

COSPAR PSW/ISWAT Roadmap Update 2022; Coordinator: Mario M. Bisi.

The *COSPAR Space Weather Roadmap* is in need of updating approximately every five years as per the *COSPAR Panel on Space Weather (PSW)* terms of reference and to address the latest societal needs/vulnerabilities to space weather as well as what areas of space weather need specific foci. This is also needed for and by the community as a whole so that the roadmap remains current and valid. The scope and coverage of the roadmap can be assessed each time the update period comes around. The original COSPAR Space Weather Roadmap (Schrijver *et al.*, “Understanding space weather to shield society: A global road map for 2015–2025 commissioned by COSPAR and ILWS”, *Advances in Space Research*, Volume 55, Issue 12, Pages 2745-2807, 2015) concentrated solely on scientific needs/gaps and the ways forward. It is expected that the updated Roadmap will include elements of operations and applications as well as the science, but will still be a science-research driven activity overall. In addition, there is a desire to bring in national/international strategies and with the proposed tiered approach to the roadmap, this can quite easily be achieved.

During the COSPAR International Space Weather Action Teams (ISWAT) Inaugural Meeting in February 2020, it was agreed through detailed discussion to adopt a community-driven approach to the Roadmap update from the bottom up and that the COSPAR ISWAT Initiative will form the backbone for it with sets of papers in layers from the bottom-up as laid out in Figure 1. Subsequent discussions by both ISWAT Moderators and the PSW Members have agreed to this plan in principle with suggestions of needing to provide more hands-on input for the middle tier of papers to ensure nothing is missed and also to bring out the less-science oriented activities, particularly looking at the space-weather impact chains from the Sun to the final effect(s). We need to remember that this roadmap is focussed not just on scientists, but also for influencing policy makers and funding agencies, and to allow potential programmes to be set up using this new roadmap as substantive evidence for doing so.

For terminology specifically related to the structure of the ISWAT initiative and how teams are grouped into clusters representing key aspects of space weather and the subsequent links to overarching activities and impacts, please take a look here: <https://iswat-cospar.org/> - this is the COSPAR ISWAT website which provides all the relevant information pertaining to the COSPAR ISWAT initiative.

A key point throughout all the envisaged paper layers is to make the distinction between what is wanted and what is possible and why some things needed may not be possible, or at least, may not be possible yet. Avenues on where those ideas are needed to go to become available will also be expected to be covered in the papers in which they are raised in general.

The bottom-level set of papers (original research) will be the COSPAR ISWAT Team-driven/Multi-Team-driven science and technology papers on ISWAT activities with reference and acknowledgement to the original Roadmap and where the next steps are in each niche area/team topic.

The lower-middle-level set of papers (quasi-reviews) will be COSPAR ISWAT Cluster-driven/Cross-Cluster-driven papers (meaning across different key space-weather

themes/domains) with additional guided papers by the COSPAR PSW to fill any gaps. These papers would primarily be referring to the bottom-level topical papers on science and technology (as appropriate), consolidating ideas from considerations of scientific and operational/monitoring needs into broader-scale requirements with reference to the original roadmap, and for expected community actions to move things forward in a more broad sense and/or in more joined-up approaches than at the bottom-level papers. Links into the Space-Weather Impacts and making use of the COSPAR ISWAT Overarching Activities and R2O/O2R concepts can be discussed within these papers too. In addition, this tier could contain papers on national/international strategies, particularly where those strategies tie into the COSPAR PSW goals and activities, and especially where they can show advancement to the COSPAR PSW roadmap and/or points the way forward. In addition, it would be really good if the roadmap could work in sync with such national/international/agency strategies and potentially reflect some of the wider needs/concerns to more-completely tie into society.

The upper-middle-level set of papers (impacts focussed) will tie together the four primary pathways/impact chains. These are akin to the original roadmap but can let the necessary detail “evolve” in each while tying back to the lower-level papers and forming a very strong foundation for the top-level paper. These papers will include the details necessary for R2O-O2R and even operations when pertinent, but will still be founded in the science that links the space-weather phenomena to these impacts. These four impact pathways are: (1) GICs; (2) Communications/Navigation/Radio Propagation; (3) Neutrals and Satellite Drag; and (4) Radiation (all radiation aspects combined together). The ISWAT impacts and science avenues nicely map into these - which are detailed here: <https://iswat-cospar.org/> on the right-hand side, with the exception of Climate. We should also be aware of the potential damage to other areas of science caused by more space-weather infrastructures; for example, more space-weather constellations in Earth orbit causing increased amounts of interference and degradations in signals for ground-based optical and radio astronomers (and these include space-weather applications too).

The top-level, single, consolidated paper (consolidated roadmap) will provide a suitably-concise PSW-/ISWAT-Moderator-led roadmap overview and recommendations paper for science, operations, and monitoring referring down the chains of papers and to the original roadmap. Still needs to be somewhat standalone, but not verbose. The roadmap, as a whole, should stimulate national space-weather investments and pave the way for the most-critical international engagements/activities that are needed globally as well as nationally/locally. Although different countries are at different stages of their planning, as is being discovered by the UN COPUOS Expert Group on Space Weather (EGSW) activities, some of the insights learned there can also be fed into the the more-strategic outcomes/directions of this roadmap, particularly as the vast majority of nations want to learn more about potential space-weather impacts on them, even if they have not even began that journey of discovery as yet.

Thus, the top-level paper will form an executive overview of the two lower-level sets of papers where the more-detailed descriptions of cutting-edge science and technology and their impact will be described. As a collection, the papers will form the Updated COSPAR Space Weather Roadmap - an ISWAT Community-led Roadmap from the bottom-up with key science, validation, old roadmap steps achieved, and where to go next/what's missing/needed... Links are likely to be made at various stages to future opportunities both

on the ground and in space, perhaps even including how space weather can fit with the COSPAR small satellites plans: Millan *et al.*, “Small satellites for space science: A COSPAR scientific roadmap”, *Advances in Space Research*, Volume 64, Issue 8, Pages 1466-1517, 2019.

In addition to that detailed thus far, an Executive Summary/Overview more open to everyone will need to also be established, again of a similar guise to the original roadmap. This could be a formal paper, a brochure-type paper, or something different still; but it needs to be fully engaging, simple, straightforward, and covering all the key points of the top-level paper as a minimum. This will be a significant challenge, but a necessary one. This is also very useful here for those in the funding agencies and people in high-director-level positions to read in a very concise and straightforward manner.

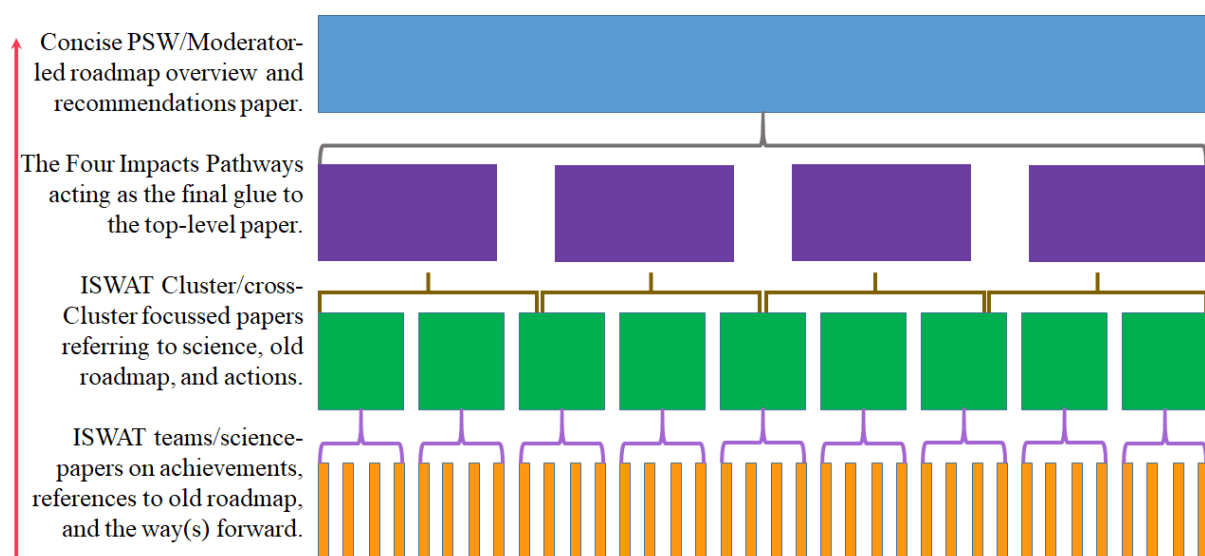


Figure 1. Overview (simplified) diagram of the papers structure forming the Updated COSPAR Space Weather Roadmap.

The papers are expected to be encapsulated in two special editions of *Advances in Space Research* (ASR), COSPAR’s in-house journal. Due to the disruption caused by COVID-19, including the postponement of COSPAR 2020 to 2021, the timeline was slipped for the preparations and eventual publication of the COSPAR Space Weather Roadmap Papers, and this is laid out below:

- 23 November 2020 - ONGOING - liaise with COSPAR ASR journal.
- 01 June 2021 - call for notice of intent and advertisement of the approach to the wider community (lower-tier papers focussed).
- 29 July 2021 - deadline for the notice of intent for each of the lower-tier papers.
- 15 August 2021 - deadline for the outlines and author lists of the middle-tiers papers including some details on what will be included in the papers.
- *We will have two separate Special Issues that form the roadmap.*
- 13-17 September 2021 and 27 September 2021-01 October 2021 - virtual ISWAT meeting (focal point for lower-tier papers).

- 08 October 2021 - finalisation of the middle tiers papers and submission of the necessary NOIs for these.
- 01 October 2021 - expected opening of submissions for both parts (or perhaps the second part ~two months later).
- 31 January 2022, (28 March 2022 to 01 April 2022 - hybrid ISWAT meeting in Portugal), 30 April 2022, 30 June 2022, and 31 August 2022 - staggered for the paper submissions - in four phases from the bottom level upwards.
- 31 December 2022 - envisaged final possible date for publication.

More details will follow in due course, including the Guest Editor Team information to propose and work with the COPAR ASR journal.

MORE GENERAL PSW NOTES:

Dibyendu: A possible pathway to bridge a science roadmap with operational recommendations is to have a discussion meeting between the scientists (writing various sub-topics) and operational folks, i.e., the end-user of space weather data products. The latter could include space agencies, satellite operators, civil aviation agencies, power grid operations etc. This meeting should be organized at a time when the science topics in the roadmap have already matured somewhat and end-users can consult these and come up with suggestions on translating the science to useful data products. This second step could in principle be a collaboration between the scientists and the operational folks and result in addendums to each of the relevant sub-topics, or alternatively, result in a separate chapter (Science to Operations).

Dibyendu: I think it is important to have a long term view of what it is exactly that we would be doing, that other groups are not already doing, or something which we are uniquely positioned to influence? IN my mind these would be: a) providing oversight to the roadmap activity, b) act as a bridge between the space weather community and space agencies through COSPAR, c) facilitate capacity building in space weather across the globe. In c) there is scope for COSPAR PSW to work together with UNCOPUS, SCOSTEP, ISWI...

Dibyendu: Can we also send a recommendation to COSPAR to write to every space agency, operational forecasting agencies, UN and an other stake holder and seek feedback on: a) Are they aware of the COSPAR space weather roadmap, b) Did they use the roadmap in any policy or planning or mission definition, c) in a revised roadmap, what would they like to see that would be beneficial to them. This will help us ascertain a proper pitch for the new roadmap.

Terry: I agree with Dibyendu that it is important to have a long term view. A roadmap needs to have a clear destination, and I think the destination for this roadmap should be improved space weather services. For each of the impact areas we cover, the roadmap should identify the space weather information that is needed (much of which is in the original roadmap), it should describe how good current capabilities are, and it should recommend the scientific research needed to make progress with the highest impact. I think the maximum influence we could have would be if we are able to say to the funding agencies, "if you fund this research or these observations, this is how we anticipate our space weather capabilities will improve."

Terry: By now we have a fairly good understanding of how space weather information is used, and we have a fairly good understanding of which improvements in prediction/specification capabilities would have significant value. But in many areas we don't have a good quantitative understanding of how good our current scientific capabilities are for providing the specific information that has value to those impacted by space weather. Nor is it clear to funding agencies which research would give the greatest return on their investment. This is what I think the roadmap should provide.

David: I'm sensing a bit of a disconnect between the roadmap and the intended beneficiaries (service providers, as Terry says, and end users). While their needs may have been adequately

addressed in the original roadmap, user requirements are always evolving, and thus space weather services also need to evolve, and the COSPAR roadmap needs to reflect this to avoid being out of date or even irrelevant. Better connection with ISES and the WMO space weather group (when it restarts) would be a good place to start. Dibyendu's workshop may also be a great way of kicking off this connection (but it needs to then be maintained). I also agree with Dibyendu's point about publicity. I thought the WMO group did a great job on developing observational requirements for space weather services (OSCAR), but when I talked about it at meetings and workshops I discovered few people had heard of it!