CEDAR Long Term Vision: Workshop Summary

In this session attendees discussed a variety of topics that focussed on the future of CEDAR. We began with four talks (found on the session wiki page): Allison Jaynes discussed the Geospace Dynamics Constellation (GDC) STDT (the next Living With a Star mission recommended by the 2013 Decadal Survey), Robyn Millan discussed the current progress of the 2013 Decadal survey, Anthony Mannucci discussed the 2019 Chapman Conference on space weather, and Jeff Thayer discussed the past, present, and future of CEDAR science. These talks were then followed by several break-out sessions. This document outlines themes that emerged from the workshop, as well as emerging action items.

Workshop Themes:

Throughout the session numerous “themes” emerged, representing ways in which the CEDAR community can improve and embrace the future. These themes are listed below, but it is important to note that several of these themes compliment each other.

Theme 1: Promote collaboration

Certainly the most discussed theme in the break out sessions was promoting collaboration with other groups. This can be facilitated in a variety of ways, such as through platforms to establish a common terminology (with particular emphasis on linking terms and concepts rather than definitions), and more hybrid (in-person and virtual) meetings which allow for diverse participation and bring more people into the field, as well as improving the value of virtual discussions. Several different avenues of collaboration have been identified:

Theme 1a: Promote collaboration with other STEM communities

Even though we have overlapping interests with other physics communities, we are all reasonably divided. These divides may be strengthened by how programs are categorized within divisions and agencies. It would be beneficial for CEDAR to take on interdisciplinary initiatives.

We should partner with close physics communities, such as exoplanets, planetary atmospheres, troposphere, and comparative atmospheres, and develop overlapping science goals with complimenting observations and models. This has already begun with overlapping CEDAR-GEM and GEM-SHINE meetings to address cross-domain science goals (and could suggest that these three groups may not exist separately in 30 years). This stated, we can even venture outside of physics, and invite non-CEDAR mathematicians, computer scientists, and engineers to CEDAR. It might be impactful to compile examples where “science bridges” have been formed (e.g. Keck Institute for Space Sciences, Systems Science institutes like Neukom and Santa Fe Institute, National Science Foundation Convergence Accelerator and Harnessing the Data Revolution and NASA Frontier Development Laboratory).

Funding is one issue with cross-disciplinary collaboration. CEDAR would require agency (e.g. NASA, NSF, and AMS) cooperation in order for the funding to follow the science need for

multidisciplinary studies. NExSS (https://nexss.info/about/about-nexss) has cross-divisional calls for proposals.

Theme 1b: Promote collaboration with tech and industry communities

Industries and government agencies, such as the DoD, have a wealth of data and capabilities that would benefit CEDAR science, and CEDAR science has much to offer these groups. There are several examples where CEDAR and industry have collaborated well (e.g. AMPERE and 10.1002/2017SW001604), and CEDAR has evolved over recent years to promote science-technology collaborations (e.g., the growth of CS (python/modeling), machine learning, smallsats, distributed sensing activities). However, CEDAR has yet to truly embrace "space 2.0" and the role of space science in the tech and industry communities, and we must re-evaluate our science-tech collaborations and small satellite collaborations.

One way this can be aided is by improving the "language barrier" between CEDAR and industries, or at least find a common language. Additionally, CEDAR needs to think more about the "user" experience of CEDAR data (identify user needs and user/operational metrics in the assessment of our models), and identify the research questions that will help industry and the "research to operations" vector. We also need to value overlapping with other professional organizations, for example instrumentation-based communities like AAIA, SPIE, etc. Another option is to include industry in the direction of CEDAR, which would allow us to train scientists and students accordingly.

Theme 1c: Promote collaboration with citizen scientists

Successful citizen science projects already exist in the scope of CEDAR science (e.g. HamSci and Aurorasaurus), which shows the potential of everyday people to change CEDAR and creates a bridge that we can leverage to improve two-way science communication. However, CEDAR can both encourage more collaboration, improve the collaborations we already have, and leverage those collaborations to achieve other CEDAR goals.

It is often very easy to validate a model in the context of non-linear, citizen measurements, but it is a completely separate problem to turn that information into something that can assist model developers or isolate specific issues. We need to better bridge the gap between citizen scientist measurements and the "parameter" scientists want, while not discarding significant amounts of information in the process.

The reality is that we don't have the scientific measurements necessary to adequately test and validate our models, nor do conventional metrics communicate in the language of operational users. Not fully understanding our users outside the scientific context has made it challenging for either community to establish targets/goals (particularly in ionospheric science). Citizen science measurements are a wealth of information that may be challenging to translate into information that can directly inform our models (that's part of the fun), but they're often much closer to and tangible for our non-scientific user base.

Citizen science and citizen science projects can also be leveraged into CEDAR outreach, both to the general public and to schools. Citizen science projects also compliment the "outreach" required for proposals.

For effective citizen science to happen, we need to create well-designed citizen science projects with ample funding for all pieces of the project (science, software, people/volunteers, education, and data storage). We also need to identify what citizens are interested in, or rather, find groups whose passions or hobbies couple into CEDAR science. Other issues are: 1) properly crediting citizen scientists, 2) ensure citizen scientists can effectively contribute to science, and 3) ensuring CEDAR returns back to the community and communicate the value of what we have found back to the citizen scientists in their language.

A potential follow-up resource is: https://nasacitsci2020.gmri.org/ (though not CEDAR specific). Also the excellent HamSci virtual meeting this year is archived online.

Theme 1d: Promote global collaboration

CEDAR has participants from all around the world, but should expand and collaborate with more groups and organizations outside of the U.S. As it stands, the geographic diversity of CEDAR depends on whether a major school has a space program. We could work to include states/areas without strong programs. CEDAR could provide further benefits and opportunities for scientists and students outside the U.S.

Theme 2: Prepare CEDAR students for the future

There are ways in which we can better prepare students for the future. One way would be to broaden the career landscape, and be realistic that not every CEDAR scientist will become a tenured professor. Part of what compounds this issue is that most student supervisors are faculty who only know how to train graduate students to become faculty. CEDAR could not change this, but could be a great supplement for students who have other career goals.

Another way in which CEDAR could prepare students for the future is to facilitate modern/cutting-edge tutorials, such as data science tutorials. Similar tutorials could be used to teach useful skills, such as proposal development.

Theme 3: Addressing the needs of society, and raising CEDAR awareness

We need to invest some CEDAR resources to address societal relevance (NASA is particularly good at this) and needs. For example, prediction of ionospheric/thermospheric conditions with higher spatial and temporal resolution is needed (commercial enterprises use their own ionospheric observations and models, such as Spire). We need to understand the needs of society (operations to research and research to operations), improve the bridge from fundamental research to applied research, and improve the feedback between society and scientists (the meteorological community does this quite well).

A similar issue is that not many people know what CEDAR science or space physics is. This can be aided with the help of a document that describes CEDAR science in simple terms, or a space weather glossary (see CEDAR education poster by Kiaya Whal and the Bishop's Acronym Guide). These documents would also help students and collaborative efforts (e.g. citizen scientists). Additionally, the inclusion of outreach folks, such as those tied to the NSF, into

CEDAR would help spread the word about the work being done without putting the burden of labor on the CEDAR scientists themselves. CEDAR should also be more vocal about Cubesats, which are success stories.

Theme 4: Improving CEDAR instrumentation and models

Several discussion points arose related to how we could better capitalize and improve instruments and models. Here are the key points made:

- The CEDAR community should ensure that the multi-scale nature of coupling is addressed by investing in instruments and instrument networks at both regional and global levels. By doing this, we can address how different temporal/space scales couple with each other (turbulence, regional, local)?
    - NASA commonly focuses on observations from global networks and spacecraft. But these observations would benefit greatly from more regional (e.g. North America) ground-based networks.
- How far would GDC be able to successfully solve either objective 1 or 2 as outlined in the report?
- What are the temporal and spatial gradients that need to be resolved? In a way, models have surpassed the data, which can serve as guidance on what to measure (as well as societal needs).
- How do we effectively combine ground-based instruments and global space-based instruments in order to study the science related to interhemispheric coupling?
- What efforts should be made to advance the usage and capabilities of our ground based instruments?
- Observations and modeling data have discrepancies on smaller spatial and temporal scales What kind of advanced observational data and tools do we need to close this gap? Do we need to work on increasing the spatial/temporal resolutions in the model, which needs larger time in simulations?
- How do we effectively compile and coordinate models?
- How do we more effectively/intelligently determine what observations we need?
- How do we incorporate OSSEs and OSEs into CEDAR planning? (OSSEs are most appropriate to evaluate potential new instrument designs and observations, while OSEs are most appropriate to evaluate the importance of existing observational datasets).
- We're often stuck in the framework of making observations (Level 1 products) and turning them into a scientifically useful parameter (Level 2 product), even though raw measurements are often more useful in assimilation frameworks (see Tomoko Matsuo's "GOLD and Data Assimilation" talk in the CONCERT session). Using raw measurements

minimizes artifacts/biases produced in the process of arriving at a parameter and provides the optimal environment for information to be shared between observations. It also reduces the amount of data being thrown away. How do we escape this framework?

    - A good example of this is in the meteorological community when microwave and infrared radiometers became mainstream instruments. They would use scans to try and improve the vertical resolution of an inverted profile, and in so doing throw out wealths of information.

Theme 5: Other ways in which CEDAR can grow

- We have looked at coupling processes so far - how should we go about addressing *complexity*?
- We need to develop fluid documents and artifacts of our activities (e.g., with DOIs). The Chapman Conference is an excellent example of what this looks like.
- There is a tendency to have the same discussions over and over again. For example, we are asking the same questions asked in the Chapman conference from 1974. How can we stop this? Can we look back to what we were doing ten years ago and deliberately change from that? Is it because of internal boundaries we established (sub-disciplines)? How can we bring in new voices and ideas, like citizen scientists?
- How do we improve student involvement in CEDAR and give undergraduates the opportunities to be engaged in the field? How do we secure funding to help students engage with CEDAR?
- What data/software infrastructure do we need/lack to address key science challenges?
- How might the decadal surveys be a model for how we need to construct our teams and smaller research projects to be comprehensive, cross-cutting, and meaningful?
- How can CEDAR implement Recommendation 6.1 from midterm assessment? How do we increase community input on 'stretch goals' for the next decadal survey?
    - Recommendation 6.1: NASA and NSF should implement and fund advanced planning for the next solar and space physics decadal survey that involves the community strategically in the formulation of decadal goals and stretch goals (ambitious objectives that might extend past the next decade). NASA and NSF could request the Space Studies Board's Committee on Solar and Space Physics (SSB-CSSP) to evaluate options for implementing this planning for the next decadal survey.
- CEDAR could have a bigger hand in helping people write proposals (aligns with NASA's 'new PI' https://science.nasa.gov/researchers/new-pi-resources)

Potential Workshop Action Items:

The following is a list of evolving potential action items. However, this list is not complete, and is part of a larger, continuing discussion:

- Create more input on 'stretch goals' for the next decadal survey
- Create a CEDAR working group on contribution to the next Decadal Survey
- Focus on the representation and linking of knowledge to understand and prevent reinvention of previous progress and to innovate new ways to achieve discovery science