UK Space Environment Impacts Expert Group
Comments on US Space Weather Benchmarks: General remarks

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Introduction

This document consolidates comments from the UK Space Environment Impacts Expert Group (SEIEG, a group of independent UK space weather experts set up in 2010, with the encouragement of Cabinet Office, to provide advice to UK Government bodies seeking to mitigate the risks posed by space weather). It provides comments on the "Space Weather 1 Phase 1 Benchmarks" produced by the Space Weather Operations, Research, And Mitigation Subcommittee of the US National Science and Technology Council.

This document contains general remarks on the benchmarks.

Summary of key points

- These draft benchmarks are an important step towards understanding extreme space weather environments, a critical element in assessing the risks posed by space weather.
- We encourage a comparison with UK work on worst case space weather environments, especially the latest report of our group (http://purl.org/net/epubs/work/25015281).
- The next steps of benchmark development would benefit substantially from iteration between engineers and scientists to identify and refine what are the most important environmental parameters.
- The benchmarks should include an explicit assessment of atmospheric radiation environments, separate from the space radiation environment.
- We would welcome the opportunity to exchange ideas with US colleagues, not least as we plan to update our worst case assessment later this year.
- We provide many detailed comments on all the benchmarks.

1 Overview

First, we are very pleased to see an independent report on the space environment and its extremes as a reference for future space weather impact assessment. It is definitely needed. We recognise that the Phase 1 document is very much a first step, and offer comments that we hope will help with next steps.

2 Background: UK work on extreme space weather environments

UK space weather experts have already done significant work to assess worst case space weather environments, in particular the work of our group published last year (Hapgood et al., 2016) and the Royal Academy of Engineering Report (Cannon et al., 2013). We note that there was a large overlap between the membership of our group (see author list in Hapgood et al above) and the membership of the Royal Academy study team (see list at end of that Report). This cross-membership has been important in building both a coherent view of space weather extremes and impacts, and a strong working relationship with key players across UK Government and industry.

We are very interested to work with US partners, building on the many personal and professional relationships that members of SEIEG already have with the US community. Thus we encourage the US benchmarks team to study, and perhaps reference, the two reports listed above. In the interests both of improving our working relationship, and improving the technical content and rationale behind our assessments to date, we welcome any feedback/comments that our US colleagues may have on these documents.

We note that there is an important difference between the UK and US approaches to evaluating the potential impacts of extreme space weather. The US benchmarks have focused on describing extreme environments without detailed consideration of how these environments subsequently lead to severe technical and societal impacts. In contrast the UK worst case study (Hapgood et al., 2016) has encouraged iteration between scientists and engineers so as to ensure a focus on environments that lead to societally important impacts. The US approach is essentially reductionist, breaking the chain of space weather cause and effect into work packages that can be done by different groups of experts. This is attractive from a management point of view, but we consider that it makes it more difficult to focus on the key issues, which may be the result of multiple causes/interactions. A holistic approach, as adopted in the UK, encourages dialogue between different groups of experts and hence a focus to identify and refine those key issues. This later approach is more challenging to manage but also delivers a better understanding of space weather for all involved and hence better advice provision to policy makers.

3 The need to consider impacts: iteration between scientists and engineers

We recommend that Phase II of the benchmarks activity should include more iteration between scientists and engineers so that the relationship between environments and impacts is highlighted. We believe that this will offer several advantages:

- It will help you to identify, and to justify, what are the right space weather parameters to consider, i.e. what factors in the environment best relate to adverse impact on technology. This can only be done through iteration with engineers. It was a key motivation for why both environment and impact were included together in the Cannon et al (2013) report. We suggest that some discussion is done at an early stage in Phase II to help direct the study. An example is where internal charging (the accumulation of charge in dielectric materials) depends not simply on the timeline of high energy electron fluxes, but rather on a history that convolves those fluxes with the conductivity of the dielectric material in the satellite system at risk (i.e. the ability of that material to slowly leak away accumulated charge). Similarly the time profile of solar particle events is important as the highest rate of single event effects is the most challenging. This applies to both spacecraft and aircraft electronics and the timescales for the latter tend to be much shorter than the former.

- Iteration with the engineering community will help you to progress those benchmarks that are poorly developed in Phase I, e.g. those for the ionosphere. Space weather is an area of significant complexity and a huge wealth of literature. A greater focus on impacts will help you identify the most critical issues to consider in the benchmarking activity and thus which literature to search and also how the teams should engage the right people with sufficient depth of knowledge to advise and contribute.
- More consideration of impacts will increase the impact of your next report. Whilst we understand the philosophy of a report that focuses on the environment, such reports may poorly engage with important audiences in government, industry and even the general public. You need to address the "so what?" question that these audiences will raise. We recommend to include at least a short summary to address this.

4 Presentational issues

- We recommend that in the Phase 2 report you include tabulated summaries of the parameters (as in Hapgood et al, 2016). Our experience is that such tabular summaries are a powerful tool for disseminating knowledge outside the space weather expert community. Our colleagues in government and industry can use such tables in risk management discussions – thereby teasing out details of the consequences of extreme space weather and of any current efforts to mitigate those consequences. It is much harder to do that with a narrative text. In the end someone has to summarise and it would be much better if that were done by space weather experts.
- The aim (Introduction, para 2) of having benchmarks for 1-in-100 year events and a theoretical maximum is a good one. But, where possible, we recommend to have a wider spectrum of probabilities vs event sizes, e.g. encompassing both longer-timescales appropriate for highly critical systems that may be vulnerable to space weather (such as radiation impacts on control of nuclear power systems) and medium-timescales (1-in-30 years) appropriate for large events, such as the geomagnetic storm of March 1989 or the radiation storms of autumn 1989. The latter helps to bring out the potential severity of a Carrington-class event. There is a risk that operators of some vulnerable systems adjust their perception of bad space weather to recent smaller events, e.g. the Bastille Day radiation storm of 2000 or even the very modest geomagnetic storm on St Patrick's Day 2015.

5 International aspects

Is the report limited to environments that physically impact US territory? Or do you plan to address physical impacts elsewhere in the world that have implications for the US, e.g. impacts on US assets in other countries, or indirect impacts on the US via economic linkages to other countries? The latter is a growing area of interest given recent progress in socio-economic studies (Schulte in den Bäumen et al., 2014; Oughton et al., 2016). This is particularly important for risks where the space weather environment needs to be customised to local conditions, e.g. latitude or ground conductivity, which may be different to the US.

6 Future UK work

Our group is planning a further update of the UK space weather worst case study later this year – to pick up on latest research on environments and impacts and to ensure that this is available for the next iteration of UK risk assessments. We will be keen to exchange ideas with the US side and also to consider publication of our next report in a peer-reviewed journal. It would be worth considering a bi-lateral meeting between SEIEG and US benchmark leads, either as videocon or face to face, if time and money allow.

We also note that there are some good prospects for wider UK-US research collaboration. Just as these comments are being written the UK's Natural Environment Research Council has notified its intention to fund two large national space weather projects: one seeking new insights into space weather impact on UK national (electrically) grounded infrastructure, and the other modelling and forecasting the Earth's radiation belts. Thus UK space weather scientists are well-positioned to make progress in both these areas and there will likely be possibilities to exchange ideas with our US colleagues, perhaps via joint workshops.

7 References

- Cannon, P, et al., (2013), Extreme space weather: impacts on engineered systems and infrastructure, Royal Academy of Engineering. http://www.raeng.org.uk/publications/reports/space-weather-full-report
- Hapgood, M, et al., (2016). Summary of space weather worst-case environments. Revised edition. RAL technical report, RAL-TR-2016-006. http://purl.org/net/epubs/work/25015281.
- Oughton, E. J., A. Skelton, R. B. Horne, A. W. P. Thomson, and C. T. Gaunt (2017), Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure, Space Weather, 15, 65–83, doi:10.1002/2016SW001491.
- Schulte in den Bäumen, H., Moran, D., Lenzen, M., Cairns, I., & Steenge, A., 2014. How severe space weather can disrupt global supply chains. Natural Hazards and Earth System Science, 14(10), 2749-2759.