THE NEED FOR INFORMED AND TARGETED HELIOPHYSICS RESEARCH

Across the planet, civilian and industrial reliance on spaceborne assets and technology is increasing at a very fast pace. A record number of 345 satellites were launched in 2017 alone, with 49 percent of them designed for Earth observation. In the previous year, there was a 47-percent increase in the number of operational satellites, as compared to the year before that. Satellite services, ground equipment, navigation, and launch industry revenues were estimated at $255 billion in 2015, $261 billion in 2016, and $269 billion USD in 2017 (State of Satellite Industry Report, 2017). With this increase in space-based assets, space weather and its impacts are a growing area of interest. Space is not the only location affected by space weather, as it can also negatively affect ground-based and communications infrastructure such as our electric power grid network (Cassak et. al., 2017 and references therein), making space weather a concern for our national security and economic vitality.

This young field of space weather has developed without a strong applied component. The lack of a robust applied space weather research community has made it difficult to assess the expected impacts of extreme space weather events to our lives and economy. The impacts of space weather on technology have been recorded over the last century and have often been sensationalized as leading to catastrophe and billions of dollars of economic loss (e.g. Cassak et. al., 2017; Baker, 2002; and Fry, 2012). The reality of these potential extreme disasters are often debated in the hallways of space weather conferences, because they are thought of as remote possibilities that do not regularly touch the lives of citizens, if ever (e.g., Forbes et. al., 2012).

Observational Obstacles and a Need for New Data

Part of the debate is hindered by the lack of a long-time series of space weather events. Since the 1960s, there has been an ever-increasing number of in situ measurements, but the space environment is still only sparsely monitored. Another issue is the lack of a database for space weather impacts. This is a difficult dataset to obtain, as it comprises confidential and proprietary information (e.g., Baker et. al., 2004, 2012; Forbes et. al., 2012; Lohmeyer, 2013). However, it is difficult for scientists to understand which phenomena and the size of the event causing different types of space weather impacts when the impact information is not readily available. This leads to misunderstandings and a lot of guesswork of what properties are important to track and forecast (Forbes et. al., 2012).

Previous Extreme Space Weather Events and Impacts

Over the last 20 years, we have experienced less active solar cycles. Although it appears that the most extreme events can and do occur regardless of the activity or phase of the solar cycle (Riley, 2012), we have seen fewer large events affecting technology (Li et. al., 2017). Along with this decrease in activity, we have also seen an increase in space-based assets and a ground-based infrastructure that may be more vulnerable to a more active era of space weather.

Within these observational constraints, we have some important data points to consider. The most famous is the Carrington Event (Carrington, 1859; Hodgson, 1859). When the Carrington event occurred in 1859, there were only 17 hours between the eruption on the solar surface and the extreme effects on technology on Earth, which caused fires in some telegraph lines and yet allowed others to continue to work while having been disconnected from their power sources. Auroras were observed at low latitudes (Green, 2006). The 1989 extreme geomagnetic storm caused a blackout throughout much of Quebec, Canada and New England (Allen et. al., 1989). Many have hypothesized about what would happen if either of these storms occurred today with our increase in space-based assets, a more interconnected power grid, and more dependence on technology, which could be affected by space weather (e.g., Baker, et. al., 2012, 2013). While our technology has increased, so has our hardening of the relevant systems and safety precautions to protect against space weather hazards (Forbes et. al., 2012; Fry, 2012). Other extreme storms have occurred throughout the century with space weather impacts observed, but it must be noted that they have not resulted in the catastrophic disruption of our lives, our economy, or our infrastructure.

No solar storm has produced the catastrophic impact often expected. However, they still disrupt our daily lives and impact our economic vitality. In fact, many non-extreme events can cause anomalous behavior or changes to how and where we work (e.g., Cassak et. al., 2017). Space weather disruptions to communications in the polar regions cause planes to take longer routes using more fuel. Disruptions to GPS can delay farming, mining, or other precision GPS-dependent activities. High-energy particle injections and solar energetic particle events can cause major problems for satellites. Although these effects are not global and may only be encountered by a few, the combined and ongoing cost can be significant (Oughton et. al., 2017).

New Targeted Fundamental Science

To better understand and constrain the expected impact of space weather, both the absolute worst-case scenario and the likely worst case during the lifetime of our infrastructure leading to improvements to our fundamental understanding need to occur. It is important to define what the worst-case scenario may be in order to have a plan in place in case it occurs. As those events are exceedingly rare, it is perhaps more useful to understand what size of events are likely to occur during the lifetime of the infrastructure, operation, or satellite.

Science has always had the ultimate goal of explaining the natural world. If we want to live and work within the Earth-space environment, we must understand its dynamic range. Historically, there has been little input from those affected by space weather to guide where more research is needed for prompt improvement for these societal benefits. Researchers have also been historically reluctant to reach out to these end users for guidance in their research questions. This has led to large improvements in our understanding of the Earth-space environment, with little understanding of which types of space weather will have the largest impact on our lives, our technology, and our economy.

The heliophysics field will greatly benefit from a more transdisciplinary approach. There needs to be more communication between the research and user communities. This will facilitate advancement in the research areas necessary to understand the space weather import to each specific user group.

Transdisciplinary Space Weather Approach

Neither the researcher nor the user are likely the best situated to determine the overall economic impact to our economy due to space weather. Thus, it is necessary to include economists within this discussion. Policy analysts and makers are then needed to take the results and guide industry and government groups to raise awareness of the impact of space weather on their specific interests. At all stages, subject matter experts and users should be consulted to ensure that the impacts of space weather on our society are correctly characterized and understood.

Benefits to User Guided Research

One concern may be that this targeted research will take funding away from more traditionally, non-user-guided research. Although this research may be more targeted than the traditional approach, it still contributes to a better understanding of our natural world. Bringing in the user community and helping to solve their problems will provide feedback and additional observational techniques, as well as identify and help set up additional funding sources. Lastly, fostering communication between the research and user communities will provide currently unrealized new job and funding markets for heliophysics graduates. Perhaps the most overlooked benefit of this guided/targeted research is the discovery of new phenomena and areas of fundamental physics to study. It is very common that through working with users, unidentified signals and responses are observed, and new phenomena are found for future study. This leads to new discoveries and advancements in our fundamental knowledge and understanding of the Sun-Earth system.

Conclusion

Many areas of science have benefited by working with the users of their science. Heliophysics will likely be no different and will see advancements from a more targeted approach. This guided research will likely produce stronger collaborations and a quicker turnaround for some research to become routinely used to benefit society. Although not all research should be directly guided, there is certainly a need to fund and encourage our heliophysics community to work with and take seriously the needs of our government and industry partners where our research may be applied.

The Aerospace Corporation

The Aerospace Corporation is a national nonprofit corporation that operates a federally funded research and development center (FFRDC) and has approximately 4,000 employees. The Aerospace FFRDC is aligned to support the most critical programs of the Department of Defense and the nation and to serve as its customers' innovation partner across the space enterprise. Consistent with the competencies outlined in our sponsoring agreement, Aerospace provides strategic value through independent, intellectually rigorous, relevant, and timely products and services. With three major locations in El Segundo, CA, Colorado Springs, CO, and Washington, DC, Aerospace addresses complex problems across the space enterprise including the DOD, Intelligence Community, civil, commercial, and other areas of national significance.

The Aerospace Corporation | 2310 East El Segundo Boulevard, El Segundo, California 90245-4609 USA | www.aerospace.org
©2018 The Aerospace Corporation. All trademarks, service marks, and trade names contained herein are the property of their respective owners.

References:

Bryce. 2017 SIA State of Satellite Industry Report, 2017. https://www.sia.org/wp-content/uploads/2017/07/SIA-SSIR-2017.pdf

Cassak, P.A.; Emslie, A.G.; Halford, A.J.; Baker, D.N.; Spence, H.E.; Avery, S.K.; and Fisk, L.A. Space Physics and Policy for Contemporary Society, J. Geophys. Res. Space Physics, 2017.

Baker, D.N. How to Cope with Space Weather, Science, 2002.

Fry, E.M. (2012) The Risks and Impacts of Space Weather: Policy Recommendations and Initiatives, Space Policy, Vol. 28, Issue 3, 2012.

Baker, D. N.; Daly, E.; Daglis, I.; Kappenman, J.G.; and Panasyuk, M. Effects of Space Weather on Technology Infrastructure. Space Weather, 2, 2004.

Riley, P. On the Probability of Occurrence of Extreme Space Weather Events, Space Weather, 10, S02012, 2012.

Carrington, R.C. Description of a Singular Appearance Seen in the Sun on September 1, 1859. Monthly Notices of the Royal Astronomical Society, 1859.

Hodgson, R. On a Curious Appearance Seen in the Sun, Monthly Notices of the Royal Astronomical Society, 1859.

Allen, J.; Sauer, H.; Frank, L.; and Reiff, P. Effects of the March 1989 Solar Activity, Eos Trans. AGU, 70(46), 1989.

Baker, D.N.; Li, X.; Pulkkinen, A.; Ngwira, C.M.; Mays, M.L.; Galvin, A.B.; and Simunac, K.D.C. A Major Solar Eruptive Event in July 2012: Defining Extreme Space Weather Scenarios, Space Weather, 11, 2013.

Baker, D.N. The Third Electric Infrastructure Security World Summit Meeting. Space Weather, 2012.

Forbes, K. F. and St. Cyr, O.C. Did Geomagnetic Activity Challenge Electric Power Reliability During Solar Cycle 23? Evidence from the PJM Regional Transmission Organization in North America, Space Weather, 10, 2012.

Green, J.L. and Boardsen, S. Duration and Extent of the Great Auroral Storm of 1859, Advances in Space Research, Vol. 38 Issue 2, 2006.

Lohmeyer, W.Q. and Cahoy, K. Space Weather Radiation Effects on Geostationary Satellite Solid-State Power Amplifiers, Space Weather, 11, 2013.

Li, X.; Baker, D.N.; Zhao, H; Zhang, K; Jaynes, A.N.; Schiller, Q; Kanekal, S.G.; Blake, J.B.; and Temerin, M. Radiation Belt Electron Dynamics at low L (<4): Van Allen Probes Era Versus Previous Two Solar Cycles, J. Geophys. Res. Space Physics, 2017.

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, 15, 2017.