutionary stage, with news headlines frequently proclaiming that a severe space weather event would “send us back to the Stone Age” (Anthony 2014). Here, infrastructures are loaded with temporal power, with their continuation or collapse enabling the global north to move forwards or backwards in time respectively.

It has become a commonplace that infrastructures are not only located in space but also in time (Appel 2018; Joniak-Lüthi 2019). In particular, scholars have highlighted the “forward-looking” (Gupta 2018: 63) or future-orientated nature of infrastructure temporalities. But the futures that circulate around infrastructure can also be pasts. In discourse on the space weather threat, infrastructures are decidedly heterochronic sites where narratives of technological progress abut with narratives of technological dependency and societal atavism.

Despite the “global threat” rhetoric, the space weather risk is rooted in uneven techno-geographies and thus unfolds at varying degrees across different national contexts. While the infrastructure-heavy global north is brought into dangerous relationality with a roiling Solar System, those countries in the global south with fewer infrastructure services and where “ruination is a constant companion of infrastructure” (Boyer 2018: 224) remain largely cut off from this cosmic connectivity (it is perhaps not coincidental that the cross-section image depicts infrastructure on “top” of the world, rather than the “bottom” or “sides” of the world; see Fig. 3 and 4). While a severe space weather event could have cascading effects across the global north/south divide, space weather is generally positioned as a problem for heavily technologised countries (Mureşan and Georgescu 2015: 59). For growing numbers of critical infrastructure protection practitioners, lack of infrastructure in the global south is increasingly perceived not as a social disadvantage but as a source of societal resilience. Space weather thus sits at the intersection of shifting spatial and temporal relations between infrastructure and modernity, and shifting distributions of risk and resilience, in the global technoscape.

### De-terrestrialising infrastructure studies

Affecting both terrestrial and orbital infrastructure, space weather unsettles the on/off-Earth binary, weaving ground-based and space-based infrastructures into larger Solar System ecologies (Battaglia et al. 2015: 246; Olson 2013, 2018). Space weather therefore invites us to greatly expand the conceptual limits and relational horizons of infrastructure. Turning scholarly attention to the more-than-earthly existence of infrastructures opens opportunities for expanding critical orientations within infrastructure studies. “Infrastructures bridge distance,” Appel et al. (2018: 14) observe, but often that distance is conceptualised along a horizontal plane. The “bridge” metaphor itself gives rise to a decidedly horizontalised rendering of infrastructure relationality. Yet, from radio waves bouncing off the ionosphere to satellite data transmissions, infrastructures also mediate exchange upwards and downwards, inwards and outwards (Olson and Messeri 2015). Space weather invites us to unflatten and verticalise infrastructure research and theory (Elden 2013; Graham 2016; Billé 2020). In doing so, it might also newly attune us to the electromagnetic lives of infrastructure, which unfold across regions of the electromagnetic spectrum that exist beyond the threshold of human perception. Following solar physicists and infrastructure engineers as they connect an increasingly technologised Earth to an electromagnetic cosmos could enable us bring into view the more-than-earthly relations and electromagnetic affordances of infrastructure that might otherwise go undetected in terracentric critiques.

### Notes:

<sup>1</sup> For a recent televisual rendering of the space weather threat, see Sky One’s Cobra (2020).

### References:

Anand, Nikhil, Akhil Gupta and Hannah Appel. 2018. “Introduction: Temporality, Politics and the Promise of Infrastructure.” In *The Promise of Infrastructure*, edited by Nikhil Anand, Akhil Gupta and Hannah Appel, 1–40. Durham, NC: Duke University Press.

Anthony, Sebastian. 2014. “The Solar Storm of 2012 that Almost Sent us Back to a Post-Apocalyptic Stone Age.” Extremetech.com. 24 July. Available at: <https://www.extremetech.com/extreme/186805-the-solar-storm-of-2012-that-almost-sent-us-back-to-a-post-apocalyptic-stone-age>.

Appel, Hannah. 2018. “Infrastructural Time.” In *The Promise of Infrastructure*, edited by Nikhil Anand, Akhil Gupta and Hannah Appel, 41–61. Durham, NC: Duke University Press.

- Battaglia, Debora, David Valentine and Valerie Olson. 2015. "Relational Space: An Earthly Installation." *Cultural Anthropology* 30 (2): 245–56.
- Beck, Ulrich. 1999. *World Risk Society*. Cambridge: Polity Press.
- Billé, Franck (ed.). 2020. *Voluminous States: Sovereignty, Materiality and the Territorial Imagination*. Durham, NC: Duke University Press.
- Boyer, Dominic. 2018. "Infrastructure, Potential Energy, Revolution." In *The Promise of Infrastructure*, edited by Nikhil Anand, Akhil Gupta and Hannah Appel, 223–44. Durham, NC: Duke University Press.
- Cabinet Office. 2012. *National Risk Register of Civil Emergencies*. Whitehall, London.
- Cabinet Office. 2014. *Space Weather Preparedness Strategy*. Version 2.1. Whitehall, London: Department for Business Innovation and Skills.
- Cavelty, Myriam Dunn. 2008. *Cyber-Security and Threat Politics: US Efforts to Secure the Information Age*. London: Routledge.
- Collier, Stephen J. and Andrew Lakoff. 2008. "The Vulnerability of Vital Systems: How 'Critical Infrastructure' Became a Security Problem." In *Securing 'The Homeland': Critical Infrastructure, Risk and (In)security*, edited by Myriam Dunn Cavelty and Kristian Sjøby Kristensen, 17–39. New York: Routledge.
- Collier, Stephen J. and Andrew Lakoff. 2015. "Vital Systems Security: Reflexive Biopolitics and the Government of Emergency." *Theory, Culture & Society* 32 (2): 19–51.
- Edwards, Paul N. 2003. "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems." In *Modernity and Technology*, edited by Thomas J. Misa, Philip Brey and Andrew Feenberg, 185–226. Cambridge, MA: MIT Press.
- Elden, Stuart. 2013. "Secure the Volume: Vertical Geopolitics and the Depth of Power." *Political Geography* 34: 35–51.
- European Commission. 2016. *Space Weather and Critical Infrastructures: Findings and Outlook*. Joint Research Centre Science for Policy Report. Luxembourg: Publications Office of the European Union.
- Graham, Stephen. 2016. *Vertical: The City from Satellites to Bunkers*. London and New York: Verso.
- Gupta, Akhil. 2018. "The Future in Ruins: Thoughts on the Temporality of Infrastructure." In *The Promise of Infrastructure*, edited by Nikhil Anand, Akhil Gupta and Hannah Appel, 62–79. Durham, NC: Duke University Press.
- Harvey, Penny. 2010. "Cementing Relations: The Materiality of Roads and Public Spaces in Provincial Peru." *Social Analysis* 54 (2): 28–46.

Harvey, Penny. 2012. "The Topological Quality of Infrastructural Relation: An Ethnographic Approach." *Theory, Culture and Society* 29 (4-5): 76–92.

Harvey, Penny and Hannah Knox. 2012. "The Enchantments of Infrastructure." *Mobilities* 7 (4): 521–36.

Harvey, Penny and Hannah Knox. 2015. *Roads: An Anthropology of Infrastructure and Expertise*. Ithaca, NY: Cornell University Press.

Hetherington, Kregg. 2014. "Waiting for the Surveyor: Development Promises and the Temporality of Infrastructure." *The Journal of Latin American and Caribbean Anthropology* 19 (2): 195–211.

Horne, Richard B., et al. 2013. "Space Weather Impacts on Satellites and Forecasting the Earth's Electron Radiation Belts with SPACECAST." *Space Weather* 11: 169–86.

Howe, Cymene, et al. 2016. "Paradoxical Infrastructures: Ruins, Retrofit, and Risk." *Science, Technology, & Human Values* 41 (3): 547–65.

Joniak-Lüthi, Agnieszka. 2019. "Introduction: Infrastructure as an Asynchronic Timescape." *Roadsides* 1: 3–10.

Larkin, Brian. 2013. "The Politics and Poetics of Infrastructure." *Annual Review of Anthropology* 42: 327–43.

Mureşan, Liviu and Alexandru Georgescu. 2015. "The Road to Resilience in 2050." *The RUSI Journal* 160 (6): 58–66.

Olson, Valerie. 2013. "NEOecology: The Solar System's Emerging Environmental Ecology and Politics." In *New Natures: Joining Environmental History with Science and Technology Studies*, edited by Dolly Jørgensen, Finn Arne Jørgensen, and Sara B. Pritchard, 195–211. Pittsburgh, PA: University of Pittsburgh Press.

Olson, Valerie. 2018. *Into the Extreme: US Environmental Systems and Politics Beyond Earth*. Minneapolis and London: University of Minnesota Press.

Olson, Valerie and Lisa Messeri. 2015. "Beyond the Anthropocene: Un-Earthing an Epoch." *Environment and Society: Advances in Research* 6: 28–47.

Pritchard, Sara B. 2011. *Confluence: The Nature of Technology and the Remaking of the Rhône*. Cambridge, MA and London: Harvard University Press.

Star, Susan Leigh. 1999. "The Ethnography of Infrastructure." *American Behavioral Scientist* 43 (3): 377–91.

Star, Susan Leigh and Karen Ruhleder. 1996. "Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* 7 (1): 111–34.

White House. 2015a. *National Space Weather Action Plan*. USA: National Science and Technology Council.

White House. 2015b. *National Space Weather Strategy*. USA: National Science and Technology Council.

---

**Cite as:** Taylor, A. R. E. 2020. "Space Weather as a Threat to Critical Infrastructure." *Roadsides* 3: 63-72. DOI: <https://doi.org/10.26034/roadsides-202000309>

---

**Author:**



**A. R. E. Taylor** is based at the Department of Social Anthropology, University of Cambridge and works at the intersection of digital anthropology, critical data studies, media archaeology and science and technology studies. He co-runs the Social Studies of Outer Space Network and is an editorial assistant for the *Journal of Extreme Anthropology*. In 2019 he co-founded the Black Sky Resilience Group, a network of researchers, policymakers and industry leaders exploring societal and infrastructure resilience in relation to global catastrophic risks. His research interests include technology and modernity, futures, outer space, techno-apocalyptic narratives and data preservation.

**Roadsides** is an open access journal designated to be a forum devoted to exploring the social, cultural and political life of infrastructure.



Visit us at: **roadsides.net**  
E-Mail: **editor@roadsides.net**  
Twitter: **@road\_sides**

**Editorial Team:**

Julie Chu (University of Chicago)  
Tina Harris (University of Amsterdam)  
Agnieszka Joniak-Lüthi (University of Zurich)  
Madlen Kobi (Academy of Architecture, Mendrisio)  
Nadine Plachta (Heidelberg University's South Asia Institute, Kathmandu Office)  
Galen Murton (LMU Munich and James Madison University, Harrisonburg)  
Matthäus Rest (Max-Planck-Institute for the Science of Human History, Jena)  
Alessandro Rippa (Tallinn University)  
Martin Saxer (LMU Munich)  
Christina Schwenkel (University of California, Riverside)  
Max D. Woodworth (The Ohio State University)

Collection no. 003 was edited by: **Christine Bichsel**  
Managing editor: **Agnieszka Joniak-Lüthi**  
Copyediting: **David Hawkins**  
Layout: **Chantal Hinni** and **Antoni Kwiatkowski**

**ISSN 2624-9081**

**Creative Commons License**

This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

