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Space Weather: A potential threat?

Sitra Khan
Australian Defence Force

Space systems are undoubtedly woven into the fabric of our daily lives. Their role in ensuring global connectivity, navigation, weather forecasting, disaster management, and national security is crucial (Pellegrino & Stang, 2016). As the 21st century unfolds, this dependence is only projected to deepen. By 2050, Australia's sovereign space capabilities are anticipated to experience significant growth (Australian Space Agency [ASA], 2019). Nonetheless, our growing reliance on these systems exposes us to potential threats from space, especially space weather.

Space Weather refers to the variations in the environment around Earth due to solar activities (National Oceanic and Atmospheric Administration [NOAA], 2023). Disruptions often arise from coronal mass ejections (CMEs), which could lead to geomagnetic storms. The magnitude of these storms can interfere with power grids, transport systems, communication networks, and satellites in orbit (Ferguson et al. 2015). Such disruptions can have economic repercussions and jeopardise public safety. This article posits that Space Weather, particularly geomagnetic storms, could be a pressing challenge to Australia's space environment in 2050.

Australia can play a vital role in the ever-interconnecting global networks for space domain awareness and environmental monitoring. While an upsurge in sovereign space activity may not directly translate to a spike in space weather impact, the rising number of satellites and space infrastructure means that there is more at stake during Space Weather events (Kennewell & McDonald, n.d.). Hence, it is imperative to recognise its impact so proper preparations can be put in place.

Over the last few centuries, several intense geomagnetic storms have hit the Earth (Moldwin, 2022). Notable incidents include the 1859 Carrington Event, which disrupted telegraphs and sparked fires (Cliver, 2006), and the 1989 Quebec Blackout that affected millions of people due to a prolonged CME (Zell, 2017). The 2003 Halloween solar storms caused disruptions in civil aviation, power grids, and made aurorae visible in unexpected regions like Texas and Mediterranean countries (Gopalswamy et al. 2005). More recently, major solar flares caused radio blackouts over parts of North America (Pultarova, 2023) and the Pacific Ocean (lea, 2023). Moreover, the *Northern Lights* were visible at the United States/Mexico border (not where they are usually seen!) due to massive solar storm events (Phillips, 2023). These episodes underscore the importance of heightening our awareness of space weather threats.

Understanding the sun is crucial for comprehending Space Weather. Solar cycles, recurring roughly every 11 years, represent patterns of solar activity marked by variations in the number of visible sunspots (Hathaway, 2010). Research by Owens et al. (2021) suggests that Space Weather events, especially extreme geomagnetic storms, are more frequent during solar maximum periods. The study also draws attention to the "data paucity curse," which limits the statistical analysis of extreme event occurrences.

Solar Cycle 25 is on track to peak in 2025 and wind down by 2030 (Singh & Bhargawa, 2021). Predictions suggest that Solar Cycle 27 will commence in 2042, reaching its peak around 2047. Given the prolonged effects of solar events, high sunspot activity may still be evident in 2050.

While our ability to predict solar flares or specific sun regions that might produce a CME remains limited (Browne, 2023), advancements have been made in forecasting the arrival and orientation of CMEs with a narrow window (Organisation for Economic Co-operation and Development [OECD], 2022). However, more comprehensive data sets and integrated prediction models are required for a deeper understanding (Nandy et al., 2021).

Recent initiatives utilising Artificial Intelligence (AI) show promise. The National Aeronautics and Space Administration (NASA), in collaboration with international partners, has pioneered the Deep Learning Geomagnetic Perturbation (DAGGER) model. This model can predict geomagnetic disturbances half an hour in advance (Thomas, 2023). However, as noted by the OECD (2022), certain solar events travel at light speed, making forecasting impossible.

Early warning systems, while beneficial, still necessitate a coordinated response. Australia has proactively established the Space Weather Service (SWS) under the Bureau of Meteorology, providing forecasts and alerts for various sectors (Bureau of Meteorology, 2022). Additionally, the Australian Government has set up the Space Environment Research Centre and Geoscience Australia, the latter overseeing geomagnetic monitoring stations that play a vital role in space weather surveillance (Geoscience Australia, 2023).

It is undeniable that space weather events pose a significant natural threat to our way of life. While geomagnetic storms could challenge Australia's space environment in 2050, the nation's efforts in prediction, awareness, and inter-agency coordination will be pivotal in safeguarding infrastructure and public safety.

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