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SHIELD DRIVE Science Center: Efforts in diversification and inclusion in heliophysics

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We present the broader impacts effort of the NASA SHIELD DRIVE Science Center, summarizing both phase I and now phase II efforts. The purpose of the broadening impact efforts are to address the overall lack of diversity in the space physics workforce through intentional programming intended to increase inclusiveness and explicit support for emerging and early career researchers. Specific efforts include an online repository of testimonials of diverse early career researchers, SHIELD webinars highlighting the human side of eminent scientists, support for REU students at different institutions, and a yearly heliophysics summer school. We also discuss efforts to support heliophysics scientists through community building events and ongoing training. The SHIELD Drive Science Center's overall broadening impact goal is to train and mentor the next-generation of team-based heliophysicists while accelerating knowledge integration, transfer, and communication across traditional boundaries.

KEYWORDS

broader impacts, heliophysics, training, underrepresented, underserved, outreach

1 Introduction

The heliophysics community, like most other space science communities, has a lack of diversity and inclusion especially with respect to gender and ethnicity (NRC, 2013). The space physics workforce is majority white and male and is also aging and retirement-eligible (Moldwin & Morrow, 2011; Bagenal, 2023). This is particularly true with regards to the work force focused on the outer heliosphere, where many of the prominent researchers got their start during the Voyager mission at a time when the field was dominated by male US scientists of European decent. Together, these factors demonstrate the need to accelerate efforts to train the next-generation of space physics workers and to increase efforts to train and retain more diverse members of the heliophysics community. Although there have been increasing efforts to support minoritized members to join space sciences, these individuals have larger burdens and more obstacles to navigate to enter the field, succeed, and persist (Berhe et al., 2022). We describe an ongoing effort to support individuals from minoritized groups and with diverse thinking and backgrounds to imagine a career in space physics and provide multiple pathways to support them from undergraduate to mid-career as an example for other efforts.

2 DRIVE SCIENCE CENTERS

The NASA DRIVE Science Centers (DSC) are part of the DRIVE (Diversity, Realize, Integrate, Venture, Educate) Initiative called for in the 2013 Heliophysics Decadal Survey (NASEM, 2020). The "Venture" aspect of the DRIVE initiatives is to "address grand challenge goals" which "cannot be effectively done by individual investigators or small teams, but require the synergistic, coordinated efforts of a research center" (NASA, 2018). The DSC's are expected to create breakthrough science in heliophysics by integrating models from different domains and approaches. The DSC models are expected to incorporate new and existing data from sources that are developed or facilitated by other portions of the DRIVE initiative. The DSC's are also expected to fulfill the "Educate" aspect of DRIVE through both outreach efforts and by promoting the creation of a diverse workforce through building inclusive environments in which that workforce can thrive. In 2020, NASA announced the selection of nine phase I DRIVE SCIENCE CENTERS (Kozyra, 2020). In 2022, NASA announced the selected of three phase II DRIVE SCIENCE CENTERS (NASA, 2022).

2.1 SHIELD DRIVE DRIVE SCIENCE CENTERS

The SHIELD (Solar wind with Hydrogen Ion charge Exchange and Large-Scale Dynamics) DRIVE Science Center was an original phase I (among nine centers selected among 30 that competed and one of three centers funded for phase II in 2022). The vision of the SHIELD DRIVE Science Center is to understand the nature and structure of the heliosphere through the collaboration of experts in observation, kinetic physics and MHD physics, high energy particle transport and acceleration physics. The center supports four research thrusts and one code coupling group that will contribute to a comprehensive, self-consistent, global model of the heliosphere. Collaborators are from eight institutions across the US and three international collaborations. SHIELD researchers include scientists from across the career spectrum from undergraduates to senior researchers. The broader impact goals of the SHIELD DRIVE Science Center are to increase the recruitment, inclusion, and retention of traditionally underrepresented (URM) groups (with a predominate focus on racial/ethnic minorities, women, LGBTQIA+, and first-generation college students) pursuing STEM careers and entering post-secondary education and to train, mentor, and build leadership skills for emerging and early career scientists, teaching team-based science.

The vision of the SHIELD DRIVE Science Center, led by a non-US born citizen who identifies as LGTBQ is to train a new type of heliophysicist, one fluent in team science and capable of working in highly-transdisciplinary, collaborative environments and contributed to making measurable improvements in the diversity of the heliophysics workforce pathway https://shielddrivecenter.com/.

2.2 Signature SHIELD DSC efforts to broaden impacts

The SHIELD Drive Science Center's broadening impact goal is to train and mentor the next-generation of team-based heliophysicists while accelerating knowledge integration, transfer, and communication across traditional boundaries. A dedicated group within the SHIELD Science Center is responsible for leading the broader impact efforts and supporting emerging, early career, and mentor scientists.

2.2.1 Broad virtual programming highlighting scientists as whole individuals

In phase I of the SHIELD DRIVE Science Center, several initiatives were created and are being continued and expanded in phase II. One of these efforts is to showcase diverse voices to STEM. *You Can't Be What You Can't See* is an online repository of testimonials of diverse early career researchers https://shielddrivecenter.com/testimonials/, including PhD students and more junior researchers in space physics. Topics include the imposter syndrome, gender fluidity, the immigrant experience, first generation students, and the impact of learning disabilities on one's trajectory in a STEM field. In phase II, we will expand these testimonials and provide an avenue for more discussion about important human issues that all researchers face as they work in space physics and in STEM in general. These testimonials will focus more on the SHIELD team and will be edited into a SHIELD trailer.

Another signature program includes a SHIELD webinar series that highlights eminent scientists, trailblazers, emerging scholars, and NASA managers who discuss career development, space physics, scientific discovery along with overcoming barriers on their paths. Unlike traditional webinars, these are frank discussions of scientists' paths highlighting challenges that they encountered and opportunities they were afforded. The SHIELD webinar series complements the vision of the testimonials to showcase the human side of how science is done. Phase I speakers included.

- Margaret Kivelson, UCLA and University of Michigan and Nicola Fox, NASA Headquarters—The Rewards of a Career in Space Physics: Opportunities and Choices
- Stamatios Krimigis, Emeritus Head of the Space Exploration Sector at the Johns Hopkins Applied Physics Laboratory (APL) and Parisa Mostafavi, Johns Hopkins University Applied Physics Laboratory—Coming From Far Away Lands: How different backgrounds Shape their Careers
- Nancy Crooker, Boston University and Fran Bagenal, Laboratory of Atmospheric and Space Physics, University of Colorado - How discoveries are made: Finding the needle in a haystack
- Charles Kohlhase, retired NASA/JPL and Suzanne Dodd NASA/JPL—Experiences from the Voyager Interstellar Mission
- Parisa Mostafavi, Princeton and Elena Provornikova, John Hopkins University, Applied Physics Laboratory—Young Voices: Heliospheric shocks Propagating Beyond the Heliosphere: How Far Does the Sun's Influence Extend into the Interstellar Medium? Interstellar Probe: a future mission to unravel mysteries of the heliosphere and its interstellar neighborhood
- Emily Lichko, University of Arizona—Young Voices: Effects of distribution structure on predictions of plasma behavior in marginally unstable plasms

- Mayra Natalia Hernandez Montrose, NASA Science Mission Directorate and Laura Delgado López, NASA Science Mission Directorate—From Puerto Rico to Outer Space
- Sandra Cauffman, NASA Science Mission Directorate - Sonar, Esforzarse y Lograr: Reach, Strive, Achieve–From Costa Rica to Mars
- Andrea I. Razzaghi, NASA—*Enabling Scientific Discovery*
- Greg Robinson, NASA—*A Perspective on the James Webb Space Telescope*. Phase II speakers (so far) include:
- Nicola Fox, NASA Science Mission Directorate, Linda Spilker, Jet Propulsion Laboratory, and Merav Opher, Boston University—The Voyager Mission: 45 years of Discovery
- Vicky Kalogera, Northwestern University—From Stars to Einstein's Waves: An Improbable Path to a Breakthrough Discovery
- Peggy Shea, retired University of New Hampshire - The Road Taken: My Journey in Space Physics from IGY (1957) to the Present

In addition to the SHIELD webinars were workshops provided by Heather Elliott, Southwest Research Institute, San Antonio TX, and University of Texas-San Antonio, on improving writing and scientific presentations. We will continue these online workshops for the community supporting the development of actionable professional skills for the community.

All webinars are archived and viewable on the SHIELD DRIVE Science Center website https://shielddrivecenter.com/shield-webinars/. The webinar series will continue throughout the phase II funding as a way to continue to highlight diverse voices and the many pathways to leadership in space physics.

2.2.2 Early career scientist training

Another important initiative is the SHIELD Distributed REU Program https://shielddrivecenter.com/reus/. Evidence suggests that undergraduate research experiences have raised awareness of the discipline; 50% of space physics graduate students report being involved in an undergraduate research experience (NRC, 2013). SHIELD will support five undergraduate students from across the United States each summer to participate in a REU program at a SHIELD partner institution. Specific recruitment is being used with the goal of supporting at least one-third of students who self-identify with at least one underserved/underrepresented group (female, racial/ethnic minorities, LGBTQIA+, persons with disability). We are working towards this goal by advertising to individuals participating in existing programs that explicitly work to support students to gain access to opportunities in space science. Two examples include the NASA L'SPACE Program (https://www.lspace.asu.edu/) that serves students across the US and the Tucson Initiative for Minoritized student Engagement in Science (TIMESTEP) (https://lavinia.as.arizona.edu/~timestep/). In addition, we continue to make personalized relationships with faculty at minority serving institutions to personally invite their students to apply. The distributed model of the SHIELD REU program will allow us to leverage existing housing arrangements and social activities at partner sites. In addition, REU students supported by SHIELD will be part of a virtual community affording them additional mentors and support in research, ethics, scientific writing, giving presentations, and pathways to graduate school or other STEM careers.

Each summer SHIELD will host a heliophysics summer school https://shielddrivecenter.com/ shield-summer-school/for up to 20 early career scientists. Recruitment will be done through minority professional societies, networks, and minority serving institutions (MSIs). Our goal is to recruit and host at least 50% of participants from underserved communities in heliophysics. SHIELD's summer School will utilize evidence-based techniques from undergraduate education research including: flipped classrooms (Abeysekera & Dawson, 2005), peer instruction (Crouch & Mazur, 2001), tutorials, and project based learning.

A signature program of the SHIELD DRIVE Science Center is Bench Strength Development. Creating a strong and diverse bench of talent is vitally important for the success and sustainability of SHIELD. In phase II, young investigators have been brought into leadership roles and will be provided training and support to lead team-based science efforts. The four research thrusts of SHIELD are led by a senior and junior investigator (Deputy); two of the five deputies are non-US born females. The Deputies are being co-mentored by a research thrust Director and a senior leader from another institution, supporting cross-training. Overall, this training will allow the Deputies to 1) increase content knowledge and gain technical skill in a team-based environment; 2) receive mentorship; 3) develop leadership skills; 4) enhance oral and written communication and presentation skills; and 5) build internal and external networks.

The executive committee will solicit seed proposals each year to bring new ideas, expertise, and personnel, including students, to the Center through the Central Education, Recruitment, and Impact Fund (CERIF). This new initiative will support small grants (~3 each funded at around $50K) competed yearly between the SHIELD institutions to support seed funding supports ideas that, although related to the proposed SHIELD work, and by extension the SHIELD technical proposal, represent something of a departure because they are innovative, emergent, possibly high-risk, and probably represent an outgrowth of proposed work. Priority will be given to ideas that are high risk, potentially high-impact, and transformative and that will lead to cross-institutional collaborations between SHIELD partner institutions. Projects need to have the potential to receive subsequent new external funding. The seed funding will be recompeted annually.

2.2.3 Community building

Building on efforts from phase I, the SHIELD team has continued virtual events for emerging scientists to get together through "coffee" chats hosted without senior leadership. These events, attended by graduate students and post-docs from multiple institutions occur each month and cover topics chosen by the participants. Topics include how to deal with advisors, looking for jobs, and how to navigate large scientific meetings. Additional support opportunities will be added for individuals who are new to faculty and research positions. In the Fall of 2022, we held

3 such coffee chats online and culminated with an in-person meeting of eight students at during the Fall AGU meeting. Coffee chats are being continued and expanded to invite graduate students affiliated with all current DRIVE science centers.

SHIELD will provide emerging scientists and early career scientists with opportunities to present their work and their experience in becoming a scientist. Communications training will be provided by Cherilynn Morrow, Public Engagement lead of the PUNCH mission in collaboration with the SHIELD Broadening Impacts team. SHIELD scientists will join an ongoing initiative of the PUNCH Mission public engagement program to participate in SciHArt, a podcast series facilitated by student (young professional) hosts who work with the Fiske Planetarium at the University of Colorado—Boulder. The primary audience is STEM-interested learners at the late high-school, undergraduate, and early graduate levels. SciHArt interviews leaders in science, engineering, and science communication who are in different phases of their career journey, from undergraduate researchers to senior professionals playing leadership roles on NASA missions. SHIELD will also provide resources for scientists to engage in outreach including resources and connections for upcoming eclipse events.

3 Conclusion

The SHIELD research effort has strong collaborative ties with a variety of other projects and current and proposed missions, including the New Horizon, Voyager, IBEX, Interstellar Mapping and Acceleration Probe (IMAP) (McComas et al., 2018) and proposed missions such as Interstellar Probe. The outer heliosphere community contains scientists from Voyager, several of whom participate in SHIELD, who will pass their knowledge to SHIELD's young investigators, allowing Voyager's legacy to continue. Throughout our efforts, we imagine that the scientists we are training, particularly a graduate student or post-doctoral researcher, will become leaders of such a mission or effort. These future leaders will be experienced in team science and be versed in inclusive leadership of diverse teams. Taken together, the SHIELD broader impacts efforts will have impacts in not only "changing the face" of heliophysics but also in training and support of individuals who will lead projects far into the future.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

SB, NG, and MO wrote the draft of the paper based the original proposal of SHIELD DRIVE Science Center. Both JW and JR contributed to the writing and substantially to the programs presented in the paper.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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