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Driving towards a more diverse space physics research community – perspectives, initiatives, strategies, and actions

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Driving towards a more diverse space physics research community – perspectives, initiatives, strategies, and actions

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Editorial: Driving towards a more diverse space physics research community—perspectives, initiatives, strategies, and actions

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Editorial on the Research Topic
Driving towards a more diverse space physics research community - perspectives, initiatives, strategies, and actions

This Research Topic welcomed papers on diversity, equity, and inclusion (DEI) in the international space physics community. Demographics of the space physics research community have been documented by the American Geophysical Union[1] and the American Astronomical Society[2], both finding the memberships in these societies are strongly dominated by white men. While these demographics are beginning to slowly change thanks to targeted efforts by select programs, significant progress has not been achieved. The field of space physics needs ongoing, intentional interventions to become a community that more accurately reflects all of humanity.

In order to achieve and, more importantly, sustain a diverse environment where all members of the research community can thrive, regardless of race, gender, ethnicity, religious beliefs, or any other discerning factor, we must nurture an inclusive, welcoming and respectful research culture. There are innumerous aspects to the research environment that result in high attrition rates of minority researchers. This is a worldwide problem that is the responsibility of every member of the space physics research community to address. Deep rooted, systemic biases, both implicit and explicit, are present throughout the research

1 The American Geophysical Union membership demographics are reported in the annual ethics DEI report, found here: https://www.agu.org/Learn-About-AGU/About-AGU/Ethics/Annual-ethics-reports.

2 The American Astronomical Society demographics committee posts their survey reports here: https://aas.org/comms/demographics-committee.

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field of space physics and can result in dramatically different experiences for minority researchers as compared to their majority counterparts. Longstanding systemic biases have led to differences in how groups are treated within a society, such as inequitable service expectations, and therefore tackling the Research Topic of structural equity is necessary to sustain diversity and inclusion within an organization or community.

This Research Topic, "*Driving Towards A More Diverse Space Physics Research Community: Perspectives, Initiatives, Strategies, and Actions*," was organized around several goals.

1. Review the current understanding of DEI in the scholarly literature, including best practices from our or other research communities and documentation of the problem of bias, exclusion and inequity impacting the space physics community around the world.
2. Document and evaluate past and present activities regarding DEI carried out by members of the international space physics research community in different environments and cultures, whether positive or negative in outcome.
3. Assemble suggestions for future actions that could be undertaken by space physicists in the area of DEI, at any level from local to global engagement.

Submissions were submitted from members of the space physics community that address opportunities offered by increasing diversity, equity, and inclusion from a variety of angles. The scope of the published articles encompasses those that conduct statistical or narrative descriptions of the state of the international space physics community and its present culture, including demographics, interpersonal interactions, and organizational standards. It also includes papers that describe policies, processes, interventions, and actions that have yielded—or could yield—improvement in one or more aspects of DEI for the space physics community. Some submissions were personal stories and advice derived from those anecdotes. In all, 19 papers were published, ranging from short Opinion articles to full-length Reviews. It is hoped that the data, findings, and recommendations from these articles will be useful to not only the space physics research community but also many others across science, technology, engineering, and mathematics (STEM) disciplines.

Two papers addressed the composition of the space physics research community. Demographics data for space physics and other STEM fields were compiled across a number of reports and analyzed by Bagenal, who found that the "pinch point" where diversity is hindered is at the high school and college stages. They also compile a large number of potential remedies to be taken by the research community, ranging from suggestions to federal agencies to actions that could be taken by individuals. Demographics data on a space physics conference series is provided by Jones Jr and Maute; an insightful conclusion they draw from their work is that the large effort of conducting equity and inclusion work needs to be properly acknowledged and rewarded in our community, including by funding agencies.

Several articles addressed ways to improve the diversity within the workforce. Gallagher Dunn et al. discuss the need for long-duration mentorship and research community involvement at the secondary school level to successfully overcome the "leaky pipeline" Research Topic so often noted at this critical educational stage. Lin et al. describe their student-led initiative to increase inclusion for Historically marginalized and Underrepresented Genders (HUG) in an engineering department (with a large space physics group) at a major research university. They describe the "chilly climate" for HUG students and the higher attrition rate that recorded in their surveys. They recommend several community-building actions, especially peer mentoring and informative workshops. Halford et al. discuss the "leaky pipeline" in which diversity of the workforce is reduced at each stage of schooling and career advancement. In order to combat this attrition, they argue for an emphasis on interdisciplinary science, better resources for stability and support of those in "soft money" positions, community-wide mentorship programs and training, and accountability for bad behavior, including better support for victims and stronger non-retaliation policies.

The specific practices within several large groups, centers, and teams were documented. The DEI initiatives of a new large-scale, multi-institutional space physics research project are described by Buxner et al. including an online repository of testimonials, career-path webinars, undergraduate research support, and a yearly summer school. Yalim et al. present diversity-building activities at their university, especially bringing local youth onto campus for short-term directed research experiences. The diversity efforts of a NASA-funded planetary mission are detailed by Curry; they focused on increasing the visibility and leadership opportunities for early career researchers within the team, eventually resulting in diverse leadership. They also strictly enforced an inclusive Rules of the Road that set a team culture toward cooperation, openness, and accessibility.

Several articles focused on nominations and hiring. Both Keesee et al. and Walach et al. consider the Research Topic of research community awards and prizes. A major recommendation from these two articles is this: take on the task of nominating your peers for awards. Another is that better demographics data is needed in order to truly assess the diversity of award nominees and winners. A third recommendation is that we need clear and transparent selection criteria and processes so that nominations can be written with the rubric in mind. Halford et al. directly address this last point, providing insights from a "Fellows" selection committee, presenting the selection criteria and evaluation process that they used. They also give suggestions for improving these criteria and processes, most notably that the process needs to start with the intentional establishment of an inclusive mindset for the committee. Burrell et al. further help with this Research Topic by providing recommendations for writing equitable letter of recommendation. They discuss the ways in which conscious and unconscious bias can influence the wording and structure of letters, and provide ways to mitigate the potential problems. Liemohn et al. provide a summary of their initiatives for equipping faculty to conduct equitable searches for new faculty, most notably taking "equity pauses" to intentionally center the broadly-based job-relevant criteria.

A few others focused on specific aspects of life within the research community. In Smith-Keiling and Keiling, recommendations are given for promoting inclusion at scientific conferences by steering personal interactions within the science program committee and local organizing committee, which sets the proper tone for the conference itself. Liemohn recapped DEI insights from serving as a journal editor in chief, recommending that, when corresponding with colleagues, is it good to use singular they when gender is unknown and assume positive intent within the writing of others. Another key recommendation is to consider those with colorblindness when developing graphics; one in twelve men are red-green colorblind[3] (deuteranopia) and using traditional plotting features like the rainbow colorscale presents an accessibility concern. A new initiative for increasing the diversity of potential principal investigators for large mission concept proposals to NASA is the PI Launchpad Workshop Hamden et al. which seeks to equip researchers with the information, skills, and contacts needed to overcome the huge learning curve of this role.

Mental health within the space physics community is another of critical importance in this Research Topic. Nikoukar et al. raise awareness of this Research Topic, not only the prevailing stigma of discussing mental health but also the negative psychological impact of the COVID-19 pandemic. They offer several actions for addressing workplace burnout, isolation, and power imbalances, noting that some can be grassroots efforts while others must be implemented by institutional leadership. Turner and Smith advocate for community support of neurodivergent talent. Defined to include the many brainstates beyond "neurotypical," neurodiversity includes attention deficit hyperactivity disorder, autism, dyslexia, anxiety, and other long-term neurotypes. They urge us to adopt neurodiversity-affirming language that does not stigmatize or cast moral judgment on a mental state and to be inclusive of all people in the workplace through better awareness of physical comfort and sensory Research Topic. In addition to these two papers devoted to this Research Topic, Halford et al. includes a section on accessibility with many recommendations for accommodating mental, emotional, and physical needs in the workplace to allow all to fully participate.

While DEI action is often motivated by the benefits to the organization (the "business case" approach), Burt et al. challenge this mindset and present evidence that institutions can make more progress towards diversifying the STEM workforce by acknowledging and focusing on the ethical and social responsibilities of historical marginalization of certain groups. They make the argument that the business case could be, in some situations, harmful, placing a stressful expectation of enhanced productivity on Black, Latine, Indigenous, women, and other marginalized professionals. That is, support DEI efforts because it is the right thing to do in an world in which inequality still exists.

The summary above provides only a few of the many recommendations for increasing diversity, equity, and inclusion within the space physics research community. We strongly encourage you to read all of these papers; their richness and breadth is both informative and inspirational. In a survey of 132 alumni of the postdoctoral program at their institution, Burt et al. found that 87% were engaged in some form of DEI-related work in their current positions. Moreover, 31% had DEI as part of their job description.

3 One group claiming this statistic, and offering many tactics for better accessibility, is Colour Blind Awareness: https://www.colourblindawareness.org/.

The early career contingent of our community is stepping up and changing our culture. We hope that these articles inspire you to make DEI an integral component of your approach to scholarly work. Our community is driving towards a better future and we hope that this Research Topic motivates further action to accelerate our progress.

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Use singular they—and other lessons learned from editing JGR-Space

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Introduction

As Editor in Chief (EiC) of the *Journal of Geophysical Research—Space Physics* (hereinafter, JGR-Space), an issue I addressed was communication and transparency between the American Geophysical Union (AGU) and the space physics research community (Liemohn, 2020). When I became EiC, colleagues would congratulate me on the selection and then complain about some aspect of publishing. When I would inquire with AGU staff, I would often learn that the offending policy or practice had changed.

To address this disconnect, I started a blog[1], writing 300 posts over the 6 years of my EiC term (December 2013–December 2019). Most posts discussed publication news, policies, and practices. Some were advice on writing and reviewing, while others were about EiC duties and life. During my term as JGR-Space EiC, issues arose regarding diversity, equity, inclusion, and accessibility (DEIA). One of my top-10 most-viewed posts[2] was on this topic, expressing disappointment in the research community for the sexism within it, as experienced by my PhD student. I went on to write ~20 more posts on this issue, plus another ~10 on accessibility concerns. In the following section is a distillation of the highlights.

Advice for increasing diversity, equity, inclusion, and accessibility awareness and action

Use singular they

I occasionally received angry emails from reviewers when an author used "he" in their response. While we should learn and use people's personal pronouns, this is impossible with anonymous manuscript reviews. This case requires gender-neutral pronouns. In addition, many of our space physics colleagues use nonbinary personal pronouns. There are several options (e.g., Atherton et al., 2016), but my favorite is "singular they." Societal acceptance of this has come swiftly, with one example being the American Dialect Society declaring "singular they" to be the

1 The blog can be found at: https://liemohnjgrspace.wordpress.com/.

2 The top-10 most-viewed post can be found at: https://liemohnjgrspace.wordpress.com/2016/06/13/women-in-space-physics/.

2015 Word of the Year.[3] If in doubt, then use they instead of assuming he or she. Singular they works exactly like singular you; it is still plural within the sentence but refers to an individual. An example of usage is in the first sentence of this paragraph.

Slow down

Kahneman (2011) describes two modes of thinking, one fast and another slow. Our fast brain is our initial reaction, the in-the-moment thoughts that pop into our mind. The slow brain is our deliberative thought process, which takes energy and focused attention. One publication-centric benefit of slowing down is conducting a thorough literature review. This should be done early in the scientific process so that effort is not spent on unoriginal research. Too often, though, it is left for late in the manuscript development process and subsequently rushed. This leads to citations of only the "famous research works" that easily come to mind rather than conducting a systematic search. There are many hidden gems among space physics studies, and it is worthwhile to take the time to find them, cite them, and compare the new results against those from these studies. This is a DEIA issue because most of the "classic" works were written by white men (see, e.g., the 2018 AGU demographic study[4]).

Another problem that could be addressed by slowing down is that of cordiality in correspondence. As EiC of JGR-Space, I saw some reviews, responses, and emails with unprofessional language. When writing in these forms, we sometimes do not take the time to edit. First, think of the golden rule—treat others as you would like to be treated—and revise your initial word choices to reflect this mantra. Moreover, I encourage you to read it again and consider applying the platinum rule—treat others as *they* want to be treated—which means respecting the background and culture of the person with whom you are corresponding (Taylor, 2016).

Furthermore, slowing down our thinking could result in better science. Several studies have found that diverse teams lead to better outcomes (see the review by Liemohn et al., 2022). Figure 1 shows my artistic support of this evidence. When forming a project team, it is useful to go beyond your immediate circle of colleagues. When hiring a new member of your group or department, move beyond research work and citation counts as your measure of "best." As stated by Hurley (2014), diversity within a meeting room or a project team matters, especially to those among historically excluded groups.

Our brains have these two systems to conserve energy and focus effort where it is truly needed. Some tasks should be done in fast-brain mode. When learning to drive a vehicle, many governments require a minimum number of hours of driving experience before the student can qualify to take the license test. This time converts the thought processes of driving away from the high-concentration slow-brain mode and ingrains them into fast-brain automatic responses. Other tasks are best with slow-brain thinking and action, as noted by Honore (2005). For some undertakings, like scientific publications, challenge the "cult of speed."

FIGURE 1
The sign the author made when he participated in the March for Science walk on Earth Day in 2017.

Assume positive intent

Some of the author–reviewer disputes I witnessed as EiC were the result of miscommunication Newport, 2016. More precisely, they arose from one or both sides inferring belligerence from the other person. Manuscript correspondence lacks delivery style nuance, and its asynchronous nature disallows immediate correction of misconceptions. Problems sometimes ballooned, creating much more work for me to disentangle the discussion and reach a decision.

As detailed by Taylor (2016), it is useful to assume positive intent in our interactions with others. In general, we do not know what others are going through, so it is useful to not take negative comments personally but rather assume that it originates from a completely different issue in their life. It is helpful to slow down and rethink the situation.

Plain language summaries

A publications-specific DEIA item that emerged during my time with JGR-Space was the use of plain language summaries

3 The American Dialect Society's 2015 "word awards" page can be found at: https://www.americandialect.org/2015-word-of-the-year-is-singular-they.

4 The American Geophysical Union 2018 membership demographics survey results are available at: https://www.agu.org/-/media/Files/AGU_Membership_Demographics_2018.pdf.

(PLS). A PLS is a second abstract written for a journal article, not for those within the field but for everyone else. It should be targeted specifically at the educated general public, typically a high school writing level (Halprin, 2021). The PLS increases the accessibility of the work because a major element of a PLS is the intentional omission of jargon.

Writing a good PLS is difficult, but helpful resources exist for their creation[5]. There is even a blog, The Plainspoken Scientist,[6] about communicating scientific findings to a broader audience. It covers many topics about speaking and writing beyond one's disciplinary colleagues, but the PLS regularly comes up and the advice given there is useful for getting into the proper mindset to write a good PLS.

Accessible and inclusive graphics

Sometimes, presentations at space physics meetings would greatly annoy me because the author has simply reused a graphic from a journal article with far too many panels for audience readability. As Morgan and Whitener (2006) explain, care should be taken to create graphics that highlight the most important point and are tailored for your specific audience. For a publication, control of information flow lies with the reader, who can spend as much time as needed to understand a figure. For a presentation, the pace is set by the speaker. Once off the screen, the graphic is no longer available to the viewer, so it must be clear. A good graphic for a presentation also works well in publications, but the reverse is not necessarily true.

Color is a major component of many scientific figures. A regular complaint I heard involved colorblind unfriendly graphics. A significant minority of the population has deuteranopia—red-green colorblindness—or other vision deficiencies for which some colors are indistinguishable (e.g., Brettel et al, 1997). Thus, certain color choices confound scientific interpretation. The most basic rule is to use either red or green in a particular graphic.

The rainbow colorscale is particularly egregious. It not only includes both red and green but also has a nonlinear intensity gradation, causing attention bias (e.g., Moreland, 2016). There have been multiple calls to the geoscience research community to stop using the rainbow colorscale (e.g., Light and Bartlein, 2004; Zeller and Rogers, 2020). Please stop using it.

End microaggressions

Microaggressions are seemingly small comments that nevertheless invalidate, devalue, or exclude some part of the population. Rosen (2017) describes the bias facing women geoscientists as a "mountain of molehills," of which microaggressions are a major component. As Clancy et al. (2017) note, the astronomy and planetary science workplace is also rife with bias. While outright sexual harassment is much worse, it is much less common. Microaggressions are a pervasive problem that degrades the inclusiveness of our work environment.

We must strive to eliminate microaggressions. Krook (2014) describes many examples of inappropriate statements made in the workplace, offering suggestions for how to respond to them. For the space science research community, I suggest checking ourselves from uttering male-focused comments. Do not make an offensive joke; it is not funny to all around you. Do not make the male-is-better analogy; these remarks are not received well by non-males. These comments perpetuate the marginalization of historically excluded groups.

It is encouraged to pause before you speak. Mentally consider the question, is my contribution appropriate and needed now? Be aware when you are dominating the conversation or when another in the group is taking up a disproportionate amount of time. Notice who has not spoken and call on them, engaging them in the discussion and helping them feel included in the group.

Volunteerism and donations

Another way to contribute to DEIA in the research community is through volunteering to help with the operations of the various scientific societies. While I especially encourage being a DEIA advocate on a business or awards committee, a good volunteering entry point is serving as a special session convener at a conference. Through this role, you could recruit speakers from historically marginalized groups. Session conveners select invited speakers and organize the submitted abstracts into oral and poster sessions. Selection for invited or oral presentations promotes career longevity and is, therefore, useful for eventually changing our community's demographics to be in line with the general population.

A more indirect but still effective DEIA engagement path is financial donation beyond the society's annual dues. For AGU, there are travel funds and award funds open to targeted donations[7] that directly address diversity and retention in our research community.

Discussion

Over the course of serving as JGR-Space EiC, I realized that our research community struggles with DEIA issues. To achieve and

5 The AGU Sharing Science page on Plain Language Summaries can be found at: https://www.agu.org/Share-and-Advocate/Share/Community/Plain-language-summary.

6 The Plainspoken Scientist blog can be found at: https://blogs.agu.org/sciencecommunication/.

7 The American Geophysical Union's list of targeted funds is found by clicking the "Funds" menu option about halfway through this page: https://www.agu.org/Give-to-AGU/Giving/.

sustain diversity, we need to be a welcoming and inclusive research community. Have the courage to actively intervene to eradicate microaggressions. We should adopt policies and community norms that foster equity. We should redefine "best" to not only encompass research excellence but also incorporate perspective and background. Slow down and take sufficient time to think, reword, and rewrite toward equity and inclusivity. Learn and use each other's personal pronouns, and when in doubt, use they. Do a thorough literature review, finding research works beyond the famous authors that come easily to mind. We should do the same when forming new project teams and when hiring new coworkers. We can be mindful of colorblindess and avoid those colorscales that cause confusion. Outer space fascinates people, and we should learn to communicate our scientific results beyond our colleagues.

Finally, we should remember the adage "practice makes perfect." The more you do or think about something, the more it is ingrained in your fast-brain reactions. So, continue to learn. Attend seminars, training sessions, and refresher workshops; read articles and books; talk with your colleagues. There is an inspiring line about perseverance from Sarah Bessey, "This is Hope, with lines on her face and silver in her hair."[8]

Let's strive to promote diversity, foster inclusivity, achieve equity, and bring forth accessibility within the space physics research community.

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8 The Sarah Bessey quote can be found at: https://sarahbessey.substack.com/p/we-had-hoped-6d3.

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UK magnetosphere, ionosphere and solar-terrestrial (MIST) awards taskforce: A perspective

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"*We don't live in a meritocracy, and to pretend that simple hard work will elevate all to success is an exercise in willful ignorance.*" (Reni Eddo-Lodge wrote in her book "Why I'm no longer talking to white people about race" (Published by Bloomsbury, London, p. 79, ISBN: PB: 978-1-4088-7)). This echoes through the academic scientific community, and can be readily seen in the demographics of physics prize winners. Prizes are extremely influential in both projecting how a community is outwardly perceived and actively shaping the community through facilitating career advancement. But how can biases in the awards process be addressed? We do not pretend to have all the answers, nor is there a single solution, but in this perspective article we explore one pragmatic approach to tackling chronic underrepresentation in the space sciences when it comes to nominations for awards and prizes.

KEYWORDS
awards, prizes, medals, recognition, bias, inclusion, diversity, equitable

Without a ticket, you will never win the lottery

The UK's Magnetosphere-Ionosphere and Solar-Terrestrial (MIST) community is composed of approximately 500 individuals from approximately 25 institutions across the United Kingdom. The most recent survey estimates 20–30% staff are women and 90% are White, proportions that are significantly distorted compared to the general population (Massey et al., 2017). In 2019, seven members of the MIST community founded the "MIST Awards Taskforce"[1]. This was inspired by the pioneering work instigated by Dr Liz MacDonald, a heliophysicist at NASA's Goddard Space Flight Center. Macdonald

1 https://www.mist.ac.uk/students-corner/242-q-a-with-the-mist-awards-taskforce

established the “Nomination Task Force” within the American Geophysical Union’s Space Physics and Aeronomy (SPA) section (Jaynes et al., 2019), upon which we modeled ourselves: We set up our own United Kingdom taskforce with the aims to 1) actively contribute towards more equal representation and a diverse range of MIST nominees for national and international awards; 2) recognise and promote the work of overlooked members of the MIST community; 3) provide a means for students and early career researchers to gain experience in preparing an effective nomination package. The MIST Awards Taskforce does not hold their own awards scheme, but rather aims to contribute to existing award and prize schemes by submitting their own and ensuring the submission of nominations.

It all starts with representation. If we want science to be more equal and more diverse, representation must happen at all levels. Awards and prizes are a crucial component of achieving this, particularly in terms of increasing visibility (e.g., prizes are a key element in Wikipedia’s “notability” criterion). It has been shown by Bol et al. (2018) that scientists who win funding, especially early on in their careers, have a different career trajectory versus those who do not. This is often the case despite similar backgrounds and abilities, and is known as the “Matthew effect” (see Bol et al., 2018). A further inference from the “Matthew effect” is that winning a prize is likely to lead to another prize or more funding. For example, it was found by Ma and Uzzi (2018) that 64% of science prizewinners had won two prizes, and 14% had won five or more. Furthermore, it is well known that minorities often face extra barriers in academia (e.g. Exum et al., 1984) and systemic racialised biases lead to funding rates for White PIs increasing relative to annual overall rates with time in the sciences (Chen et al., 2022). At NASA, for example, White PI’s proposals were funded at rates 1.5 times higher than those by Native American[2]/Alaska Native, Black/African American, Native Hawaiian/Pacific Islander, multiracial, and Hispanic or Latino PIs from 2014 to 2018 (Chen et al., 2022). Gender biases have also been identified; no awards were given to women physicians during 2013–2016 by the Association of Academic Physiatrists (Silver et al., 2018). The combination of systemic barriers and a small group of individuals winning prizes produces inequitable representation.

In MIST science, we lack good, reliable data on the demographics of both the whole community, those that are nominated, and the prize winners, which is a problem in and of itself. There are a number of processes that have recently been put in place to begin monitoring the overall community demographics (e.g., by the Royal Astronomical Society) and the prize nominees (e.g., by the Institute of Physics). Qualitative analysis suggests that there is reason to think that the biases reported in other fields are present in our own.

Awards, prizes and medals aim to reward excellence. As such, the same biases can arrive at every junction (i.e., from nomination to final selection). Prizes may mirror the scientific community, but they can also help shape the community, making it vital to actively tackle these biases.

We acknowledge that the Taskforce does not and cannot directly address all inherent bias in the system—there may well be fewer award candidates from diverse backgrounds that fit the sometimes narrow and exclusive definitions of “success” (Davies et al., 2021), simply because the odds have been stacked against them since school. But ensuring that there is fair representation nominated from the given demographics is something we can work towards. And our hope is that active promotion of subsequent award winners’ work will mean more equitable recognition. This may then lead to our secondary hope being fulfilled, which is that students are exposed to a diverse range of role models, which may influence future generations of MIST scientists.

Even a strong candidate needs a strong sales pitch

We started out as a small group of volunteers and over time, we have lost and gained members, approximately keeping parity from all career stages: professors, postdocs, and PhD students.

Over the years, we have adapted and tried different methods. The first year, we wrote a number of nomination packages ourselves and primarily submitted to one prize-giving body. Whilst this was daunting to some of us who had never written a nomination before, it turns out to be relatively straightforward and is a valuable and rewarding experience. Often it is much easier to be able to see and understand other people’s contributions than your own. And, importantly, nomination packages usually require less than two pages of writing. Since our first year, we have branched out to target several different national and international award schemes.

We also asked members of the community to nominate their colleagues and collaborators directly, thus gaining a much wider reaching approach. Mostly our role here is to raise awareness of the opportunities and the relevant work of their immediate colleagues, and develop a stronger culture of regularly nominating for awards. Responses have generally been very positive. This is crucial if we want the culture to change, but not everyone is willing or able to volunteer their time. Sometimes, reservations remain due to a lack of experience on the part of the proposer. What comes with experience is the ability to succinctly highlight why someone deserves a prize, and the knowledge that

2 Chen et al., 2022, the U.S. National Science Foundation and the U.S. Office of Management and Budget use the term American Indian instead of Native American, and define this ethnicity as: “A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment”.

most nomination schemes typically require less time and effort than it may initially appear.

We have had a number of award successes and award-policy impact on both national and international levels. In particular, we have successfully lobbied for career breaks to be explicitly accounted for in award eligibility criteria. Since most awarding processes are confidential, we are not able to name specific details, but we are able to share that we have had a success rate of 20% in our first year, followed by a success rate of 66% in the second round from two separate awarding bodies, despite increasing the total number of nominations. We speculate that our increased success rate is due to increased experience and efficiency in writing nominations.

"We should not be nominating for the sake of it"

Without a nomination, a person cannot be considered by an award committee (in some cases, such as the Institute of Physics, self-nominations are permitted but generally this is not the norm). Thus, without a colleague's recommendation, there is no nomination; ultimately, unless people nominate their colleagues, there will be no prizes.

We have come across varying attitudes towards nominating colleagues. For the most part, people are willing to nominate colleagues who they personally deem most worthy, but this is a problem for two reasons. Firstly, this biases towards colleagues for whom they already have a strong familiarity with their work, i.e. biasing towards those individuals who are already most visible. Secondly, criteria for "exceptional" work and individuals are extremely subjective. This means colleagues sometimes position themselves as quality control, which can further perpetuate biases. But our job, and the community's job, is only to provide high-quality nominations. It is the award panel's job to select what they see as the most worthy nomination, which hopefully happens in a way that acknowledges the existing biases and barriers present to different individuals. This is important because we have seen cases where colleagues were reluctant to write a nomination, as the chance of success was deemed to be remote. There were a number of instances where we did prepare a nomination, despite the reservations, and the nominees did go on to win awards. This could be seen as a sign that bias is present in the community and that we should not jump to conclusions and try to take on the job of the awards committees by overly pre-judging people's worthiness. Of course, there is a balance to be struck. There is never enough time to nominate everyone eligible, and it is disheartening for a proposer to spend a huge amount of time writing many nominations that have no impact.

What changes do we need?

There is still more work to be done. The struggle of recognizing the work of underrepresented demographics starts and ends with accurate data. We know that the Royal Astronomical Society (RAS) demographics are less likely to be from minority ethnic backgrounds than the population at large in the United Kingdom (Massey et al., 2017), but we do not know if this can be extrapolated to the MIST community or prize nominees and winners.

We do not have accurate statistics on our own United Kingdom MIST community. This data is difficult to acquire but we are working towards this as part of the next RAS Demographics Survey. Our Awards Taskforce starts the process of who to consider for a nomination by attempting to survey all eligible candidates across the MIST community, but we have incomplete data as it is based on personal knowledge and often incomplete institutional websites. We then use this information to select underrepresented demographics and others on precarious contracts. It is a starting point, but it is no substitute for accurate data.

A further issue arises as most award and prize schemes are shrouded in mystery. It is the norm that nominees should not know they are being nominated. This hinders awards committees and the community in accurately knowing the demographic make-up of their nomination pool and the extent of any nomination-bias problems. So, all a panel can do is guess whether the nominations are representative of the community. And all we can do is nominate the people who we think may not be nominated by their peers, such that the panels have a diverse pool of candidates to choose from.

The only way demographic information can be reliably obtained is if the awarding bodies seek this information from the nominees directly, which includes telling the nominee that they have been nominated. This inherently makes the process less secretive but the data more reliable, which we should surely strive for as scientists. This is not as controversial as it seems, since it has already been implemented with great success by the Institute of Physics in the United Kingdom. We would suggest that this could be an effective strategy moving forward.

To make science more equitable, nominations need to be for all, and come from all. Every scientist is qualified to write a nomination, regardless of career stage. We should approach nominating our colleagues for awards as a routine part of the "community service" our jobs entail, like reviewing papers and grant applications. Writing a nomination is not as time consuming as it may at first seem, and it is a deeply rewarding exercise. We call on the scientific community to consider putting forward those "long shots," and those without obvious mentors in the field. Who you see as the best candidate may not be the same as the award panels, so do not second guess. Instead, write.

Data availability statement

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

Author contributions

M-TW wrote the first draft of this perspective article. All authors contributed to the ideas and content of the article. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

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The PI launchpad: Expanding the base of potential principal investigators across space sciences

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The PI Launchpad attempts to provide an entry level explanation of the process of space mission development for new Principal Investigators (PIs). In particular, PI launchpad has a focus on building teams, making partnerships, and science concept maturity for a space mission concept, not necessarily technical or engineering practices. Here we briefly summarize the goals of the PI Launchpad workshops and present some results from the workshops held in 2019 and 2021. The workshop attempts to describe the current process of space mission development (i.e. space-based telescopes and instrument platforms, planetary missions of all types, *etc.*), covering a wide range of topics that a new PI may need to successfully develop a team and write a proposal. It is not designed to replace real experience but to provide an easily accessible resource for potential PIs who seek to learn more about what it takes to submit a space mission proposal, and what the first steps to take can be. The PI Launchpad was created in response to the high barrier to entry for early career or any scientist who is unfamiliar with mission design. These barriers have been outlined in several recent papers and reports, and are called out in recent space science Decadal reports.

KEYWORDS
space missions, space sciences, PI training, inclusion, workshops

1 Introduction

The process of successful space mission development is long, iterative, and challenging. It can also be extremely rewarding, inspiring, and even fun! Due in large part to the competitive nature of the proposal process, the behind the scenes work of developing a new mission and writing the resulting proposal can be relatively opaque. It is often a challenge for new PIs to break into this space, finding themselves behind the ball from the start, uncertain of next steps, and without adequate support and resources to move forward. These obstacles are borne out by the demographics both of PIs and Science team members for selected and proposed space missions, which tend to be both very male and very white (Centrella et al., 2019). A recent report by the National Academies of Science, Engineering, and Medicine has detailed both the problem in PI demographics and made recommendations which cover, among other things, de-mystifying and simplifying the proposal process, supporting potential PIs with training, building PI training into existing missions, and supporting underrepresented groups (National Academies of Sciences and Medicine, 2022a).

Here we present the PI Launchpad, a workshop which seeks to address some of the challenges a new PI will inevitably run into when developing a mission concept for the first time and give them tools and contacts to address these challenges with an eye towards mission success. The workshop is jointly funded by the Heising-Simons Foundation and NASA. The first workshop was held in November 2019 in Tucson, Arizona, over 3 days. A second workshop was held virtually in June 2021 and took place over 2 weeks. A third workshop is in development for July 2023 in Ann Arbor, Michigan. Additional workshops will be held every 2 years.

For more detail on the proposal process itself, including NASA's review and evaluation process, please see NASA's webpage for new PIs (New PI Resources) and a colloquium by Dr. Thomas Zurbuchen which describes the evaluation process (Link to Youtube). In addition, a presentation from the 2019 PI Launchpad provides an outline for the NASA evaluation process (Proposal Process), with a graphic from this presentation shown in Figure 1. For more detail on best practices for proposal development, with a focus on how to create compelling science-driven mission concepts, see Wessen et al. (2022).

2 The 2019 and 2021 launchpad workshops

The PI Launchpad workshop addresses the challenges a new PI might face by providing information at a high level about the

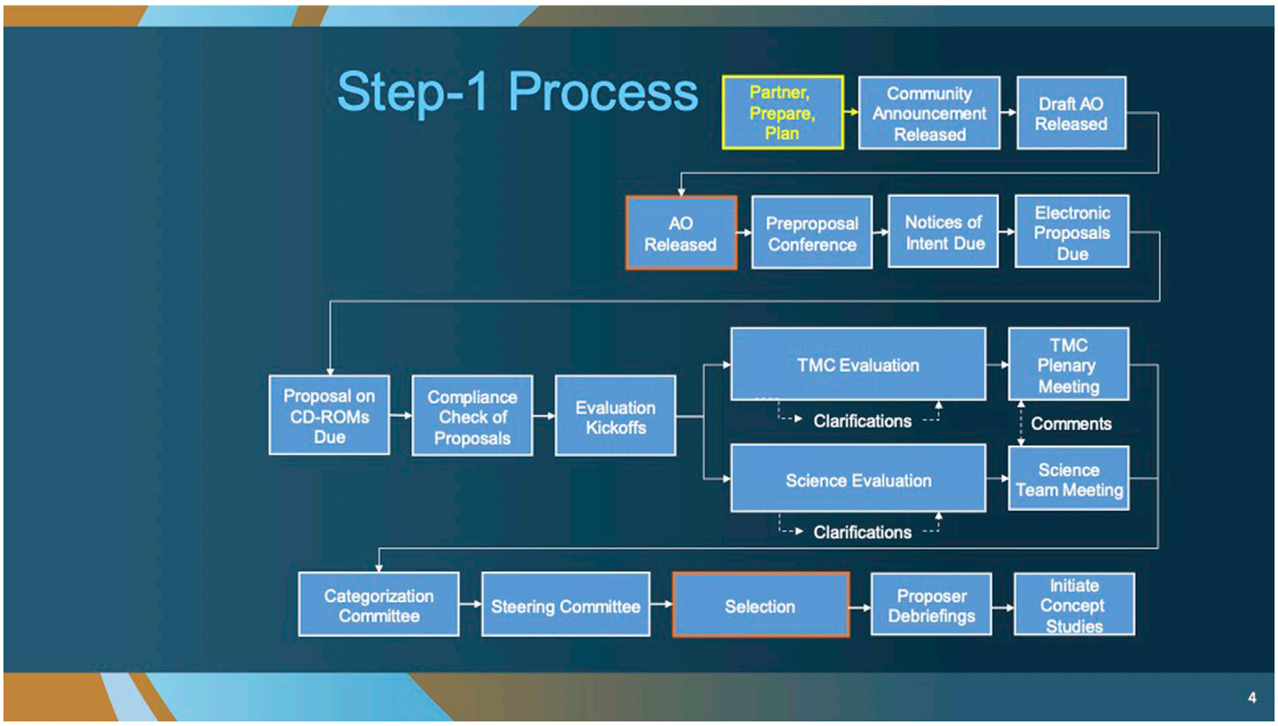

FIGURE 1
A flowchart of the NASA evaluation process for PI lead missions. Slide taken from 2019 PI Launchpad.

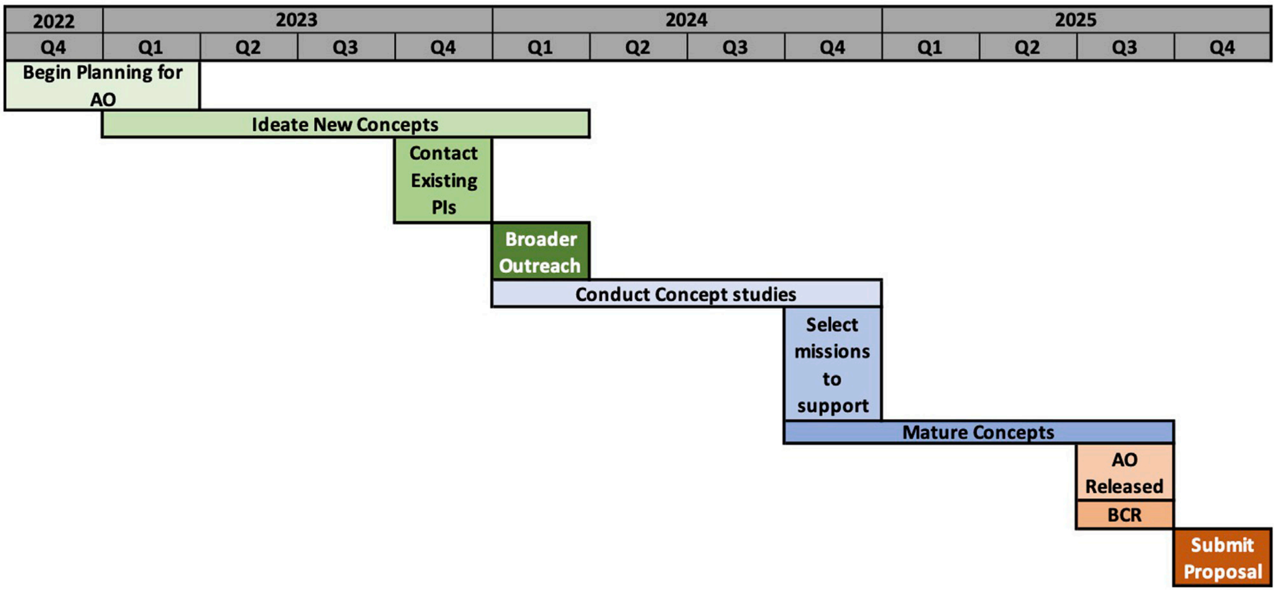

FIGURE 2
A mock timeline for a Discovery-class mission development from a NASA center, with an expected Final AO release in Q3 of 2025. Proposal development at the center can start as early as 3 years before the expected AO. Successful missions will be in development for 2 years prior to the submission. This graphic was adapted from a graphic presented by JPL at the 2019 PI Launchpad (Timeline presentation).

typical mission development process and conveying to interested scientists the recommended timelines and steps for proposing a mission.

The inaugural PI Launchpad was held in November of 2019, at the University of Arizona. It was a 2.5 days workshop and was jointly funded by NASA and through a grant from the Heising-Simons Foundation, which paid for 40 in-person attendees, supporting travel, housing, food, and transportation. The workshop was widely regarded as a success, and the participants expressed their overall enjoyment of the program captured in a report prepared by a STEM-equity consultant, Movement Consulting. Of particular note was the importance of the networking opportunities (both informal and formal) that the workshop provided. To increase outreach and accessibility, we recorded all talks and panels during the workshop, and posted closed captioned videos and materials online on a NASA-hosted website (PI Launchpad). The experience attending this workshop was described by one participant as “transformational” for them.

A second workshop was held in July 2021, in an all-virtual format of two 90 min sessions per day, spread out over 2 weeks, with a mix of panels, small group activities, lectures, and discussions. The switch to a virtual format was necessitated by the COVID-19 pandemic. There were again 40 participants. Two highlights were a panel which included all NASA Science Division Directors moderated by Prof. Erika Hamden (University of Arizona), to discuss what they were looking for in PI-led missions. This demonstrated both the buy-in from NASA decision makers for improving PI demographics, and their commitment to transparency by answering questions frankly and clearly. A second highlight was a “fireside chat” with NASA Science Associate Administrator Dr. Thomas Zurbuchen, who spoke at length with Ellen Gertsen about NASA’s overall objectives with PI-led missions. For both of these events, participants could ask questions freely of the NASA administration. In the 2021 workshop, small groups of participants were paired with a mentor virtually and there were virtual networking sessions. The virtual nature of the workshop was a hindrance in creating organic networking opportunities. As with the 2019 workshop, all content was posted online after the workshop for anyone to freely access. In addition, a report was generated by our STEM-equity consultant with suggestions for improvements and analysis of the impact of the workshop on participants.

For both workshops, the number of applications we received far exceeded the number of participants we could support. This indicates that there is still a large population of potential NASA mission PIs who want to learn the basics of building a successful proposal and team. For both workshops, we worked with a STEM Equity Consultant, Dra. Nicole Cabrera Salazar of Movement Consulting, Inc, who conducted pre- and post-workshop surveys and assessments, interviews with participants, and compiled reports which analyzed strengths and areas for improvement. Based on these reports, we know that most participants found the workshop to be incredibly valuable to them. Prior to the

2019 workshop, only 13% of participants reported knowing what the next steps were for their mission, after the workshop, that number jumped to 90%. For the 2021 workshop, those numbers went from 13% who knew next steps prior to the workshop to 82%. Anecdotally, the team has heard from numerous people, participants and non-participants, who felt that the PI Launchpad and the online content was instrumental in them developing their own mission concept. One participant e-mailed the following:

> Being a part of the PI Launchpad gave me the confidence to take the reins of a project that was wildly beyond my skill set, while also giving me the tools to figure out the best way forward for my team and for my science. I'm not sure I would have agreed to be PI . . . without the PI Launchpad.

3 Brief overview of the PI launchpad content

The PI Launchpad works to cover a wide range of topics that are relevant to a new PI or mission team member. There, of course, are a nearly infinite number of topics which could be included and thus, the challenge for organizing it is to ensure that the most important topics are highlighted and given time to be explored, while also providing resources for a potential PI to continue to learn and explore the process of mission development on their own. Briefly, these topics fall into a few categories: Timelines; Mission and Science Team Roles; Developing a Science Case; Networking and Building Partnerships; Accessing Resources and Support. Both previously held workshops provided an overview of these topics, to varying levels of detail.

3.1 Timelines

The time required to develop a mission concept to a level of maturity for a successful proposal varies depending roughly on the cost of the mission. An Explorer class mission (150–300 M$) will typically take 2 years of development prior to submission. A concept that has already been proposed may not need as much time, since it is relying on work done previously by the mission team. A smaller mission, such as a Mission of Opportunity (MoO) or Pioneers-class mission (20–70 M$) may only take a year of development, while larger missions such as Probes or Discovery Class missions (>500 M$ to 1 B$) may take even longer. Flagships (> 1 B$, which don't have PIs) are in process for over a decade. An example timeline is shown in Figure 2, adapted from a presentation by JPL for the 2019 Launchpad. These are rules of thumb, and each particular experience will be slightly different. But the primary takeaway is that the earlier a PI starts their mission concept, the better positioned they will be when the Announcement of Opportunity (AO) is released and the proposal deadline is set. NASA SMD provides a projection for when they anticipate various calls for proposals coming out *via* the Science Office for Mission Assessments (SOMA) website (SOMA Planning Website). At least one session per workshop is devoted to discussing timelines and how early to start.

3.2 Mission and science team roles

The role of the PI is just one of many critical roles in mission development. Other roles include a Deputy PI, Project Scientist, Instrument Scientist, Project Manager, Leads for various science objectives, and others. In addition, a PI will need to build a science team made up of many scientists with complimentary roles and specialities in order to ensure that the science can be achieved. Building these teams can take some time and should be approached with care. A PI needs to build a supportive team, identify key team members early, and provide team members with an understanding of the expectations for each role and the timelines involved. Team dynamics, leadership skills, and excellent communication are necessary skills for building a successful science team. Several sessions for each workshop cover topics related to this, including diversity in science teams, how to build a science team, and non-PI roles in the mission.

3.3 Developing a science case

Developing a science case is the most important aspect of building a successful mission and proposal, but it can also be one of the most challenging. A new PI may be uncertain of the maturity of their concept, uncertain if it is actually a good or a bad idea. It is a long process to turn an initial idea into mature "Science Objectives" that can motivate a mission. The only way to address these concerns, mature the mission, and determine if the concept will work is to start engaging with other scientists and get additional input on possible instrument implementations. This process of development is iterative and will take time. Early on, it may feel like the science concept is too amorphous to list into objectives, or that it is difficult to achieve the level of specificity that a science objective requires. By discussing the concept with more people, and asking them to join a science team with regular meetings, a new PI can begin to hammer out what will work and what doesn't. In particular, focusing on developing a story about the science concept and building a Science Traceability Matrix (STM) can help to refine the science case. A large fraction of the PI Launchpad focuses on this, with sessions focusing on science storytelling, developing a pitch, refining science objectives, and how to use graphics to tell a story.

3.4 Networking and building partnerships

Similar to the process highlighted in Section 3.2, a PI will also need to build partnerships with managing centers, industrial partners, and science team members. These partnerships take time to solidify and many potential partners will begin their process of mission development as early as 2 years before an AO will be released. This means a future PI will need to start developing a science case and then approaching possible partners between two and 1.5 years before the AO is released. The science case does not need to be finalized. In fact, it must be an iterative process that the PI conducts along with their partners. But a new PI should have an idea of what they want to explore as they begin to approach potential partners. This step can be challenging if, with new PIs frequently unsure of who to contact at a possible industrial partner. Many aerospace companies and NASA Centers have “New Business” leads who are a good first point of contact. If they are not the right person, they can direct a new PI to the right person. The most important step is to make an initial contact. The PI Launchpad typically has two “Speed Networking” sessions so participants can make contacts at a range of industrial partners and NASA Centers.

3.5 Accessing resources and support

Finally, developing missions and writing proposals costs money. Many universities and institutions have funding available for a new PI, if one knows who to ask. This funding can provide partial salary support for the PI or team members, pay for engineers to create optical or mechanical designs, pay for graphics support, and additional support. In addition, institutions that have proposed missions in the past may have example proposals that can be shared with a new PI. Each institution is different, and determining what support is available is critical to secure the seed money needed for a proposal to be successful. Each workshop has at least one panel focused on what types of institutional support are available and how to access them.

4 Will your mission be selected?

It is important to provide realistic expectations early on the chances of selection. Most submitted proposals are not selected. Most selected missions have been proposed multiple times. NASA’s Transiting Exoplanet Survey Satellite (TESS) provides a good illustration of how long the process can be, even after a proposal is first submitted (Ricker, 2021). The idea for TESS came out of the team that worked on the High Energy Transient Explorer-2 (HETE-2). A group out of MIT realized that HETE-2, a UV/high-energy transient mission, could be repurposed to look for exo-planet transits, and suggested this to NASA in 2005. NASA declined, citing the upcoming launch of the Kepler mission, which was better suited to this type of work. The team then formulated the TESS concept and proposed it as a Small Explorer in 2008. It was selected for a Phase A study, but ultimately not selected for flight. The team re-proposed in 2011 as a Medium Explorer, and again was selected for a Phase A study. In this instance, it was selected for development and was launched in 2018. Thus, from first conception in 2005, TESS went through several iterations, two explorer proposal rounds, two Step 2 rounds, and 13 years of development before launch. Kepler itself was proposed 5 times before being selected in 2000 for launch in 2009. A new PI should anticipate that their experience may be similar and be prepared for multiple rounds of proposing to see an idea through.

5 Where else to look for information

NASA maintains a website for the PI Launchpad workshop (PI Launchpad Website), which has pdfs of presentations and recordings of many of the workshop sessions from 2019 to 2021. In addition, the PI Launchpad Workbook and additional resources are also available at the same website. The National Academies report on diversity in PI-led missions (National Academies of Sciences and Medicine, 2022a) provides a comprehensive overview of the NASA side of the proposal evaluation process.

6 Discussion

The PI Launchpad, after only two workshops, has already had a national impact. It has been directly called out in the Astro 2020 Decadal Survey (National Academies of Sciences and Medicine, 2021), and the Planetary Science and Astrobiology Decadal Survey (National Academies of Sciences and Medicine, 2022b), as the type of program that NASA should support and expand. The immediate impact on the 80 participants has been captured in their survey responses, but it remains to be seen what the long term impact will be. Anecdotally, many PI Launchpad participants have joined or lead science teams for proposals at all scales of mission sizes. In the long run, the impact will depend on NASA’s willingness to fund and support new PIs and to require diversity in science and mission team membership. In the current status quo, compelling and groundbreaking science ideas may never see the light of day because of the challenges of being a first-time PI. We are all the poorer for it.

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

All authors provided substantial contributions to the design and execution of the PI Launchpad Workshops, either in 2019, 2021, or both. EH wrote the draft of the manuscript. All authors provided edits and comments on the draft. EH, MN, EG, NCS, BP, RW, PP organized the 2019 workshop. EH, MN, BP, ML, RW, RQ, PP, KP, EG, PE, NCS organized the 2021 workshop.

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Increasing recognition of historically marginalized scientists: Lessons learned from the Nomination Task Force

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The Space Physics and Aeronomy (SPA) Section of the American Geophysical Union (AGU) created a Nomination Task Force (NTF) in 2017 upon concerns that the numbers of women nominated for AGU Fellow were significantly lower than would be expected based on SPA membership representation, including as low as zero in two of the four preceding years. Now that the NTF has been in existence through four cycles of AGU Honors and Awards, the outcomes indicate the success of the NTF in increasing the number of nominations for scientists from historically marginalized groups. These data indicate that the work of the NTF has enhanced the nomination pool rather than occurring at the expense of other nominees. Until recently, the ability to collect and distribute demographic information has been limited, and cisgender binary identities are often inferred. Moving forward it is a goal of AGU to be more inclusive and intentional with respect to gender, racial, and ethnic identities. We share our best practices and success stories with a broad audience to help others build upon the work of the NTF within their own institutions and professional groups. We also discuss challenges that we are still facing and provide suggestions for continuing to improve the process.

KEYWORDS

diversity and inclusion, awards and prizes, professional societies and associations, recognition and appreciation, best practices

1 Introduction

The STEM (science, technology, engineering, and mathematics) fields have been making strides to become more diverse and inclusive. Yet, a National Science Foundation report indicated that the Geosciences have one of the least diverse demographics

(National Science Foundation and National Center for Education Statistics, 2017). The Space Physics and Aeronomy (SPA) section of the American Geophysical Union (AGU) is approximately 20% women. Space Physics falls in the Division of Plasma Physics within the American Physical Society (APS), which is one of the least diverse divisions within APS. Members of the Space Physics Research Community have been working towards improving diversity and inclusion. Liemohn et al. (2021) described "Increased Workforce Diversity" as one of the four topics that are emerging as "Instigators of Future Change in Magnetospheric Research."

Despite efforts to increase diversity and improve the climate, there have been many challenges. A news feature in *Physics* describes the pros and cons of scientific prizes, including the lack of diversity among prize winners not reflecting the diversity of the field. They also note the likelihood that multiple prizes are given to a few people instead of spreading the recognition (Popkin, 2022). Unfortunately, there are many barriers that prevent scientists in historically marginalized groups from being considered for awards and honors at an equitable level across STEM fields (e.g., Symonds et al., 2006). Within AGU, between 2014 and 2018, women were not being nominated for AGU awards and honors at a rate proportional to their membership numbers at the related career stage (McFadden, 2018). In the 2021 Fellows nomination cycle, one AGU section chose not to select any nomination packages to forward to the Union Fellows committee due to the lack of diversity in their nomination submissions (Harvey, 2022). There have been numerous ensuing calls for action to improve this situation within AGU and other scientific professional societies. One barrier to improving the situation, particularly for the most eminent prizes such as the Nobel prize, is the lack of transparency and data on nominations (Blunier, 2022). While the AGU nomination process has more transparency, the data collection is limited to identity categories that are inferred, such as binary cisgender identity. In 2017, a grass-roots group within SPA noticed a lack of diversity in its Fellow nomination pool and created a Nomination Task Force (NTF) to support nomination packages for scientists that identify in historically marginalized groups. An initial report on the NTF was published in AGU's science news magazine, EoS (Jaynes et al., 2020). Now that the NTF has participated in five nomination cycles (with data available for four), we present results and lessons learned to share our best practices and success stories with a broad audience to help others build upon the work of the NTF and to adapt these practices to their own institutions and professional organizations. We emphasize that the goal of the NTF is not to change the criteria for selection of AGU Fellows and other honors and awards; it is to increase the nomination rate of scientists from historically marginalized groups to a level that is more representative of the overall community membership.

2 American Geophysical Union Space Physics and Aeronomy section member demographics

We first present data on the demographics of the AGU SPA Section. One argument why the representation in awards and honors is low is that the overall representation is low, but that is often not the case. The gender distributions for AGU SPA section in 2021 as a function of career level (**Figure 1**) are shown. One example demonstrating that low representation in awards and honors is not due to overall representation: from 2014 to 2017, 6% of nominations (3 of 50) for AGU Fellow in the SPA section were women (see next section), far lower than their 14%–25% representation in the mid-career/experienced category (**Figure 1**) from which Fellows are usually nominated.

3 Nomination task force outcomes

Since its inception, the NTF has been involved in 24 Fellow nominations, 29 nominations for other AGU awards, and 5 nominations for a non-AGU award (see **Table 1**). Several of these nominations resulted in awards. Since the NTF was created based on data on nominations for AGU Fellow, such nominations have been a primary focus. Results from the last eight nomination cycles are shown in **Table 2**. While detailed demographic data is collected from the AGU membership, such data are not collected from nominees and are inferred based on name and institution. This limits the ability to demonstrate impact on other demographics, but the NTF certainly considers nominees from other marginalized groups. We note that the work of the NTF has increased the overall number of nominations submitted, demonstrating that this work is not reducing the potential recognition of any demographic, while also increasing the number of women that have been awarded fellowship.

While Fellow nomination packages are an important part of the NTF effort, we also work on other awards and honors (e.g., Joanne Simpson Medal, Macelwane Medal, SPA Scarf Award), and even some non-AGU awards to a lesser extent. The NTF created a tool to help find appropriate AGU awards and is publicly available at https://connect.agu.org/spa/committees/ntf/award-finder. Our work has also influenced the mindset of other decision processes, such as the selection of named lecturers at the AGU Fall Meeting. All of these results enhance and promote the equity, diversity, and inclusion within the field. AGU has recently implemented the need for nomination canvassing committees similar to the NTF for each of its sections, and the NTF provides continuous feedback to AGU on this process. The American Astronomical Society Solar Physics Division also has initiated an NTF as an official ad hoc committee with the help of SPA NTF members.

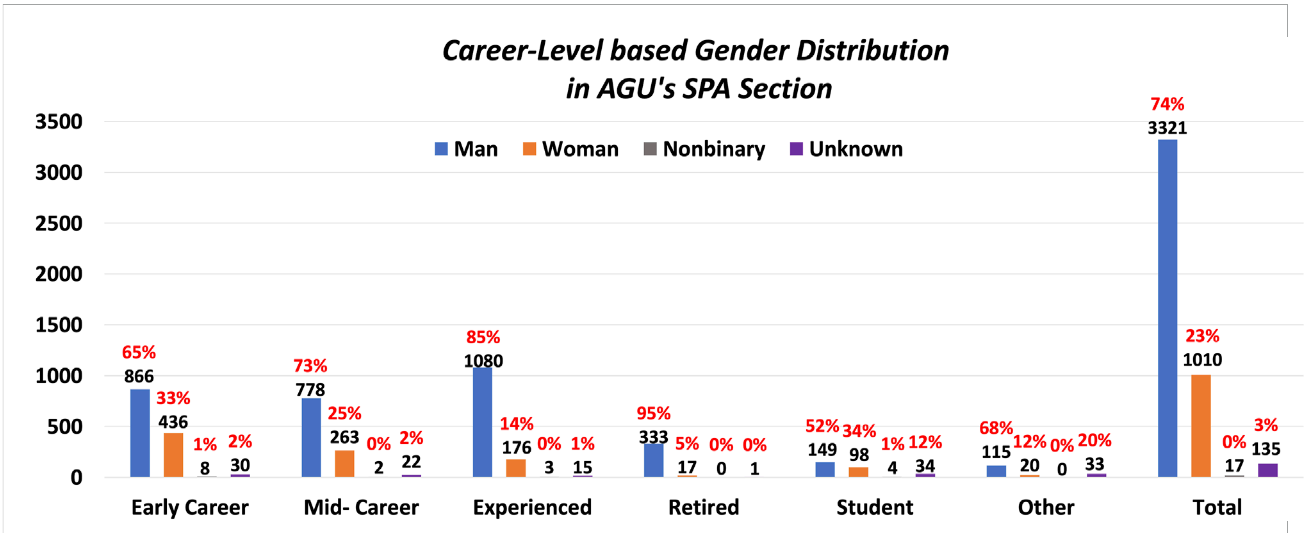

FIGURE 1
Gender distribution of the AGU SPA section as a function of career-level with Early, Mid and Experienced levels based on number of years from Ph.D. i.e., ≤10,≤20 and >20 years, respectively. The percentage (red text) and number (black text) are shown at top of the each category.

TABLE 1 Number of nomination packages submitted by the NTF.

	2018	2019	2020	2021	2022
AGU fellow	4	6	4	7	3
Other AGU awards	1	3	7	9	9
Non-AGU awards	1	1	1	0	2

4 Nomination Task Force lessons learned

Nomination packages typically require in-depth volunteer work from a number of individuals close to the nominee but benefit from a coordinated team approach. This grass-roots, distributed approach divides the work of creating robust, winning nomination packages while considering privacy and a number of other sensitivities. Quality is increased with informal peer-to-peer review and crowd-sourcing at each step of the way. The group culture values transparency and teaches others how to do what was once privileged knowledge passed primarily among select senior members. This distributed approach scales and is transferable to other societies. Participating in the NTF is a valuable and unique opportunity to learn more about the AGU awards process and to help ensure that award nominations come from a wider and more representative fraction of SPA. Early-career scientists benefit

TABLE 2 Fellow nomination packages received and awarded from the AGU Space Physics and Aeronomy Section.

	2014	2015	2016	2017	2018[a]	2019	2020	2021
Nominations								
Male	11	9	13	14	19	15	17	18
Female	2	0	1	0	6	9	4	5
Total	13	9	14	14	25	24	21	23
International	N/A	3	3	4	5	3	3	6
US	N/A	6	11	10	20	21	18	17
Total	13	9	14	14	25	24	21	23
Awards								
Male	4	5	4	4	5	3	2	4
Female	1	0	1	1	1	3	1	2
Total	5	5	5	5	6	6	3	6
International	1	0	1	0	2	0	0	1
US	4	5	4	5	4	6	3	5
Total	5	5	5	5	6	6	3	6

[a]Indicates the first nomination cycle that the NTF was in effect.

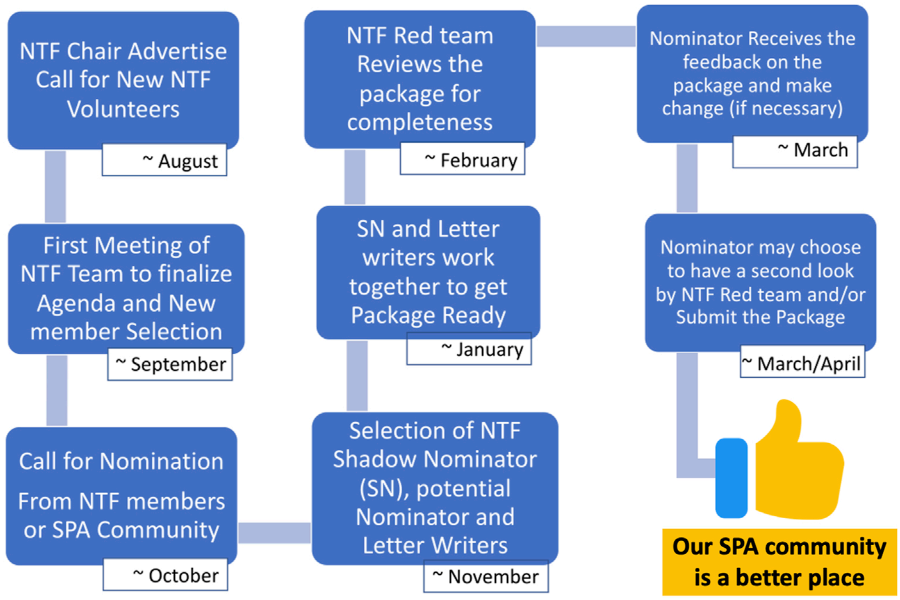

FIGURE 2
NTF workflow and timeline.

from the opportunity to network with more senior colleagues on a regular basis. The NTF meets regularly throughout several months of the year on video teleconferences and in person at the AGU Fall Meeting, usually for a social meal. Additional communication happens among the team for each nomination package.

The NTF has had a number of discussions of best practices in general nomination writing as well as specific practices to improve AGU nominations, and have compiled many of these resources into one location at https://connect.agu.org/spa/committees/ntf/ntf-reading. A common debate is whether to inform the nominee of the nomination. While some people prefer to conduct the nomination in secret, the nominee can help with getting suggestions for nominators and providing updated bibliographies and curriculum vitae. Another debate is whether to include the h-index, which has been shown to be biased (Chapman et al., 2019). The NTF often suggests including the h-index if it is high, and the source of the index, as well as citation counts, should always be included. When working with the letter writers, it is helpful to ensure that they will use the full length allowed, that the secondary writers will each focus on the details of a specific topic to avoid duplicating each other with a summary provided by the lead nominator, and that they will use a common referencing to the bibliography. It is also helpful to ensure they're using appropriate language in their letters, such as using non-gendered descriptive words, avoid using first name, and using strong language (scientists are reluctant to use subjective qualifiers like groundbreaking, pioneering, paradigm shift). Many of these recommendations are described and implemented by the "Equitable Letters for Space Physics" resource (Burrell et al., 2021).

The timeline for the NTF work each year is based on the AGU awards cycle, but could be adjusted to match other award cycles. The deadline for AGU honors and awards nominations is typically in March/April. Thus, NTF telecons begin in the Fall of the prior year and continue until the award deadline date (see **Figure 2**). Telecons are typically held once every 2 weeks and last 1 h each. The NTF work begins on our telecons where a list of names of potential award nominees is discussed. The list of names is maintained from year to year, with new names added all the time. Additions come from NTF members, or from non-members *via* requests for suggestions during presentations at workshops and conferences and advertisement in newsletters and social media. Nominee suggestions can be made by communication to any NTF member or through our online "nominee suggestion" Google form. We then brainstorm to identify potential nominators and letter writers for each nominee. Once these individuals have been identified and confirmed, the assembling of the nomination package begins. Much of the work on the package creation is done offline, interacting *via* email. This entire process is iterated on in the time leading up to the awards deadline, ultimately resulting in a set (typically 5–10) of nomination packages that are submitted to AGU for award consideration.

NTF members have a variety of levels of experience with the nomination process, and the work is distributed so that people can participate as their experience and availability allow. An email list of members is maintained for basic communication, including meeting scheduling and reminders as well as solicitation of potential nominees. Once a list of potential nominees has been created, NTF members volunteer to champion the nomination package as "Shadow Nominator," a role that we have found to be very important. This person is a regular NTF participant who coordinates the creation of a nomination package for a specific nominee, working closely with the "lead nominator." This includes contacting senior/highly-accomplished members of the community for nomination and supporting letters, ensuring that the various package components are being produced in a timely manner, reviewing the package materials for typos/inconsistencies, and acting as an interface/liaison between the lead nominator and the NTF. And most importantly of all, the Shadow Nominator ensures that the nomination package is submitted before the deadline!

The NTF works as a group to identify potential lead nominators for an individual's package, who are then contacted by the Shadow Nominator to gauge their interest. Some lead nominators prefer to arrange and contact supporting nominators, while others enlist the help of the Shadow Nominator. The lead nominator is usually a senior/highly-accomplished member of our community who writes the overarching nomination letter and works with the Shadow Nominator to assemble the package. The lead nominator can be an NTF member, but very often they are not, in which case the Shadow Nominator serves as the interface/liaison between the lead nominator and the NTF.

Another important element that we have found for successful nomination packages is to have a red-team review. This is conducted by a group of NTF members (ideally 2–3) who look over the nomination letters, CV, and bibliography as they are being created and again before submission. The red team looks for, for example, redundancy between nomination letters and, if found, suggests ways in which the letter writers can refine their letters to instead focus on different achievements. A nomination package is only sent out for a red-team review if the lead nominator and all supporting letter writers agree that it can be shared with the red team and that the letter writers will be open to making suggested changes.

In order to reduce the burden on a few individuals, often from historically marginalized groups themselves, it is important to continue recruiting new NTF members and turn over the leadership each year. This also helps to spread the recognition to more subfields as volunteers will recommend nominees whose work they are familiar with. Within SPA, there are three sub-sections (SH, SM, SA). Since the NTF was initiated with SM leadership, the majority of volunteers, nominees, and subsequent chairs have been within SM. We have worked to recruit more members from SA and SH to ensure we are recognizing deserving scientists from those subsections. This would be similar in any field where volunteers are needed from multiple subfields. One challenge we found in a particular subfield is that it has been hard to recruit lead nominators because many senior scientists themselves have not been recognized with fellowship.

Details about the NTF are maintained at https://connect.agu.org/spa/committees/ntf. The website includes a Code of Conduct, FAQ, and extra resources; many of these are general enough for other groups to utilize.

5 Summary

The AGU SPA Nomination Task Force has made a demonstrable impact on the diversity of awards and honors for the SPA membership by developing robust and sustainable approaches to share and manage the workload of nomination packages. The group has developed best practices for preparing strong nomination packages and continues to work on them to incorporate lessons learned. A critical next step is to improve the data gathered about nominees' demographics and identities.

Data availability statement

The datasets presented in this article were requested from the American Geophysical Union. Some data are available at https://www.agu.org/Learn-About-AGU/About-AGU/Diversity-and-Inclusion. Some of the above web-links may change in future, in that case please visit NTF website https://connect.agu.org/spa/committees/ntf.

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Assessing the demographics of the 2021 and 2022 CEDAR workshop

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The Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) community is made of engineers, scientists, physicists, and students with a mission to understand the fundamental properties and predictability of the space-atmosphere interaction region, including the mesosphere, thermosphere, ionosphere, and inner magnetosphere. At the 2020 CEDAR annual workshop, community-wide feedback received on diversity, equity, and inclusion (DEI) in CEDAR warranted a grassroots effort focused on addressing the DEI issues raised. This led to the creation of the CEDAR DEI task force, whose goals were to 1) Assess and formalize DEI efforts in CEDAR; 2) Establish and normalize a DEI presence in the CEDAR community; and 3) Foster improvement in CEDAR through implementation of actionable initiatives that promote diversity, equity, and inclusion. Of these actionable items collecting demographic information on those participating in the Annual CEDAR Workshop was identified as the top priority. This paper therefore, reports the demographic information obtained from CEDAR registrants for the virtual workshop in 2021 and in-person workshop in 2022. In general, the demographics of CEDAR are consistent with those in broader science, technology, engineering, and mathematics (STEM) fields, that is, most participants identify as male, White, and or Asian/Middle Eastern. On average, women and historically underrepresented races and ethnicities in STEM fields make up roughly 30% and 10%, respectively, of all 2021 and 2022 CEDAR Workshop registrants over the past 2 years. We further discuss the demographics of CEDAR relative to reports published in recent years by other organizations, where possible.

KEYWORDS

heliophysics, aeronomy, diversity, equity, inclusion, CEDAR, demographics

1 Introduction and motivation

All of us who work in the astronomical and space sciences are first and foremost people, whose different lived experiences, both consciously and unconsciously inform the way we do science. In our continued pursuit to understand how the Sun and atmosphere impact our everyday lives, we cannot lose sight of this people first perspective. This people first perspective is essential to the vitality of the astronomical and space sciences fields now, and into the future. As such, it is well established that when a person feels accepted, safe, and valued at work they can perform at their peak ability (e.g., Cho and Barak, 2008; Halkos and Bousinakis, 2010; Østergaard et al., 2011; AlShebli et al., 2018; Way et al., 2019; Haacker et al., 2022). The opposite is true as well, that is, hostile and unsafe educational and work environments cause people, especially women and people of color, to leave the scientific enterprise (e.g., Price, 2010; Gayles and Ampaw, 2014; Bradforth et al., 2015; Thiry et al., 2019; Watson, 2019; Marín-Spiotta et al., 2020; Donovan, 2021). It is also well established that diverse groups are more innovative and produce better science (e.g., McLeod et al., 1996; National Research Council, 2015; Lerback et al., 2020). Currently, there are several different efforts to reduce barriers associated with implicit and explicit bias in the scientific enterprise, but it can be difficult to understand the current landscape, set goals, make changes, and assess progress without ample and consistent demographic data (e.g., Else and Perkel, 2022; National Academies of Sciences, Engineering, and Medicine, 2022). Without data, scientific organizations, policymakers, programs, and stakeholders have had difficulty implementing structural interventions (e.g., Pendergrass et al., 2019) that could be the catalyst for promoting a more people first mentality in astronomical and space sciences.

Diversity, equity, and inclusion (DEI) became of greater public interest in America in late spring of 2020, which lead to a broader push to acknowledge and address structural inequities in the scientific enterprise (e.g., Subbaraman, 2020). Following this broader interest, a workshop session entitled "DEI in CEDAR" was held at its Virtual Workshop in June 2020. The CEDAR workshop is funded by the US National Science Foundation. CEDAR's scientific community consists of students, faculty members, researchers in academia and industry from various fields such as engineering, physics, computational science, atmospheric science, etc. Whose mission is to understand the fundamental properties of the space-atmosphere interaction region, including the middle and upper atmosphere, ionosphere, magentosphere, and the geospace environment.

In the "DEI in CEDAR" session community members raised a number of issues and suggested practices regarding diversity, equity, inclusion, and accessibility in CEDAR. From the received feedback by session participants, the conveners and the CEDAR Science Steering Committee deduced that a grassroots effort focusing on addressing the raised DEI issues could lead to real progress within CEDAR and the broader Heliophysics communities. A first step was the creation of a permanent, community based CEDAR DEI Task Force with the following goals 1) Assess and formalize DEI efforts in CEDAR; 2) Establish and normalize a DEI presence in the CEDAR community; and 3) Foster improvement in CEDAR through implementation of actionable initiatives that promote diversity, equity, and inclusion.

Of the actionable items suggested by different stakeholders in CEDAR, the top priority was to include questions on the CEDAR Workshop registration to obtain demographic information, including, career stage, race/ethnicity, gender identity, and association with the LGBTQ+ (lesbian, gay, bisexual, transgender, queer (or sometimes questioning), and others) community. Demonstrating current and future progress on DEI related initiatives in CEDAR requires data. Therefore, this short paper seeks to report the demographic information voluntarily obtained from willing CEDAR registrants for the 2021 virtual workshop and the 2022 in-person workshop. This paper also attempts to place CEDAR demographics in the context of other demographic information within the atmospheric and space sciences reported by the American Geophysical Union (2018), National Center for Science and Engineering Statistics (2021), and National Academies of Sciences, Engineering, and Medicine (2022). Our findings are generally consistent with the findings of these other studies and indicate that the majority of CEDAR registrants in 2021 and 2022 identify as male, White, and or Asian/Middle Eastern, across all career stages.

2 Collection of demographic information and methodology

Starting in 2021, optional demographic questions were included in the registration form for the annual CEDAR Workshop. Please see the CEDAR website for information. The CEDAR workshop provides an opportunity for the community to self-organize and exchange ideas in the form of breakout workshops, poster session(s) with a student competition, science lectures, and a student day. All CEDAR registrants, either in-person or virtual were asked to provide an answer to a series of questions about their career stage, race/ethnicity, gender identity, and association with the LGBTQIA+ (lesbian, gay, bisexual, transgender, queer (or sometimes questioning), intersex, asexual, and others) community.

For career stage the following categories were used:

- Students (including both undergraduate and graduate students)
- Early Career (0–5 years after your terminal degree)
- Mid-Career (6–15 years after your terminal degree)
- Senior Career (>15 years after your terminal degree)
- Non-scientist (Citizen Scientist, DEI Experts, Experts outside the CEDAR Community)

For race/ethnicity the following question was asked, "What race(s) and/or ethnicities do you identify with? Select all that apply." The following options were listed:

- White (Hispanic, Latinx or Spanish)
- White (Not Hispanic, Latinx or Spanish)
- Non-white Hispanic, Latinx or Spanish
- Asian or Middle Eastern
- Black or African American
- African
- American Indian or Alaska Native
- Native Hawaiian or Pacific Islander
- Not listed, please specify
- Prefer not to answer

Note the above races and ethnicities were slightly different in 2021 and 2022, as a result of feedback from CEDAR registrants in 2021. All the races and ethnicities listed above were on the CEDAR Workshop registration for both years, but some options may have been listed separately in 2021, whereas they were combined in 2022 (e.g., Asian or Middle Eastern).

For gender identity, the following question was asked, "To which gender do you most identify with?" The following options were listed:

- Female (she,her,hers)
- Male (he,his,him)
- Nonbinary (they, them)
- Not listed, please specify
- Prefer not to answer

These demographic data were collected by workshop organizers and shared with the authors. The survey results depicted and discussed in the subsequent section highlight the participants' responses to the career stage, race/ethnicity, and gender identity listed above. Note that any special processing of these demographic data will be provided in the discussion of the figures shown in Section 3.

3 Results and discussion

We first illustrate demographic data on the career stage and gender identity of the 2021 and 2022 CEDAR Workshop registrants. Specifically, Figure 1A depicts the career stage distribution, Figure 1B the gender distribution, and Figure 1C shows the gender distribution as a function of career stage of the 2021 and 2022 CEDAR Workshop registrants. Participation in 2021 CEDAR Workshop was much larger than in 2022 with a total registration of 839 in 2021 and 324 in 2022. This increased registration in 2021 is most likely the result of a fully virtual workshop with no registration fee, whereas the 2022 CEDAR Workshop was a hybrid (i.e., in-person and virtual plenary and select small sessions) workshop with a registration fee (i.e., for both in-person and virtual participants). Figure 1A shows the career stage distribution of CEDAR registrants is generally consistent between the 2 years, with the student population approximately equaling those that identify as senior career/experienced.

Figures 1B,C illustrate that the majority of CEDAR registrants for the annual workshop identify as male, outnumbering those that identify as female or non-binary colleagues by a 2-to-1 ratio. The overall percentage of the different gender identities that registered for the past two CEDAR Workshops, was fairly consistent, including those that chose 'no-answer' to this question. Further analysis of the gender distribution of CEDAR registrants as a function of career stage (Figure 1C), shows that in general female registrants make up between ∼30–40% of all CEDAR Workshop registrants, with a few exceptions. Most notably is the stark drop-off between female participation in the early-career category during the 2021 virtual workshop from 45.2% to 17.9% during the 2022 hybrid workshop. Also note that those registrants that identified as non-binary were either students or early in their career.

The gender identity demographics of those that attended the annual CEDAR workshop in 2021 and 2022 are broadly consistent with those reported by several other studies including American Geophysical Union (2018), National Center for Science and Engineering Statistics (2021), and National Academies of Sciences, Engineering, and Medicine (2022). These studies generally show that those identifying as female represent ∼30% (±10%) of the student and professional population in the Space Physics and Aeronomy (SPA) Section of the American Geophysical Union (AGU), doctorate-holding non-faculty researchers in the atmospheric sciences, and serve as principal or co-investigators in Heliophyiscs research and analysis proposals submitted to the NASA Solicitation and Proposal Integrated Review and Evaluation System between 2014 and 2020. However, comparing CEDAR gender identity demographics, especially as a function career stage is quite difficult given the lack of consistent demographic collection across the geosciences and heliophysics. This is demonstrated in the above cited reports, including the variance in the types of demographic information collected and how it is qualitatively categorized by different prominent professional societies and funding agencies, CEDAR community members typically participate in and receive funding from.

Figure 2 illustrates the race and ethnicity demographics from the CEDAR 2021 and 2022 Workshop registrants. Registrants could select multiple race/ethnicities which we counted separately and therefore the total percentage by career stage in Figure 2B can be larger than 100%.Note that Figure 2B only depicts race and ethnicity demographics as a function of career stage from 2021 CEDAR Workshop, as the 2022 CEDAR Workshop race/ethnicity demographics as a function of career stage are very similar. The 2022 CEDAR Workshop race/ethnicity demographics as a function of career stage are included as Supplementary Material.

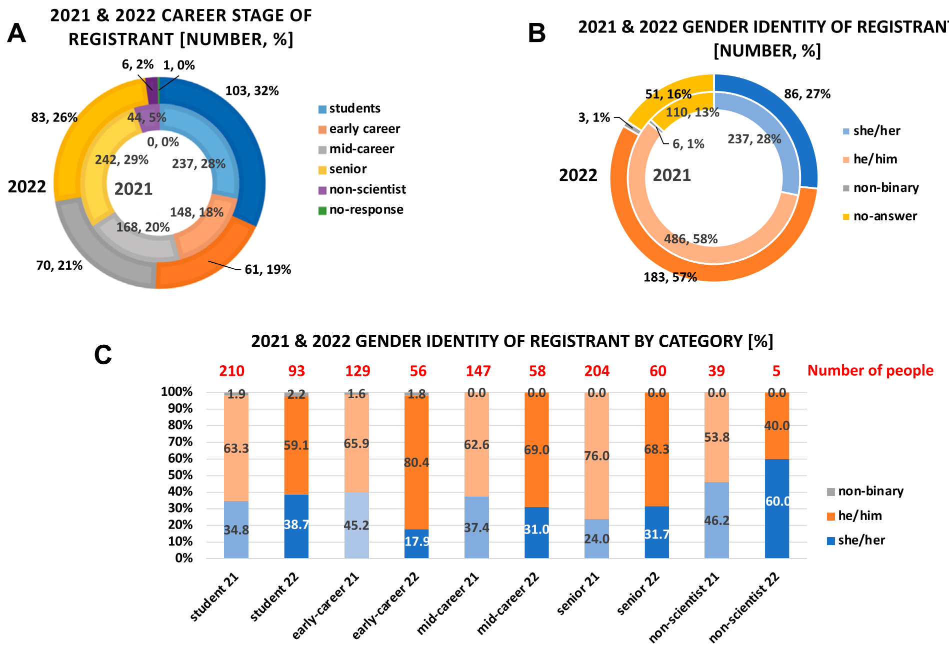

FIGURE 1
(A) Career stage distribution of the 2021 (inner ring) and 2022 (outer ring) registrants for the Annual CEDAR Workshop in both total number and percentage; **(B)** Gender identity distribution of the 2021 and 2022 Annual CEDAR Workshop registrants in both total number and percentage; **(C)** Gender identity distribution as a function of career stage of the 2021 and 2022 Annual CEDAR Workshop, excluding those of whom declined to answer. Shown are the percentages in black or white text and the total number of people in each category in red text.

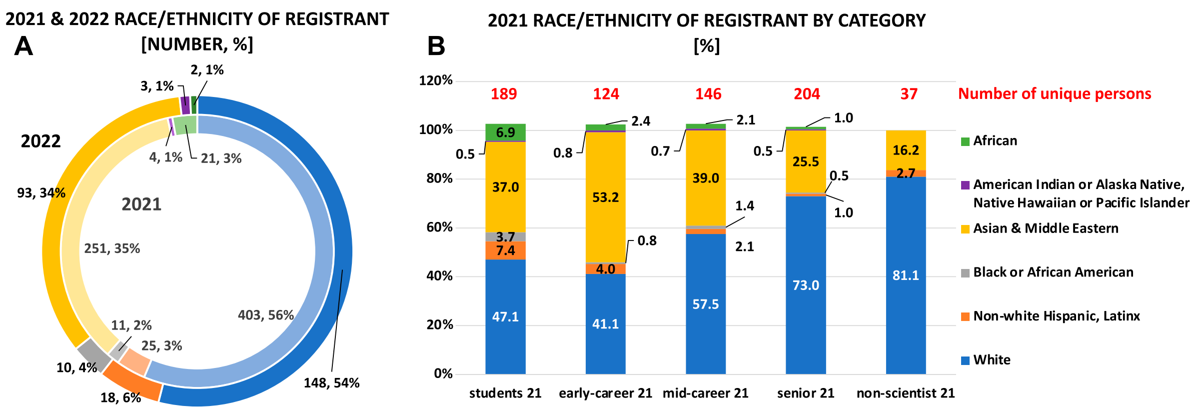

FIGURE 2
(A) Race/ethnicity distribution of the 2021 and 2022 registrants for the Annual CEDAR Workshop in both total number and percentage. Note that multiple races/ethnicities were counted. **(B)** Race/ethnicity distribution of the 2021 Annual CEDAR Workshop registrants in both total number and percentage. Note that multiple races/ethnicities were counted, and the number of unique persons are shown in red text.

Figure 2A indicates that the race and ethnicity distribution of CEDAR Workshop registrants fairly consistent for these 2 years, with those identifying as White and/or Asian and Middle Eastern representing ~90% of all CEDAR Workshop registrants in both years. In total for both years all other races and ethnicities of CEDAR Workshop registrants that are historically underrepresented in science, technology, engineering, and mathematics (STEM) fields as described by the NSF (e.g., National Center for Science and Engineering Statistics, 2021)—Black people, Hispanics, and American Indians or Alaska Natives or Pacific Islanders–represent 9–12% of all registrants. Also note that no individual historically minoritized community in STEM represents more than 6% of the CEDAR Workshop registrants in either year.

Figure 2B generally shows that earlier career (e.g., students and early-career participants) CEDAR registrants tend to be slightly more diverse than those at mid- and senior career levels. Specifically, historically minoritized communities in STEM for student registrants for the 2021 CEDAR Workshop represent slightly greater than 15% of all student registrants, which research (e.g., Cain and Leahey, 2014) cites as an important benchmark for realizing the benefits of diversity in groups. In 2021, for no other career stage do historically minoritized communities in STEM represent more than ∼8% of all CEDAR Workshop registrants. In 2022, participation by historically underrepresented minorities in STEM at the CEDAR Workshop was slightly improved, as just over 10% of registrants at early and mid-career stages identified as Black, Hispanic, and American Indian or Alaska Native or Pacific Islander. However, this still falls short of the benchmark set forth by Cain and Leahey (2014).

Similar to the gender identity demographics of CEDAR Workshop participants, race and ethnicity demographics of CEDAR Workshop participants are broadly consistent with the demographics reported by several other organizations including, American Geophysical Union (2018), National Center for Science and Engineering Statistics (2021), and National Academies of Sciences, Engineering, and Medicine (2022). Also like gender identity demographics it is quite difficult to compare CEDAR race and ethnicity demographics against other available STEM data sets due to different categorizations. However, it is clear from **Figure 2B** that the student population of CEDAR is more diverse than any other career stage. National Academies of Sciences, Engineering, and Medicine (2022) describes that the low retention rate (∼11%) in space science disciplines during undergraduate (but also graduate) schooling, and racial/ethnic disparity of a factor of ∼3 thereof (i.e., 4% retention rate among African American, Hispanic American, and Native American, Alaska Native and Native Hawaiian students), significantly limits representation and restricts diversity of future NASA science and mission leadership. Thus, it is suggested that the CEDAR DEI Task Force focus efforts on incorporating evidence-based practices aimed at retaining its diverse student population, with the hope of increasing diversity in CEDAR, unlike the lack thereof in the geosciences over the last 40 years (e.g., see Bernard and Cooperdock, 2018).

4 Summary, challenges, and lessons learned

This paper reports on the gender identity, race, and ethnicity demographics of the registrants of the 2021 and 2022 CEDAR Workshops. Collecting and analyzing CEDAR participant demographic information presented herein is a first step to acknowledging CEDAR's lack of diversity and implementing structural interventions to make CEDAR a more diverse, equitable, inclusive, and accessible community to all people. Although this is just a first step, it is an important step, because demonstrating progress on DEI-related initiatives in the CEDAR community requires data. Further, retaining, sharing, and continuing to consistently collect demographics on the CEDAR community over an extended period of time provides a means to measure the impact of the CEDAR DEI Task Force and other DEI-related initiatives, while also creating accountability (Pendergrass et al., 2019) for all people in the CEDAR community.

Also, it is important to reflect on some of the lessons learned throughout this process. The authors of this report are classically trained scientists and physicists, and while having a relatively good understanding of mathematics and statistical techniques, employing such expertise on demographic information presented some challenges. These challenges included 1) attempting to use the same demographic categories across organizations to provide the best inter-comparison, and 2) the amount of time and effort which goes into careful data processing, which should not be underestimated. To really affect change in DEI there needs to be accountability, equitable funding from major agencies, and guidance/support to do such work. As Pendergrass et al. (2019) states, transparency in equity and inclusion work is key, and it is our hope that funding and guidance from major funding agencies would provide a means to openly share data and assessments with them and the wider STEM community, about our future DEI successes and failures in CEDAR.

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 authors.

Author contributions

MJ lead the conceptualization and drafting of the this manuscript. AM lead data collection and the production of figures. Both authors contributed to manuscript citations, editing, revisions, reading, and approved the submitted version.

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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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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fspas.2022.1074460/full#supplementary-material

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Check for updates

Thoughts from a past AGU SPA fellows committee

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Community honours, such as those bestowed by professional scientific societies like the American Geophysical Union (AGU) are an important element of both individual career advancement and contributes to the historical record of scientific progress. The process by which honours are bestowed is not widely shared amongst the community. The purpose of this article is to share the recent experiences of several members of the AGU Space Physics and Aeronomy (SPA) Fellows committee. We outline the criteria for selection, the evaluation process, difficulties encountered by the committee, and steps taken to mitigate these difficulties. Of particular note is the impact of implicit bias in the award system. Steps could be taken by the awarding scientific societies to reduce the impact of these biases, but in the meantime individual award committees can employ some of the strategies we outline in this article. By sharing our experiences, we hope to improve the process of granting awards and honours for the scientists putting together award nominations, future committee members, and the scientific societies granting these awards.

KEYWORDS

diversity & inclusion, committee, honors and awards, equitability, bias, recommendation

1 Introduction from Dr. Halford, previous chair

I served on the AGU Space Physics and Aeronomy (SPA) Fellows committee from 2017–2020, chairing it in 2019 and 2020. Like many, I knew that I did not fully understand the award process. Today, I recognise that each section and committee work differently, and the interpretation of the award criteria changes each year as members cycle in and out. I believe this subjectivity, along with the obfuscation of the definitions and interpretations of the award criteria, leads to confusion about why some nomination packages succeed while others fail. Here, we aim to shed light on how our committee approached this task, increase the transparency of the process, and detail the steps we took to mitigate systemic biases. We hope that future committees will continue to improve transparency and that this will encourage everyone to submit nomination packages.

A constant in each section's committee from year to year is the solemnity that members bring to table. All members show the highest respect for each nominee's contribution to the field. However, each committee does, and must, work differently. Factors contributing to this include number of packages, which can vary significantly, and geographic distribution of members. The SPA section typically receives 20–30 packages to evaluate within a month. This quantity of packages falls roughly in the middle of other AGU sections. The time constraint means that each SPA package receives, ~12 min of group discussion. This does not include the time invested by individual committee members, who (during my leadership) read over all individual packages and delve in-depth into 3—5 packages. Leading and participating with such dedicated committee members has been an honour.

I want to applaud and acknowledge my fellow committee members. Our committee comprised 12 individuals from across the world and SPA disciplines. They were asked to tackle a substantial workload in a short period. They did so with complete professionalism and diligence. Committee members made great efforts to attend meetings while at conferences and on travel. Many went above and beyond, meeting at times well outside reasonable work hours. As the chair, I am incredibly thankful for their dedication to this voluntary commitment, not least because many of the hours they dedicated to this committee came from their personal time. The rest of this paper is from the entirety of the co-authors and work done by all committee members - thus the pronoun we will be used.

2 Committee criteria for selection

AGU has laid out three criteria for nominating an AGU member (https://www.agu.org/Honor-and-Recognize/Honors/Union-Fellows AGU (2021)):

1 Breakthrough and/or discovery,
2 Innovation in disciplinary science, cross-disciplinary science, instrument development, or methods development, and
3 Sustained scientific impact.

Our committee did not prioritise one category over another, nor did we systematically consider whether or not a candidate met more than one category. As these criteria can be subjective, our committee established a common interpretation of these criteria and how to handle different evaluation metrics through a group discussion before viewing the nomination packages. These interpretations will likely change from committee to committee. One example of our committee's standard is how we handled the h-index, an optional metric that may be included in the nomination package AGU (2021). By listing the h-index as an option on the AGU website, its perceived value as a shortcut metric is elevated above other evaluation criteria. However, well-known biases are associated with the h-index, including biases that affect women and non-binary researchers, minorities, and fields or sub-fields that publish at different rates Rørstad and Aksnes (2015); Cameron et al. (2016); Tahamtan et al. (2016); Leydesdorff et al. (2019); Chapman et al. (2019); Pico et al. (2020). Given the well-documented biases of the h-index that cause it to poorly reflect on the quality of the research, we excluded it from consideration in our committee and strongly recommend others do so as well. Examples of other optional metrics that have been used, and have their own issues, include the number of successful Ph.D. students and the number of instruments built and flown.

2.1 Defining and interpreting the evaluation criteria

Our committee decided that there should not be any predetermined order or weight to the itemised definitions or criteria. Each evaluation criteria provided by AGU are defined in detail below.

2.1.1 Breakthrough or discovery

An idea that once accepted, allows others to frame ideas or approach problems differently and more effectively than before.

2.1.2 Innovation in disciplinary science, cross-disciplinary science, instrument development, or methods development

- Enabling collaborations across many sub-fields.
- Development of new instruments that have been successful in the field and lead to new* understandings.
- Development of new* methods that other scientists have adopted and have led to new* understandings within the field.
- Produced a data product or a method that is used on a routine basis even if not correctly cited (Has an open data/code policy and has become so routine, people have forgotten that this is either produced by someone or was not a standard product previously).

*New: something that deviates enough from 'standard understandings' in any one field in the presented form, even if the process to arrive at 'new' happened through a series of gradual improvements or advancements.

2.1.3 Sustained scientific impact

- Something that has changed the way other scientists approach a problem, perhaps on a smaller scope but cumulatively changes people's perceptions over time.
- Enabled long-lasting collaborations leading to significant impact within the field.
- Mentor a significant number of collaborators/scientists/students, enabling their development as researchers.
- Produced continued excellent research over the course of their career.

The SPA committee definitions and interpretations are still general, and perhaps not fully inclusive. We used this to establish a *lingua franca* within the committee, aiding discussions throughout the evaluation process. For instance, within the sustained scientific impact discussions often discussions included information on service activities and other best research practices and metrics such as those discussed in the Australian code for the responsible conduct of research or the Danish Code of Conduct for Research Integrity National Health and Medical Research Council (2018); Ministry of Higher Education and Science (2022).

2.2 Evaluation process

After creating consensus on the evaluation criteria, our committee began by considering previous failures of the process: the SPA section has continuously failed to equitably recognise all portion of our community (e.g., gender, race, or ethnicity) Jaynes et al. (2019). We acknowledged that each of us held similar implicit biases as members of our own cultures and research sub-fields. The first step the chair took, with the help of the residing SPA president, was to mitigate the impact of our implicit biases by constructing a balanced committee. For the last few years, our SPA Fellows nomination committee was approximately gender balanced and comprised of nearly equal representation from the solar, interplanetary, magnetosphere, and ionosphere/atmosphere communities (the major sub-fields within SPA). We also included representation from across the globe and career levels. Dr. Halford was the most early-career committee member (in 2019, 7 years post Ph.D.), with others among the most senior ranks of our field. This committee construction aimed to gather people with contrasting implicit biases so that the impact, on average, could be mitigated. Our individual rankings showed that we still held implicit bias for our sub-fields. However, our diverse committee mitigated the impact, resulting in an equal distribution of each subfield within the final rankings. For example, if we had had a persistent magnetospheric bias in our committee, we suspect that more magnetospheric nominations would have been put forward to the union committee.

The broad time zone difference between committee members meant we needed to consider the best times and methods for discussions. We took two approaches: staggering meeting times and maintaining an online repository. Each week we had two meetings, one that was not at obscene hours for Europe/Africa and another that was not at obscene hours for Australia/Asia. In addition, our shared online repository was accessible and editable by all members. It allowed committee members to access notes about each package asynchronously. The two steps we took (thoughtful committee construction and moderated committee interactions) laid a solid foundation for successful meetings. Without these two steps, the nominees we put forward (while still accomplished) would not have represented our community.

During the first meeting, we discussed the different biases we each hold. We reminded ourselves to be conscious of them throughout the rest of the process. Below is the list of potential biases we identified and attempted to mitigate through a balanced committee and open discussion.

- Gender
- Nationality
- Race/Ethnicity
- Career level (retired/senior/expert vs. mid or even mid/expert/senior)
- Extrovert vs. Introvert (impacting who is seen, heard, and remembered)
- A country or institution's socioeconomic status
- Large Mission participation vs. smaller projects such as CubeSats, rockets, and balloons.
- Experimentalist vs. theorist vs. observationalist
- Dependence on intrinsically biased, short-cut metrics
- Sub-field bias (familiarity)
- Publication/collaboration environment
- The Matthew Effect (credit being attributed to the most well-known name, not the person who necessarily had the ideas or did most of the work) Merton (1968).
- The Matthew/Matilda affect (where men tend to get the credit more so than women who did just as much or more of the work) Lincoln et al. (2012); Rossiter (1993).
- Work in "up-stream" fields. For example, much of solar physics impacts the other sub-fields, but the ionosphere does not impact the Sun.
- Work in a traditional academic environment
- Multidisciplinary work
- Number of other awards received.

We took a broad view and discussed how biases might affect our perspective on the nominee's scientific impact. These biases can have positive or negative affects. For instance, we discussed how a mentee's work should be considered in a nomination package for their mentor (the Matthew effect) Merton (1968). We questioned whether the credit given to the nominees should be attributed to the mentee, especially when the package presented the work done by the mentee as a breakthrough or discovery by the mentor. Or should the nominee rather get credit for supporting and collaborating with the mentee, in an excellent example of sustained scientific impact? For cases like this, how a nomination package presented the work significantly impacted the committee's perception.

Many of the identified biases were found to affect a package's shortcut metrics (e.g., the h-index) Tahamtan et al. (2016). The types of projects and work environments a person engages in will significantly impact their number of papers. For example, a person working within a larger collaborative group is likely to be on more papers with a large number of co-authors Tahamtan et al. (2016). Specifically within space physics, the number of co-authors is correlated to the number of citations Moldwin and Liemohn (2018). Another factor that can impact the number of co-authors is visibility within the field, which further leads to more extensive and diverse collaborations Ale Ebrahim et al. (2014). For example, are the nominees able to attend conferences regularly, and are they invited to speak Ford et al. (2018)? The number of papers and citations were found to bias the perceived prestige of the project and the nominee associated with that project instead of the impact and quality of the work. Additionally, shortcut metrics such as the h-index moved the discussion away from the substance of the publications. It did not leave room for acknowledgement of essential, but poorly cited scientific contributions, such as the improvement and curation of geomagnetic indices that are frequently improperly referenced. We discussed similar data sets and tools that are now considered well-understood standards and "owned by the community" Chapman et al. (2019) for each nominee's package.

The biases we previously identified can affect how the impact of a nominee's package is recognised. To mitigate this, our committee worked towards building a safe environment where all members felt empowered to speak up when they observed the influence of biases on discussions. This was accomplished by first addressing the issue of bias *via* email. AGU also addresses these issues in the orientation for the committees. We further discussed and were open with each other about our own biases during the first meeting. As the chair, Dr. Halford asked a few of the committee members to make sure to call her out on biases. This showed that it is okay to be called out. It ensured that we put forward the most accomplished scientists from our field. At least once during each meeting, we asked if anyone had noticed any biases during the discussions, without needing to assign bias to any particular committee member.

Committee members read all nomination packages, and many read the papers referenced within the packages. The materials in the nomination packages provide evidence for the nomination citation and subsequent claims made within the nomination package. Some members initially broke the packages into three groups, top, middle, and bottom, to help focus discussions. Many discussions revolved around what evidence was presented, what was omitted, and if the nomination and supporting letters were consistent with the short citation, CV, and the selected bibliography.

The meetings were timed to ensure each package had a similar amount of discussion time. If a particular package needed extra discussion, if time allowed, it was returned to. Committee members presented the packages and led discussions about what achievements were described and had evidence related to the three previously outlined criteria. If members could not attend the meeting or felt more comfortable providing written comments, they contributed asynchronously to the summary for the nominee so other members could read their comments.

During the final meetings, we discussed the ordering of the nominations. We considered multiple ranking strategies including mean rank, median rank, and rank choice. We found that with few exceptions, the ranking of the nominee changed minimally (typically no more than a shift of 1 - 3 positions) with any given method. This provided confidence in our choices put forward to the Union Committee and their final order. If the ranking did change significantly, or if the shift occurred at a critical boundary (e.g., changed who would be put forward to the Union Committee), we considered the deviation between the rankings. We discussed the reasons behind any scores that significantly differed from the majority opinion. We also took the time to check our potential biases. Given the distribution of submitted nomination packages, we found an even distribution of sub-fields, gender, and other underrepresented groups. We feel confident that through a diverse committee and discussions about potential biases, we sufficiently mitigated our biases and put forth the most deserving nominees.

The top four candidates are typically unanimously supported by the committee. The most contentious packages were those whose nominated work undoubtedly contributed to our field, but did not address the connection between their work and the SPA sub-fields. It is sometimes unclear what the best route is to take with these nominations. Often they are dual submissions with another field such as Planetary or Atmospheric and Space Electricity.

3 Committee recommendations for the program process

At the end of the committee's work, we reflected on the process to identify issues that may have affected our discussions and rankings. These were added to the list of potential biases for the following year. For example, after 2019 we identified a new bias favouring science within the solar community. The data products and scientific results from this sub-field are frequently utilised by the magnetospheric and ionospheric/atmospheric communities, and so perceived as valuable by members from these communities. However, solar scientists are frequently unaware of the work performed within other sub-fields. The impact of this physical reality was seen both in the applicability of a topic to interdisciplinary science and in the likelihood of Journal articles obtaining higher citations. During committee discussions, we determined that some aspects of this bias are not actively harmful. Each SPA sub-field has a different scope. Unlike the solar community, the magnetospheric and ionospheric/atmospheric results may be perceived as having a more immediate impact on society. This could further interact with the experimentalist/theorist bias. Scientific advances in these sub-fields may be unconsciously interpreted as being more applied science and less worthy of being considered a discovery or breakthrough. Although the committees have been unable to determine the best way to address these biases, they were identified and discussed.

Another example is the number of other fellowships or awards won by a nominee. This shortcut metric was not consistently perceived as good or bad. Some committee members interpreted a large number of awards as a reliable indicator of quality science. Others perceived the presentation of other awards negatively or neutrally. They did not consider it a reliable short-cut metric for excellence, and it took up space that could have discussed the scientific impact made by the nominee. Still others felt we should acknowledge those who did not have other awards, but had an outstanding scientific impact.

We found it essential to discuss biases and the evaluation criteria we would use. We also found it beneficial to have these discussions before reading and ranking the nominations. It provided a moment for everyone to check their thought process before forming an opinion on a package.

AGU's software plays into one implicit bias. The first information that shows up pertains to the nominator. It should not matter who the nominator is. Putting this upfront gives the impression that the nominator is more important than the nominee. This perpetuates the idea that science is still a "good ol' boys club". Putting the nominee information up front would help mitigate the Matthew bias and return the emphasis where it belongs: on the nominee's skills and accomplishments.

4 Conclusion

The Fellows honour is the highest honour AGU bestows. Thus, it is paramount that the evaluation criteria reflect the values of our community. Most nomination packages deserve high praise for the nominee's work and commitment to the AGU community. However historically, some very important values were overlooked. These typically fall under the "sustained scientific impact" section of the AGU Honours nominating criteria and include: the impact of service and sustained support activities, such as data curation, which enables countless others to lead breakthroughs and discovery or perform cross-disciplinary work. Unfortunately, there is also a long history of ignoring the breakthroughs and contributions made by individuals from underrepresented groups. This includes women (~12% of current SPA fellows) and racial/ethnic minorities (< 12% of current SPA fellows) among others. These biases against marginalized groups and institutions can be mitigated by avoiding heavy-weighting metrics such as h-index and past awards Chapman et al. (2019); Leydesdorff et al. (2019). For example, within the SPA community, we have had years where zero women were nominated. This has led to discussions concerning who becomes, or more accurately, does not become, a Fellow. This has improved in recent years thanks to the efforts of the Nominating Task Force Jaynes et al. (2019), the Fellows committee, and AGU's efforts to acknowledge and mitigate implicit biases. However, we must continue to be vigilant and work towards ensuring we recognise all who are deserving of becoming an AGU fellow. We encourage the AGU community, Union section, and AGU leadership to reflect as we continue to consider biases within our fields. Furthermore, we continue to work towards ensuring that colleagues who have been forgotten because of the "invisible" work they do are honoured according to their contributions. The following are recommendations for other award committees from our experience:

- Build a safe environment for people to become aware of their own biases and bring up biases that they see surface within the discussions
  - Build in ways for biases to be checked throughout the process
  - Develop and maintain a list of implicit and explicit biases to look out for
  - Check for bias at before finalisation of recommendations.
- Build a diverse committee
  - Discipline/expertise/sub field
  - Gender
  - Institution type
  - Geographic location
  - Career Level
- Ensure work can be done asynchronously.
- Provide useful feedback to nominators for improved nomination letters.

Author contributions

AH wrote the initial draft of the paper and all co-authors helped edit and refine the document as well as served on the SPA fellows committee which developed the best practices included in this document.

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The ethics of diversity, equity, inclusion, and justice in the earth system sciences

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Institutions' motivations for pursuing diversity, equity, inclusion and justice (DEIJ) often center on the benefits to the organization, an argument known as the business case for diversity in which diverse teams are more creative, set high bars for research, and produce ideas that are more innovative than those produced by homogeneous groups. As the sole motivation for DEIJ efforts, the business case is flawed and does not address the harmful workplaces many marginalized scholars encounter. Institutions can make more progress towards diversifying the STEM workforce by acknowledging the ethical responsibilities for doing so and transitioning to an equity-centered approach. Emphasizing personal motivations to actively engage in DEIJ work resonates with individuals more, rather than engaging with DEIJ to benefit an institution's goals. Two recent studies support this argument. The first is an alumni survey and focus groups of postdoctoral fellows in the Advanced Studies Program at the National Center for Atmospheric Research to explore alumni efforts and motivations for engaging in DEIJ work. The second study surveyed attitudes towards DEIJ efforts among STEM graduate students at Colorado State University who took a course on social responsibility in science. Both studies show the motivations for scientists to support and get involved in these efforts and indicate that the business case is misaligned with the motivations of students and professionals in STEM. Understanding the attitudes and motivations that individuals have for DEIJ in STEM presents an opportunity for how institutions can best learn from and support these motivations for systemic change.

KEYWORDS

stem, workforce, diversity, equity, inclusion, justice

Introduction

The science, technology, engineering, and mathematics (STEM) fields continue to struggle with improving diversity, equity, inclusion and justice (DEIJ) in its community. Challenges range from attracting and retaining diverse talent in schools and the workforce, to making progress on changing how we do science in more inclusive and equitable ways so everyone can bring their full self. Although there has been an increase in

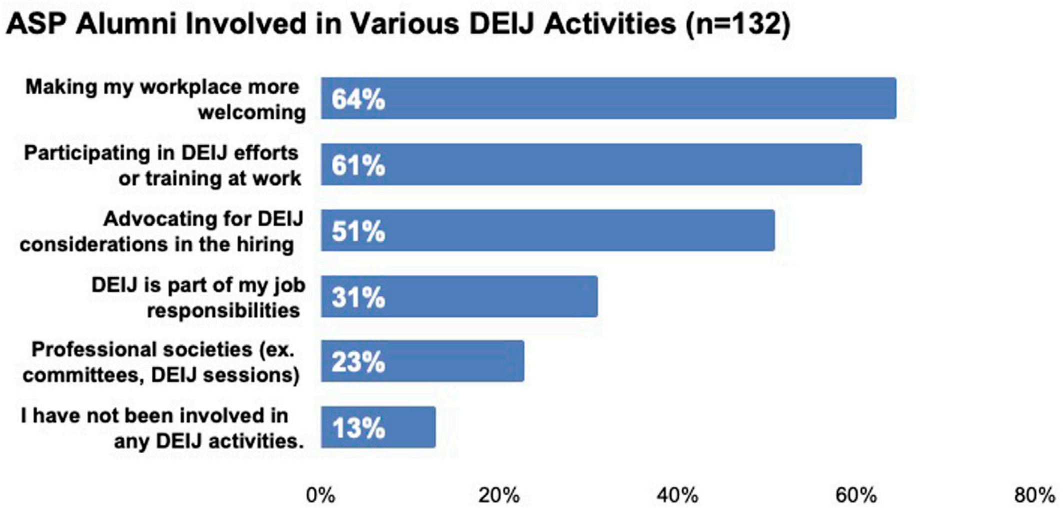

FIGURE 1
Results from the survey question, "Please indicate if you have been involved in efforts to make the workspace/science community more diverse, equitable and inclusive. Please select any of the activities that you have been involved in." *n* = 132 respondents. Respondents were able to select as many response categories as applied to them.

racial and ethnic diversity at the undergraduate level in STEM [1,2], little progress has been made in terms of increasing the numbers of professionals from diverse backgrounds [2,3]. People from marginalized communities face multiple obstacles when pursuing STEM degrees and careers, such as hostile environments and being made to feel that they do not belong in science [4]. In addition, they face persistent barriers presented in the forms of lack of representation and poor mentorship [5]. Efforts to diversify the STEM community and workforce have largely focused on recruitment of individuals who identify as Black, Latinx/e, Indigenous, women, and people from marginalized communities, often referred to as the pipeline model [6]. Augmenting the numbers of marginalized scholars represents a passive process with the hopes and intentions of leading to a diverse workforce [7,8]. In reality, this passive approach fails to illuminate the barriers, exclusionary practices, and hostile environments that individuals from marginalized communities often experience [4].

While the challenges for marginalized scholars remain, efforts to accelerate DEIJ in STEM in meaningful and persistent ways have gained support in recent years. The discourse about the urgency and necessity has expanded beyond being a topic for those only involved in human resources or STEM education. Ways to broaden participation and make opportunities in STEM more equitable are discussed in academic and research circles, the private sector, and professional societies. Discussions have progressed from the lack of DEIJ constituting a problem, to efforts and actions on what to do. While interest to invest efforts in DEIJ has increased, motivated by social movements like Black Lives Matter and heightened awareness of racial injustices and systemic inequalities, it is not clear yet if interest will be sustained and lead to meaningful efforts, or if efforts will remain ineffective.

The business case for diversity is flawed

One of the reasons why DEIJ efforts are often seen as performative is that institutions' motivations for recruitment and retention center around what is known as the business case for diversity, motivations which are often misaligned with the motivations of their own staff and students. The business case makes the argument that diverse teams are more creative and set high bars for research and scholarly excellence and produce ideas that are both more innovative and more feasible than those produced by homogeneous groups [9] and also help private industry connect to more diverse consumer groups. These benefits have often driven private sector companies and academic institutions to invest in diversifying the workforce or their student and faculty body. Private sector interest in DEIJ is driven by the potential to increase profits, and academic institution interest in diversifying the STEM workforce is driven by a desire for scholarly prestige.

While this rationale has been previously supported, recent papers have highlighted the shortcomings of this argument [10] and the potential harm to Black, Latinx/e, Indigenous, women, and people from marginalized communities [11,12]. Specifically, the argument that diversifying the workforce will lead to better science and outcomes can inadvertently place heightened and unrealistic expectations on the few marginalized scholars brought onto a team and create an unwelcoming work environment for them where they will experience self-doubt and identity threat [13]. Black, Latinx/e, Indigenous, women and marginalized professionals should not have to overperform to be valued and evaluated positively by their peers.

A study of diversity statements of private sector and public institutions found that public sector institutions have a better employment image if they used moral arguments for DEIJ efforts over business reasons [14]. Specifically, they found that *"public sector organizations are expected to be more concerned with serving societal interest than self-interest."* [14] and that institutions that express moral reasons for diversity efforts are perceived as having higher morality and competence than public institutions that espouse a business case for diversity [14]. Concluded that moral arguments for diversity can lead to higher attractiveness of an institution for prospective employers. [12] found that for multiple marginalized groups (including women in STEM and African Americans in higher education) the business case for diversity undermined a sense of belonging to an organization and increased social identity threat, concluding that the business case deters rather than attracts diverse talent. [12] state that *"the most prevalent organizational diversity case works against organizations' stated diversity goals, by paradoxically warding off the very groups they need to attract to become more diverse."*

Understanding motivations to engage in diversity, equity, inclusion and justice

To truly transform STEM institutions and make progress on DEIJ, institutions need to examine and change their motivations for broadening participation. To do so, STEM institutions can learn from their own students, staff and STEM professionals and ask why community members get involved with DEIJ efforts.

For example, a study of alumni of a postdoctoral training program at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado revealed perceptions about today's scientific workforce, training needs in DEIJ, as well as individual motivations of STEM professionals for getting involved in DEIJ activities and mentoring. The training program, known as the Advanced Study Program (ASP), began in 1964 and has supported over 600 postdocs. The alumni study of 2021 and 2022 included 140 former postdocs from the past 40 years.

The study found that the majority (87%) of alumni surveyed are involved in DEIJ efforts, and many (61%) are involved in more than one type of DEIJ effort (Figure 1). These results indicate interest and motivation to transform STEM work cultures and the composition of faculty and staff at institutions by making workplaces more welcoming, advocating for DEIJ issues in the hiring processes, and participating in DEIJ efforts through professional societies. From the study, 33% of participants consider DEIJ as part of their job responsibilities today which shows that DEIJ has become an important part of institutional practices.

The ratio of men to women among survey respondents on questions about participation in DEIJ was 90 men to 38 women or 2.4:1.0. Responses indicated that men and women were similarly motivated to engage in DEIJ efforts to make their workplace feel more welcoming (about 66% of their respective pools) or because DEIJ is part of their job responsibilities (about 33% of their respective pools). Women were about twice (1.75 x) as likely as men to engage in committee work or DEIJ sessions with professional societies, and 1.42 times as likely as men to participate in DEIJ efforts or training at work. In terms of making structural changes in the workplace, women were much more likely than men to advocate for DEIJ considerations in the hiring process (68%: 44% or 1.55 times).

On average, those who participated in DEIJ activities were 1.4x as likely to report that their employers consistently supported their professional development compared to those who indicated that their employers "occasionally" supported their professional development. Those who participated, on average, were 1.2–3.2 times as likely to recommend that future postdocs engage in professional development focused on management, data analysis, and interpersonal skills, and DEI. There were 13% of respondents who reported that they do not participate in DEIJ activities and do not recommend it as a needed skill. This suggests that engagement in DEIJ activities in the workplace leads to an increased value placed on DEIJ training.

"In just five years, the expectations have dramatically changed in terms of my faculty roles. For example, there's now a DEIJ section in our faculty activity reports, so we report on [it] annually. It also features prominently now on the tenure and promotion materials. . ."

In addition, some of the DEIJ activities in and outside of work included serving as a mentor to colleagues from marginalized communities, initiating DEIJ training at work, creating DEIJ courses at their institution, and founding a DEI-focused non-profit.

An analysis of respondent comments and career experiences that were shared in the study found experiences of alienation, gender discrimination, and workplace harassment. In the words of one alum, *"During my 40 years career I never found a workplace where I felt completely accepted, supported and at home. There was always too much competition for grants and power."* Similar themes were found for some alumni who described how their career advancement was obstructed due to sexual harassment, gender discrimination, and hostility from supervisors. Despite the challenges that some alumni faced, the study found that 76% of alumni mentored due to a sense of social responsibility, 70% as a way to give back, and 30% because they wanted to be a role model. Reasons for getting involved in mentoring differed by gender, with more women than men mentoring to be a role model to others (47% Women; 31% Men, $n = 125$). Responses for individuals who identify as non-binary/transgender/non-conforming/prefer not to answer were too small ($n = 5$) to include in the analysis. Close to half of all alumni in the study recommended training in DEIJ as important for today's workforce. The study showed that mentoring students and others, and participating in DEIJ efforts are driven by values and personal motivations.

Further evidence of the importance of personal motivations for engagement in DEIJ work comes from a study of student participants in a new course on "Social Responsibility in Atmospheric Science" at Colorado State University. The course piloted in 2021 and offered again in 2022, provided students an introduction and practical training on DEIJ issues in geosciences. Students expanded their personal and professional growth through readings, video lectures, guest speakers and other activities, and gained a critical understanding of intersectionality, gender, social identity, systems of oppression, and historical perspectives on social change movements. When asked why students decided to take the course, one student shared that they wanted to *"learn about the biases that exist in the field I am entering and to confront the biases that I hold. I want to be a part of the solution moving forward, but to do that I need to understand the problem."* Another student noted that *"because my research area (climate intervention) raises a range of ethical questions and has a particularly poor history with respect to equity and inclusion*." Faculty in the department have encouraged students to take the course because it sets the tone and culture to engage in discussions on DEIJ in their research and lab environments, and for future cohorts of graduate students. Involving students in understanding DEIJ challenges and becoming part of the solution is an important step towards changing STEM workplace cultures.

The two studies show that motivations for engaging in DEIJ efforts are deeply personal, and less connected to current priorities that benefit STEM institutions. Institutions can make more progress towards diversifying the STEM workforce by acknowledging the moral and ethical responsibilities for doing so and transitioning to an equity-centered approach. Emphasizing personal motivations to actively engage in DEIJ work resonates with individuals in the field and institutions can learn from their staff and students in articulating new rationales that include the moral, ethical, and value-driven motivations that a) reflect the motivations of community members, b) reflect the values of marginalized communities in STEM, and c) better speak to the populations being recruited and retained in STEM.

A call to transform our STEM institutions

The STEM field can achieve its goals in DEIJ if institutions incorporate the perspectives, ideas, and hope that motivate students, scientists, and staff to bring meaningful change to STEM. Institutions that use the business case to prioritize the benefits of diversity to the institution can potentially alienate DEIJ supporters and even harm the populations being engaged. From our surveys we have found the business case for DEIJ work is misaligned with the motivations of those in STEM. Understanding the attitudes, opinions, and motivations that individuals have for DEIJ in STEM presents an opportunity for how institutions can best support these motivations to bring forward systemic change. STEM organizations will be able to make more progress when espousing moral and ethical responsibilities for diversifying its workforce and by moving to what we call an equity-centered approach.

A move towards a value-driven and equity-centered approach will transform institutions to become safe and welcoming spaces *versus* being institutions focused solely on increasing numbers within diversity categories. The social and equity benefits of diversity advocated for do not depend only on the contributions of current Black, Latinx/e, Indigenous, women and other marginalized scholars or by only increasing the number of scholars with these identities but will arise from our collective actions to create inclusive and equitable spaces that allow STEM scholars to be valued and recognized fairly.

In implementing DEIJ goals, institutions need to be cognizant that diversifying the workforce and student body at any organization must be paired with systematically creating equitable and inclusive spaces that enable everyone to bring their full self, where persons can be valued unequivocally for who they are, and where performance is equitably evaluated. Organizations can take first steps towards an equity-centered approach by reflecting on their motivations for recruitment and retention of a more diverse workforce and student body and acknowledging the ethical and societal responsibilities they have in their communities as centers of learning and creativity. We invite institutions to review their DEIJ statements and goals and update them to include moral and ethical rationales, and include these considerations into DEIJ training for staff and students. We call for institutions to thoughtfully and intentionally co-create inclusive environments in STEM with students, staff, and scholars, and use moral, ethical and valued-based foundations to transform our field.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the UCAR Human Subjects Committee (HSC) under Memo #2021-17 Colorado State University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

All authors contributed to the conception and design of the study. MV and VS led surveys and focus groups of the ASP study and MV, VS, and PM performed the data analysis. MB led the CSU study and analysis. All authors wrote the manuscript and contributed to manuscript revision, read, and approved the submitted version.

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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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Tips for writing a good recommendation letter

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Bias exists in letters of recommendation, and it is reflected in the language used to describe and evaluate different candidates for countless opportunities in academia. Professional organizations are becoming more aware of this issue, and are pursuing avenues to address it. This paper discusses the type of information, that is, useful to have on hand when writing a recommendation letter, the structure of the letter, a process to follow for proof reading, when to say no, a compilation of additional resources, and tips for people asking for recommendation letters. Specifically, we discuss common grammar mistakes, the purpose of each portion of the letter, and ways conscious and unconscious bias can influence wording and structure. This paper is intended to provide a single place where people can go to learn all of the basics needed to write a strong recommendation letter, as currently available letter writing resources in the space physics community tend to focus on one aspect of letter writing.

KEYWORDS

recommendation letters, bias, equity, inclusion, space physics

1 Introduction

Bias is defined as a prejudice in favor of or against one thing, person, or group compared with another usually in a way, that is, considered to be unfair. There are two different types of bias: conscious (or explicit) bias and unconscious (or implicit) bias. A recent report from the National Academies of Sciences, Engineering, and Medicine. (2022) highlighted that structural racism, sexism, interpersonal attitudes, stereotypes, and bias all contribute to the a lack of opportunity for early and sustained research experiences for women and historically underrepresented groups in space physics. Further, a number of prior studies (e.g., Dutt et al., 2016; Houser and Lemmons, 2018; Madera et al., 2019; Rojek et al., 2019) have demonstrated such bias often appears in recommendation letters, especially those in STEMM (science, technology, engineering, mathematics, and medicine) fields. Since recommendation letters, letters of support, *etc.* are a near universal requirement for awards, promotions, scholarships, acceptance into graduate school, internships, and postdocs, *etc.* writing a strong recommendation letter, free of bias is critical to recruiting and retaining talented people in space physics, especially those from historically underrepresented and marginalized groups.

Writing a recommendation letter for a colleague or a student can be a daunting prospect. After all, the future of their career hinges on your words. How can you best describe their strengths and suitability for this position? This guide will help you write a letter that shines the best possible light on the person you are recommending, and limit instances of bias.

2 Before you start

Gather information about the recommendee[1]. You may need to ask the recommendee for an updated copy of their résumé or Curriculum Vitæ (CV). This will help you gather the important details you will need for the recommendation letter.

1) When did you work with this person?
2) How long have you known them?
3) What job position did they hold at the time of your interactions?
4) What qualities about this person made them good at their job at this time?

You should read the opportunity for which you are recommending them. What are the key qualities are they looking for in an applicant? This will help focus your recommendation letter by including examples that demonstrate the qualities that the employer (or award committee, *etc.*) desires. You may want to explicitly include some of the language from the opportunity in your reference letter to strengthen this connection.

Different opportunities also have different format requirements for recommendations. Recommendation letters are commonly one page long for early-career positions, but are frequently longer for senior positions, scholarships, or awards. Some institutions accept PDFs akin to traditional letters, while others use online forms with boxes asking the writer to answer a prompt. Still others prefer to ask questions over the phone. Knowing the recommendation format before you start will help you craft the best response for the opportunity in question.

3 Structure

In most situations, recommendation letters will follow a similar format: a greeting; an opening paragraph introducing the recommendee and yourself; 3–5 paragraphs providing detailed examples that demonstrate the recommendee's qualities; a final paragraph concisely recommending the recommendee for the desired position; and a closing statement followed by your signature.

3.1 Greeting

In formal English letter writing, the opening greeting follows the form "Dear Title Surname:". Like informal writing, "Dear" is used as an opening. Unlike informal letters, a colon is used to end the line instead of a comma.

If you know the name and title of the person you are writing to, it is best to include it. If you know the person's name but not their title, you may either omit it and use their full name or use the highest title associated with their position. If you are unsure of the correct pronouns and the highest appropriate title is gendered, consider omitting the title. Making incorrect assumptions about gender or marital status is a sure-fire way to put the evaluating reader in a bad mood.

If you do not know the name of the person you are writing to, using a term that refers to the position or group is acceptable; for example, "Dear Hiring Committee:". We recommend not using "Dear Sir or Madam:" as the person you are writing to may be non-binary, or prefer a different title such as Dr. or Prof.

3.2 Opening paragraph

First, state the recommendee's full name (with or without a title) and what award or position you are recommending them for. Describe how you know the applicant and briefly summarize why you are recommending them for this opportunity.

After the first sentence where the recommendee's full name is used, it is important to refer to them in a professional manner throughout the rest of the letter. Using their professional first name, full name, or title and surname are all acceptable. This should be the name they choose to use in professional circles (which may not necessarily be their legal name; for example, someone who publishes under their maiden name). Avoid using friendly nicknames, as many cultures consider this to be rude or vulgar in a formal setting. It can also introduce an unconscious bias against the recommendee, as nicknames commonly use diminutives that are associated with children, and this could lead to the recommendee appearing less qualified.

In some instances, it may be useful to establish your credentials as an authority in the field. This would most likely be necessary when writing a letter to someone outside your field (e.g., for a visa or citizenship application). When doing so, be as succinct as possible to avoid removing the focus from the recomendee.

3.3 Central paragraphs

Each paragraph should focus on a reason that the recommendee is suited to the opportunity (for instance, in a job application you might use a paragraph per item on the person specification). Make sure your details are specific and relevant to the opportunity. You should concentrate on measurable achievements instead of commenting on a person's general demeanor or appearance. For example, if you cite the quality of the recommendee's papers as evidence in our letter, you could quantify this by including details like the number of papers written (within the context of how many might be expected) or how impactful the papers were to the community. Pick strengths where you can enthusiastically recommend the candidate, that are relevant to the position for which you are recommending the candidate, and that you can support with detailed examples and evidence. Quantifiable comparisons (e.g., "in the top ten percent of all the students I have worked with") frequently draw the attention of evaluators, and so should be used when appropriate and fully supported. You should not include negative examples.

If the recommendee has a quality that you perceive as a potential reason to not hire them, either do not mention it (it is not something you are recommending) or do not write the recommendation letter. Remember that the role of the recommendation letter is to provide positive information about the recommendee. Anything you choose to not mention, that is, vital to the role will be interpreted as a negative without you needing to say anything.

1 Note for recomendees: If you have a web presence, make sure to keep it up to date with your CV information so it is easy for people to find.

3.4 Final paragraph

Restate why you are recommending this person for the opportunity and reemphasize the strength of your recommendation. This is the last thing the committee will see, and will likely stick in their mind. Again, do not comment on a person's general demeanor or appearance. Focus on measurable achievements that are relevant to the position or award.

3.5 Closing

These standards will vary by country and evolve over time, but the standard is to be polite and professional. At the time of publication, *Sincerely,* is commonly used in the United States, *Best regards,* is the standard in the United Kingdom, and *Very respectfully,* is standard in the military. Including your printed name with appropriate titles below your signature. However, this should not be a long block of awards or affiliations. It should not take up space that would be put to better use writing about the recommendee in the central portion of the letter.

4 Proofreading

Once the letter is written, it is essential to proofread the letter. Keep an eye out for spelling and grammatical errors, and ensure the letter strongly states why you are recommending this person for the opportunity. Here are some things to look for in your letter.

1) Spelling and grammatical errors: while minor, these errors can distract from the thrust of the letter and may weaken the recommendation.
2) Consistency in naming practices: make sure that the name of the recommendee is correct and the form of address you choose to use is applied consistently throughout the letter.
3) Pronoun check: Ensure that the correct pronouns are used consistently throughout the letter.
4) Number of compliments: expect to have 3-5 major reasons that you think this person is a good fit for the opportunity, and align these reasons with the person specification (or equivalent).
5) Detailed and substantive examples: make sure each compliment is supported by several sentences of substantiating information, ideally providing quantitative metrics that allow the recommendee to be compared favorably to other candidates.
6) Adjective check: consider using a thesaurus to find the most appropriate and positive adjectives to support your case, and using a gender-bias calculator (Forth, 2013; Lowe, 2015) to identify adjectives that may undermine your recommendation.
7) Formatting: make sure the letter is consistently formatted and easy to read.
8) Word count: some organizations place limits on the word count for recommendation letters, so check to make sure the letter will not undermine the candidate's application through non-compliance.
9) Outside eyes: strongly consider asking a colleague or a service (such as ELSP, Burrell et al., 2021) to review the letter, as an objective opinion will often notice weaknesses imparted through your habitual writing style.

The best way to spot mistakes is to proof read something you have not written, or have not written recently. Spotting typos, unclear wording, or unconscious bias is difficult to do for yourself. Thus, whenever possible, we highly recommend having a colleague or review service proofread for you. If you are proofreading for someone else, here is a checklist that can help you identify potential strengths and weaknesses in the letter.

1) Run the text through a gender bias calculator to obtain an initial percentage of male- and female-associated words.
2) Read through the letter, highlight things that jump out at you.
3) Fix typos and grammatical errors.
4) Determine the number of compliments to establish the positive aspects that are being imparted.
5) Figure out why you highlighted the different statements and say, generally, what would make them present the candidate in a better light.
6) Optionally, rewrite the letter using positive adjectives suggested by the context of the compliments.
7) Identify areas where more or different examples would be helpful.
8) Consider general formatting, such as the amount of white space or the word count.
9) If any re-writing was done, re-run the gender bias calculator to track improvement.

5 When to say no

If you are asked to write a recommendation letter, you are not required to say yes. In certain situations, you may do the recommendee a favour by saying no. Good reasons to turn someone down include.

1) Not being able to, in good conscience, recommend the person to the position for which they are applying.
2) Not having sufficient experience working with the recommendee.
3) Having already agreed to write a recommendation letter for another applicant to the same opportunity.
4) Simply signing a recommendation letter that the recommendee wrote themself.

Kindly turning a person down allows them to find someone who will provide them with a strong recommendation, improving their career prospects.

In some cases, communication between yourself and the potential recommendee may result in you agreeing to write a letter despite not being able to accurately present the recommendee as a strong candidate. It is vital to provide accurate information in your recommendation letter, but only appropriate to write such a letter if the person you are writing for is aware that this will not be a strong, positive recommendation. A common example of when this may occur is for an undergraduate transfer student. In this example, the student may not have close relationships with enough professors and consider one generic, positive letter out of several better for their application than not providing the requested number of recommendation letters. In cases where you are not writing a strong recommendation letter, be extra careful to ensure that you are accurately portraying the recommendee's abilities and are not negatively influenced by biases.

6 Resources for writing a strong nomination

The Equitable Letters for Space Physics (ELSP) group is providing a review service for recommendation and nomination letters (Burrell et al., 2021). This service functions similarly to the journal review process, and reviews letters for unconscious bias as well as factors like spelling and grammar. A review is expected to take about 2 weeks.

Additionally, there are many helpful resources available to guide you in writing a good nomination. Most university student unions or career centers provide in-person support, online grammar guides, and online recommendation letter examples. The ELSP website (Smith et al., 2021) also hosts links to resources from universities, journals, and professional services. This includes links to a gender bias calculator (Schmader et al., 2007; Lowe, 2015), a tool to identify inconsiderate writing (Wormer et al., 2017), and various websites on best practices for writing professional letters. The ELSP website also provides example of good and bad letters for different types of recommendation and nomination letters, showcasing different ways implicit bias can occur.

7 Tips for recommendees

To obtain a strong letter of recommendation, there are some "best practices" that you can use. Start by asking a potential recommender, "Do you think you could write me a *strong* recommendation?" If they say yes, then provide the recommender with as much information as possible regarding your achievements (for example, your résumé or CV and a list of accomplishments) and the opportunity you are applying for or want to be nominated for. This will allow the recommender to spend a higher percentage of their time writing a strong letter instead of researching the information in order to write the letter. Among others, the Institute for Broadening Participation: Building Partnerships to Support Diversity in STEMM (Kauer et al., 2018) and Gonzaga University (Brackmann, 2021) provide excellent articles/checklists on the best practices for requesting and obtaining a strong letter of recommendation. The most important of these best practices are summarized below:

1) Give recommenders plenty of lead time: 2–3 months in advance if possible.
2) Provide short descriptions for the jobs, scholarships, and awards that will request references on your behalf.
3) Prepare a packet for each recommender that highlights your strengths (for example, résumé/CV, classes taken, awards, community-building activities, work experience, mentoring experience). Make sure to include in this packet several reasons why you have asked the recommender to write this letter, including any additional information you hope they will discuss.
4) Make the logistics of submitting the letter as straightforward as possible. Provide a "hard" deadline, the name of the person receiving the letter (if possible), and instructions about how the recommender should submit the letter.
5) Follow up with each recommender to let them know their letters have been received. Thank them for supporting your career and let them know the outcome of your applications.

8 Summary

Recommendation letters play a critical role in the academic selection process, and offer a more personal and subjective view into a recomendee's "fit" for a position, program, *etc.* This article offers suggestions to improve the quality of recommendation letters coming from the space physics community (and the broader STEMM fields), including providing recommendations and resources to reduce instances of bias. Specifically, we encourage those writing recommendation letters to allow enough time for an independent review by a colleague(s) or review service. Similar to submitting a manuscript for publication in an academic journal, independent proofreading of recommendation letters will greatly improve the quality of your letter and reduce and or eliminate any conscious or unconscious bias.

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

AB led the conceptualization and drafting of the this manuscript. All other authors contributed text to specific sections in the manuscript, as well as contributed citations, edited, revised, and approved the submitted version.

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Enhancing demographics and career pathways of the space physics workforce in the US

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We present the demographics data for the space physics workforce which are compared with other space sciences fields, physics, plus science and engineering in general. We focus on the early stages of college, and draw some lessons from looking beyond the US by discussing this in the context of physics degrees awarded in different countries. We review some of the studies from the National Academies, extracting some relevant recommendations. Studies of the science, technology, engineering and mathematics (STEM) workforce, the physical sciences profession, and specifically the space sciences show that the "pinch point" where the demographics narrow down is at the high school to college stages. We considered the actions that could be made nationally by federal agencies, locally by an institution or individually to enhance and diversify the career pathway through the space sciences.

KEYWORDS

stem education, workforce, diversity, demographics, space physics research

Introduction

Many studies have shown that multiple forms of diversity in a workforce enhance creativity and productivity (Hong and Page, 2004; Campbell et al., 2013; Freeman and Huang, 2014a; Freeman and Huang, 2014b). NASA Science Plan 2020 states,

> "As research has shown, diversity is a key driver of innovation and more diverse organizations are more innovative. . . We will increase support by actively encouraging students and early career researchers. . . . We will also increase partnerships across institutions to provide additional opportunities for engagement and increasing diversity of thought. NASA believes in the importance of diverse and inclusive teams to tackle strategic problems and maximize scientific return."

A national focus on diversity, equity, inclusivity and accessibility (DEIA) over the past few years has nudged institutions to look at the demographics of their workforce and find quick ways to "fix" discrepancies. However studies of the science, technology, engineering and mathematics (STEM) workforce, the physical sciences profession, and specifically the space sciences show that the "pinch point" where the demographics narrow down is at the high school to college stages (*Advancing Diversity, Equity, Inclusion, and Accessibility in the Leadership of Competed Space Missions (2022),* hereafter National Academies of Sciences, Engineering, and Medicine, 2022a). This means that the changes need to be made within the education system (i.e., basically, at the state and/or county level in the US) and the impact on the demographics of senior levels of the profession will likely take many years.

The goal of this paper is to pull together the various studies and reports and present a summary for people who are new to the topic but would like to know where to find out more. We are providing the "CliffNotes" for the topic of demographics and career pathways in the field of space physics. In this article we first present the demographics of the space physics profession, addressing gender, race/ethnicity and current trends. We then compare the demographics of space physics with other space sciences (planetary, astrophysics, Earth science), as well as internationally. We next summarize the findings and recommendations of various reports, mostly from the National Research Council (NRC) or the National Academies of Science, Engineering, and Medicine(NASEM). Finally, we summarize some of the research on how STEM education at the college could be improved to retain a more diverse population of STEM degrees. Our conclusions are listed from immediate actions that could be taken locally to longer-term, institutional and/or national policy approaches.

We simplify references to the three Decadal Surveys carried out by NRC or NASEM as follows: *Solar and Space Physics: A Science for a Technological Society* is called SSP 2013; *Pathways to Discovery in Astronomy and Astrophysics for the 2020s* becomes Astro 2021; *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032* is shortened to Planet 2023.

First the numbers

Surveying the workforce in solar and space physics is not as straightforward as it might seem at first. We belong to different professional organizations (AGU, AAS, APS, etc.), attend different conferences, get funding from different agencies (NASA, NSF, NOAA, etc.) and work at a range of types of institutions (agency labs/centers, universities, non-profits, industry, etc.). It is a similar story for planetary science and for astrophysics. Yet, to study the state of the profession for a Decadal Survey, each area needs to know the demographics of the appropriate workforce.

Luckily, there is an umbrella organization—the American Institute of Physics (AIP)—that has a Statistical Research Center with staff who are experienced in carrying out surveys. The AIP was sponsored by NSF to carry out the 2011 Survey of Solar, Space and Upper Atmospheric Physicists (White et al., 2011a). Moreover the AIP keeps a tally of physics departments across the US and tracks the number of faculty and degrees (bachelor's, masters and doctorates) being awarded.

At the same time, the landscape of how demographics are described is changing. Terms to describe gender, race and ethnicity are evolving as society begins to recognize that identity can be more complicated than thought a decade or so ago. Nevertheless, looking at the numbers, albeit simplified, can guide policies and programs to enhance the diversity of the field.

Space physics workforce

In preparation for the 2013 Solar and Space Physics Decadal Survey process, the Education and Workforce Working Group developed a survey of the profession. The survey was implemented by the American Institute of Physics and funded by the National Science Foundation (NSF). The survey request was sent to 2560 unique email addresses gathered from various professional groups: AGU's Space Physics and Aeronomy Section (SPA, the largest group, with 1,792 unique names); AAS's Solar Physics Division (SPD); Space Weather Week conference attendee lists, and NSF PI lists. The survey received 1305 responses (51% response rate), of which 1171 indicated that they considered themselves in the field of Solar, Space and Upper Atmospheric Physics (SSUAP) and currently work and reside in the US. If one makes the assumption (probably crude) that the 51% response rate applies across the board, then one can estimate that the profession comprises a total of approximately 1171/0.51–2300 space physicists in the US.

Figure 1 summarizes the basic demographics of this SSUAP population. In 2011 the gender split was 83% men, 17% women. When considering race/ethnicity it is useful to compare the respondents who obtained their doctorate degrees before vs after 2000. The percentage of White respondents drops from 83% with earlier doctorates to 69% with later doctorates. Meanwhile, the percentage of Asian or Asian Americans rose from 12% to 24%. The percentages of Black or African American and Hispanic or Latino respondents made small increases in percentage of doctorates from 1% to 2% and 1%–3% respectively.

A few decades ago most people in the SSUAP fields came through graduate programs in physics departments. Physics is still the most common (62% of respondents) undergraduate degree. Figure 1 shows that since 2000, more doctorates were in the specialized fields of Space Physics and of Solar Physics. While AIP keeps track of numbers of doctorate degrees in physics, it is hard to keep track of trends in sub-fields unless surveys are repeated to specific areas such as SSUAP. A more effective approach would be to make SandSP a formal dissertation research area or subfield in the NSF Annual Survey of Earned Doctorates. This would provide tracking of PhD production and data to assess the health of graduate programs. (See National Science Foundation, Survey of Earned Doctorates, available at http://www.nsf.gov/statistics/srvydoctorates/).

Education and workforce issues

The SSP2013 Decadal Survey included an Education and Workforce Working Group that evaluated not just the 2011 SSUAP Workforce Survey (White et al., 2011a) but also carried out separate studies of such things as PhD production rate and the job market (*via* job advertisements) over the previous 10 years (see Appendix D of the SSP2013 report).

Figure 2 (left) shows the trends in PhD production in solar and space physics (in Canada and the US) as well as the number of job advertisements for post-doctoral, research scientist and faculty positions (from Moldwin et al., 2013). The Moldwin et al. (2013) study showed a total of "475 PhDs were produced at 76 different institutions. The top 10 institutions produced 238 (or 50 percent) of the total. Thirty of the 76 institutions produced only 1 solar and space physics PhD during the decade." Prior to 2007 about ~5 PhDs per year were produced in the sub-fields of Heliophysics, Space Plasmas and Solar Physics, while ~12 PhDs per year were produced in Magnetospheres and Ionosphere-Thermosphere-Magnetosphere

	% All Respondents	Respondents Earning Doctorates...	
		1999 & Earlier (%)	2000 & Later (%)
Gender			
Men	83		
Women	17		
Race/Ethnicity			
Asian or Asian American	13	12	24
Black or African American	1	1	2
Hispanic or Latino	2	1	3
White	81	83	69
Other	3	3	2
Employment			
Student	8		
Full-time Employed	79		
Part-time/Unemployed	13		
Field of Doctorate			
Physics		40	27
Space Physics		22	36
Astronomy/Astrophysics		17	11
Solar Physics		4	10
Engineering		7	9
Other		10	7

FIGURE 1
Results from the 2011 Survey of Solar, Space and Upper Atmospheric Physicists (White et al., 2011a). Responses were received from 1,171 individuals who resided in the US at the time of their response.

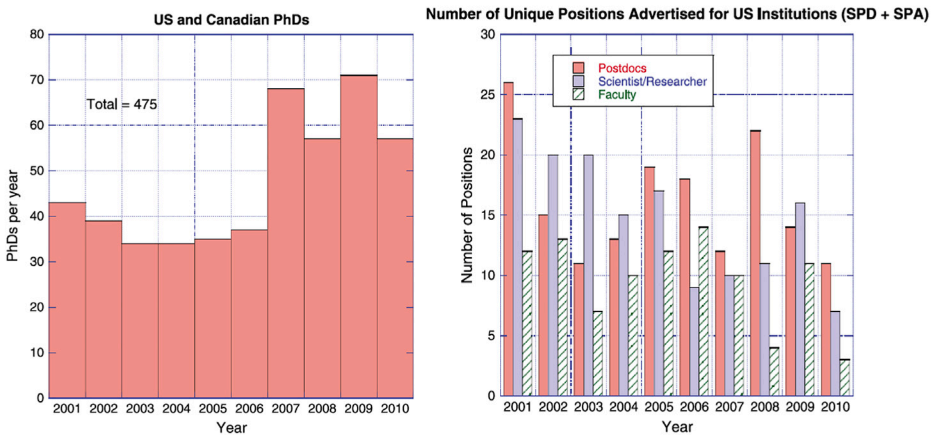

FIGURE 2
Total PhDs in solar and space physics (2001–2010) and number of unique positions advertized (*via* solar and space physics newsletters) for US institutions at levels of postdoc, research scientist and faculty. (Moldwin et al., 2013).

Coupling (ITM). Between 2007 and 2010 the number of ITM degrees shot up to ~25 while Solar Physics increased by about a factor of 2.

The right side of Figure 2 shows the number of unique positions advertised for US institutions in the AGU-SPA and AAS-SPD newsletters. These numbers were gathered in a study by Moldwin et al. (2013) who reported "the field—though small—is vibrant and growing. However, there is concern that the number of positions, especially faculty positions, is not keeping track with the growth of the field. Continuation of the NSF Faculty Development in the Space Sciences program would directly address this concern".

The big question is what has happened in past decade? Have the trends shown in the two plots of Figure 2 persisted or changed? These are questions for the Status of the Profession Panel of the next Decadal Survey.

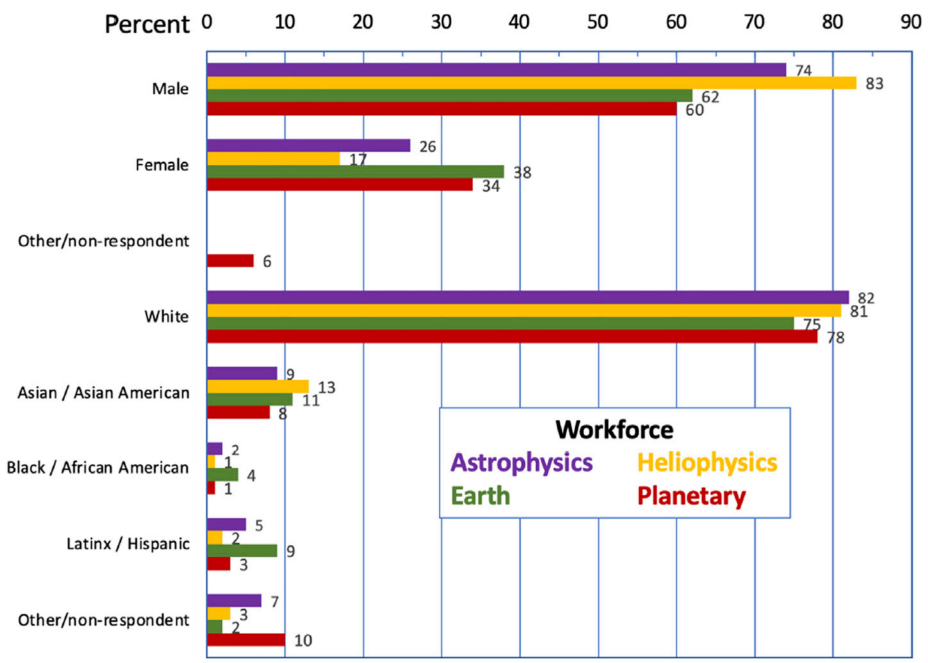

FIGURE 3
Demographics of the space science research workforce (PhD scientists working in the US) derived from workforce surveys. Based on data from Bernard and Cooperdock (2018), National Science Foundation National Center for Science and Engineering Statistics, Pold and Ivie (2018), Porter and Ivie (2019), Porter et al. (2020), and White et al. (2011a).

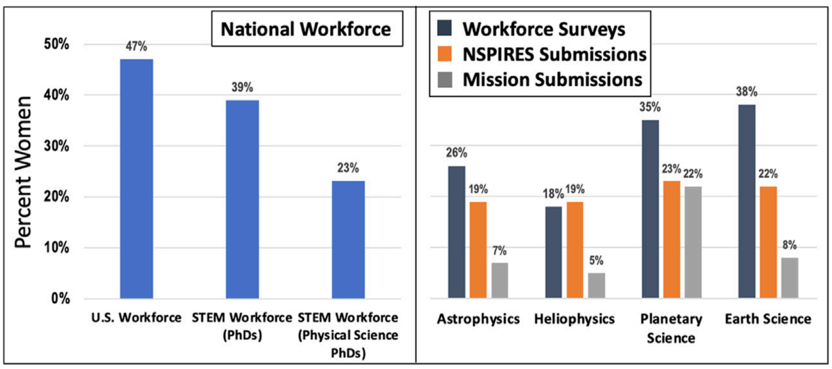

FIGURE 4
Gender statistics of competed mission team leaders compared with the workforce of corresponding NASA SMD divisions and the U.S. STEM workforce overall. Female percentage of populations: PI of submitted mission proposals, PIs and Co-Is of NSPIRES proposals, workforce for SMD science fields, U.S. STEM workforce (Physical Science PhDs), U.S. STEM workforce (PhDs in any field), total U.S. workforce. Based on data from Bernard and Cooperdock (2018), National Science Foundation (2019), Pold and Ivie (2018), Porter and Ivie (2019), Porter et al. (2020), and White et al. (2011a),White et al. (2011b).

Comparisons with other space sciences

For the recent NASEM study on *Advancing Diversity, Equity, Inclusion, and Accessibility in the Leadership of Competed Space Missions (2022),* hereafter National Academies of Sciences, Engineering, and Medicine, 2022a, demographic data were compiled for four of the divisions of NASA's Science Mission Directorate (SMD): Heliophysics, Astrophysics, Planetary Science and Earth Sciences. (The fifth division, Biological and Physical Sciences, was not included because it does not generate satellite missions, the focus of the study). Figure 3 shows that workforce data are pretty similar across these four science divisions and illustrates how these fields are predominantly white and male. Heliophysics has a notably low percentage of women (17%), half the representation in Earth and in Planetary Sciences. When considering race/ethnicity, all four divisions have similarly very low percentages of non-White populations.

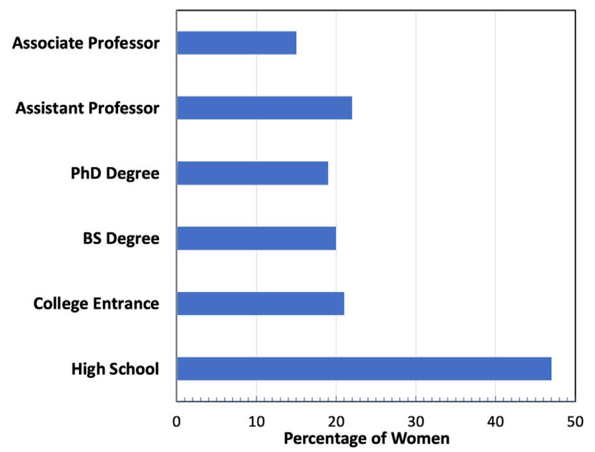

FIGURE 5
Percentage of participating physicists that are women at various academic stages. College entrance refers to first-year student's intent to major in the field. Based on Hodapp and Hazari (2015).

Figure 4 compares gender demographics data for these four NASA divisions with (left) the percentage of women shown in workforce data across US, for all STEM fields and specifically in physical sciences. On the right the data for the four divisions come from the workforce surveys (Figure 3), all research proposal submissions through NASA's online NSPIRES platform, and proposed missions with women Principal Investigators (PIs). The involvement of women in Planetary and Earth Sciences is comparable to the overall STEM workforce (39%), while Astrophysics and Heliophysics workforces (perhaps not surprisingly) are comparable to the national workforce in physical science (23%), as are all four percentages of women submitting research proposals to NSPIRES. When it comes to women PIs submitting mission proposals, only Planetary Science has a percentage comparable the national physical science workforce while the other 3 divisions have much lower (5%–8%) representation. Clearly, the workforce of these four NASA SMD divisions have a way to go to reach gender parity.

Education and career pathway

As discussed in the National Academies of Sciences, Engineering, and Medicine, 2022a Advancing DEIA study, as well as the Decadal Surveys, the "pinch point" in the diversity of careers in the physical sciences comes at the high school to college stages, well before graduate school and doctorate degrees. Focusing on physics (the primary subject underlying most of space sciences), analysis of AIP data by Hodapp and Hazari (2015) shows in Figure 5 how at high school the participation of women in physics classes is close to parity with men. The participation plummets to ~20% at college entrance. While the total numbers along the career path to professor decrease drastically, the participation of women remains around the ~20% level, suggesting the career path is not differentially leaky for women.

This major drop of the participation early in college by women-and racial/ethnic minorities-is consistent with studies of when and why students switch out of STEM majors, as discussed at length in the 1997 book *Talking About Leaving: Why Undergraduates Leave the Sciences* (Seymour and Hewitt, 1997). The TAL study illustrates the "iceberg effect" that many of the issues that caused student to switch out of classes were also experienced by the students who persisted, emphasizing that these issues need to be addressed even if departments are willing to let a significant fraction of students switch their major. Twenty-four years later, the follow-on 2019 book *Talking About Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education* (Seymour and Hunter, 2019) found, through many interviews of students and teachers at six different universities, that the same factors continued to affect students' decisions to switch majors. Briefly stated, these factors are:

- Poor teaching in introductory math, physics, chemistry classes (e.g., disorganized, disinterested, poor delivery of content ("chalk talk"), unwilling to help, etc.). Across persisting and switching students, 78% expressed frustration with poor teaching.
- "Weed-out" culture (e.g., high workload, fast pace, tough grading on a curve, little support, etc.)
- Loss of interest in STEM major, discovery of interest outside STEM
- Inadequate math preparation at high school

Additional factors emerging in the second book TALR were:
- Competitive class climate
- Financial difficulties

While more women than men switched majors, the difference was much reduced over 24 years (perhaps partly related to changes in culture and parental support). For students of color, given greater emphasis in TALR, the primary issues were poor high school preparation, difficulties making the transition to college, the competitive nature of STEM classes, and being discouraged by getting low grades. We return to these issues and their potential remedies in a later section.

Degree data

Meanwhile, let us consider how the total numbers and demographics of physics bachelor degrees have varied over time. In the top of Figure 6 we show total numbers and below is the percentage awarded to women, Hispanic Americans and African Americans. The total number of bachelor's degrees (summing all subjects) has risen steadily since the 50 s from ¼ million to just over 2 million. By contrast, the number of physics degrees oscillated around ~4500 ± 20% for about 50 years and then proceeded to climb, at a faster rate than the All Bachelor's slope, to a peak of ~9300 in 2019 (the 2020 and 2021 numbers may be affected by COVID). The lowest curve on the top plot shows the total number of women getting bachelor's degrees in physics, steadily rising from 1980 to 2020, but not as steeply as the men or total. The net result of the flatter curve for the women means that fraction of physics bachelor's degrees awarded to women actually dropped between ~2000 and ~2013 before kicking back up again. At the same time the

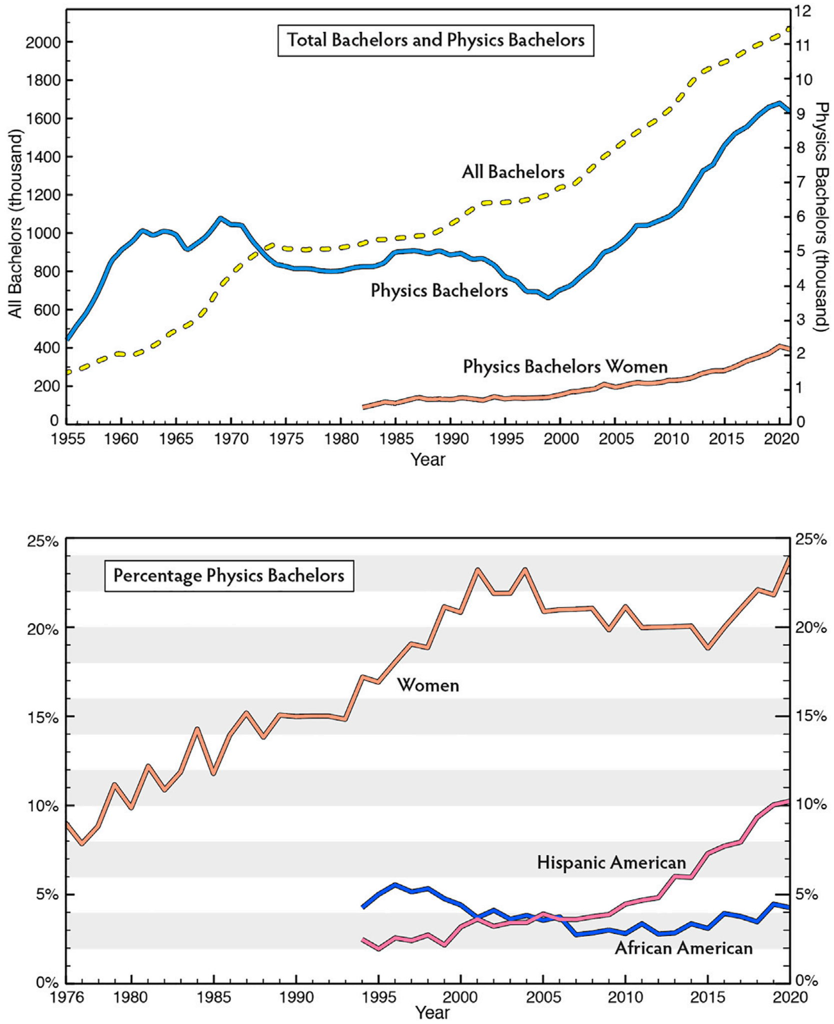

FIGURE 6
Top: Number of bachelor's degrees (all topics) and physics bachelor's degrees (1955–2021). *Bottom:* Percentage of Bachelor's degrees in physics awarded to women, to Hispanic Americans and African Americans. Produced using data from the Statistical Research Center of the American Institute of Physics, see https://www.aip.org/statistics.

percentage of undergraduate physics degrees awarded to Hispanic Americans has been steadily rising over the past 30 years, reaching nearly 10% (still below the overall percentage in the US population of 19%). The number of African Americans decreased over most of the past 30 years (~5%–3%), perhaps slowly rising back to 4%, well below the 12.5% of the US population.

Turning to graduate students, Figure 7 shows the total numbers of physics degrees between 1975 and 2020. The peak number of about 1900 doctorates (in 2018) corresponds to a little under 1 in 5 of the 9300 physics bachelor's degrees. However Figure 7 also shows that since the mid-90 s about half of the physics doctorates have been awarded to people born outside the US (while only ~20% of physics bachelor's degrees were awarded to non-US students). This means that only about 1 in 7440/950 = 7.8 of US students getting physics bachelor's degrees went on to get PhDs in physics. The total number of doctorates awarded to Black/African Americans has hovered around 10–20 while the number of Hispanic/Latinx physics doctorates has increased over the past decade from ~15 to over 40. Note that these numbers are far below their representation in the US population as a whole which would currently be 143 (14% in US) for Black/African Americans and 195 (19%) for Hispanic/Latinx.

The story with women getting physics doctorates may be more complicated. The total numbers have been increasing steadily over the past 45 years up to an annual rate of ~400 per year (about 21% of the total). But, as we see in the next section, a disproportionate number of these may be non-US.

International comparisons

Obtaining numbers for physics degrees in the US is hard enough—but getting numbers for other countries is even harder. Ivie and Guo (2006) reported data on degrees awarded to women in about twenty countries for 1999 and 2000 shown in various ways in Figure 8. First (top) we show the total numbers of physics bachelor

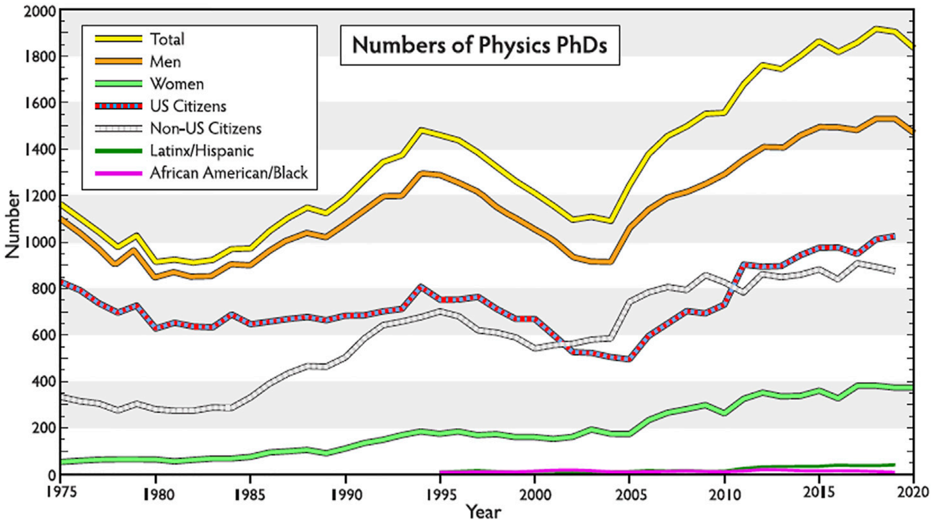

FIGURE 7
Trends in Physics disaggregated by gender and citizenship status as well as race/ethnicity. Produced using data from the Statistical Research Center of the American Institute of Physics, see https://www.aip.org/statistics.

and doctorate degrees. Readers may not be surprised to see the US produce the highest numbers. But when these numbers are plotted per million people of each country's total population, the US slips way down the league table of *per capita* degree production. Even more surprising is the plot of percentage of physics degrees awarded to women. These data are now 2 decades old and the current numbers could be quite different. But the data get one thinking about possible reasons why each country sits where it is in these plots. What are the cultures and policies that drive high/low *per capita* production of physics degrees or high/low percentage awarded to women? Are a significant number of women getting physics doctorates in the US coming from the countries that award a higher fraction of their bachelor degrees to women?

Comparing the US career paths (Figure 5; Figure 6; Figure 7) with demographics from a United Kingdom survey by the Royal Astronomical Society, 2017 (published in 2017 and summarized by Massey et al., 2017) we see that the participation of women in Solar System science in the United Kingdom is similar to the US while in astronomy there is a steeper drop with rank. Students pursuing PhDs in the United Kingdom have similarly exceptionally poor non-white representation. While the permanent staff and graduate students were largely British (73% and 69% respectively), only 48% of post-docs were from the United Kingdom. The 33% of post-docs from the European Union (EU) may drop following the British withdrawal from the EU.

The international data from Ivie and Guo (2006) are limited in their coverage. Their paper says "To be included, countries had to provide appropriate data from reliable statistical agencies". A couple countries that are notably absent in Figure 8 are India and China. In fact, over the past 20 years, science and engineering education in China and India have taken off (see top plot in Figure 9). Moreover, China's expenditure in RandD is also sharply rising (see bottom plot in Figure 9). The three factors of i) US's low *per capita* production of bachelor degrees in STEM degrees; ii) the high fraction of US doctorates awarded to students born outside the US; and iii) the steep rise of production of STEM doctorates outside the US, has caught policymakers' attention. The 2022 report on *The State of US Science and Engineering: Science and Engineering Indicators* from the National Science Board (2022) notes:

> "The STEM workforce relies heavily on foreign-born individuals, who account for about one-fifth of the STEM workforce (and higher proportions in certain fields). Among foreign-born STEM workers with an SandE degree, about 50% are from Asia, with most from India or China."

They also show a chart that illustrates the US share of worldwide RandD expenditure decreasing between 2000 and 2019 from 36% to 28%. Over the same period, the share of China increased from 4% to 22%. Hence, a key takeaway of the report is:

> "The global concentration of RandD performance continues to shift from the United States and Europe to countries in East-Southeast Asia and South Asia."

A report from the American Academy of Arts and Sciences in 2020, *The Perils of Complacency: America at a Tipping Point in Science and Engineering* is even blunter. One of their key messages is:

> "The United States is in severe danger of no longer being the premier destination for SandE talent. An increasingly unwelcome environment for foreign talent, together with a failure to cultivate an adequate domestic SandE workforce, threatens a decline in American health, prosperity, and national security."

This report (from a committee co-chaired by Norm Augustine and Neal Lane), including many graphs, presents the case that:

> "The United States is today at a "tipping point" with regard to its ability to compete globally. Decisions made in the next few years

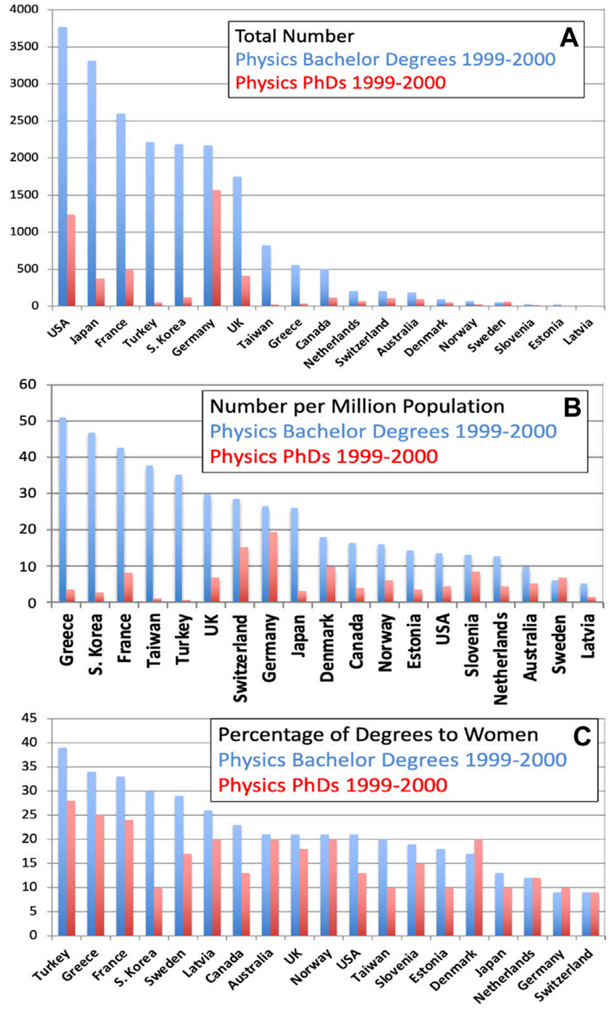

FIGURE 8
Physics degrees awarded (averaged over 2 years 1999–2000) for 19 countries. **(A)** Total number; **(B)** per million people in each country's population; **(C)** percentage to women. Based on Ivie and Guo (2006) which says "To be included, countries had to provide appropriate data from reliable statistical agencies".

> will determine what kind of country America will leave to future generations. A decision to compete will require a renewed commitment to enhancing the four essential elements of American innovation: human capital, knowledge capital, an ecosystem that promotes innovation, and financial capital."

These reports present the workforce situation. Next we consider what actions they recommend be taken to change things.

Remedies

While the studies discussed above present the issues with the workforce demographics, their recommendations also suggest remedies. Some issues need the attention of the Federal Government (hence could take some time), but there are also local actions that small groups or even individuals could take.

Report recommendations

Each NASEM study presents multiple recommendations in their reports (usually lengthy). We highlight here some of the recommendations related to workforce issues. First we consider the NASEM Decadal surveys in space sciences.

The SSP2013 recommendations were primarily focused on research but they also recommended further hands-on spaceflight experience (through sub-orbital flights and Cubesats), financial support for graduate students and expanding summer schools. The survey committee recommended implementation of a new, integrated, multiagency initiative (*DRIVE—Diversify, Realize, Integrate, Venture, Educate*) to develop more fully and use more effectively the many experimental and theoretical assets at NASA, NSF, and other agencies. The Educate component entails *Educate, Empower, and Inspire the Next-Generation of Space Researchers*. To date there have been 9 Step 1 funded DRIVE projects that were down-selected to 3 currently-funded DRIVE projects.

Much of solar and space physics involves physics of plasmas. The community of plasma scientists in the US carried out a decadal survey that primarily addresses issues of funding and organization of research but they also recognize the need for enhancing education and diversity of their workforce (*Plasma Science: Enabling Technology, Sustainability, Security, and Exploration*, National Academies of Sciences, Engineering, and Medicine, 2021):

> Recommendation: Federal agencies (e.g., DOE, NSF, NASA, DoD) should structure funding to support undergraduate and graduate educational, training, and research opportunities—including faculty—and encourage and enable access to plasma physics for diverse populations.

The Astro2021 report contained a substantial component on what they called Foundations of the Profession, including seven recommendations related to education and enhancing workforce diversity and climate, several of which gave suggested funding levels. These recommendations are to fund programs to diversify faculty and the research workforce, train undergraduate, graduate students and post-docs, as well as systematically gather demographic data and ensure that relevant organizations have policies that address harassment and discrimination. We highlight the following recommendation for which they recommend funding of $1M each by NSF, NASA and DOE:

> Recommendation: NSF, NASA, and DOE should implement undergraduate and graduate "traineeship" funding. . . . to incentivize department/institution-level commitment to professional workforce development, and prioritize interdisciplinary training, diversity, and preparation for a variety of career outcomes.

The Planet2023 report included a chapter on the State of the Profession which also gave seven recommendations for how demographics and climate of the profession should be improved. While the Planet2023 recommendations did not include specific funding levels, the report did point out the reduction in NASA funding to the extended community for outreach activities:

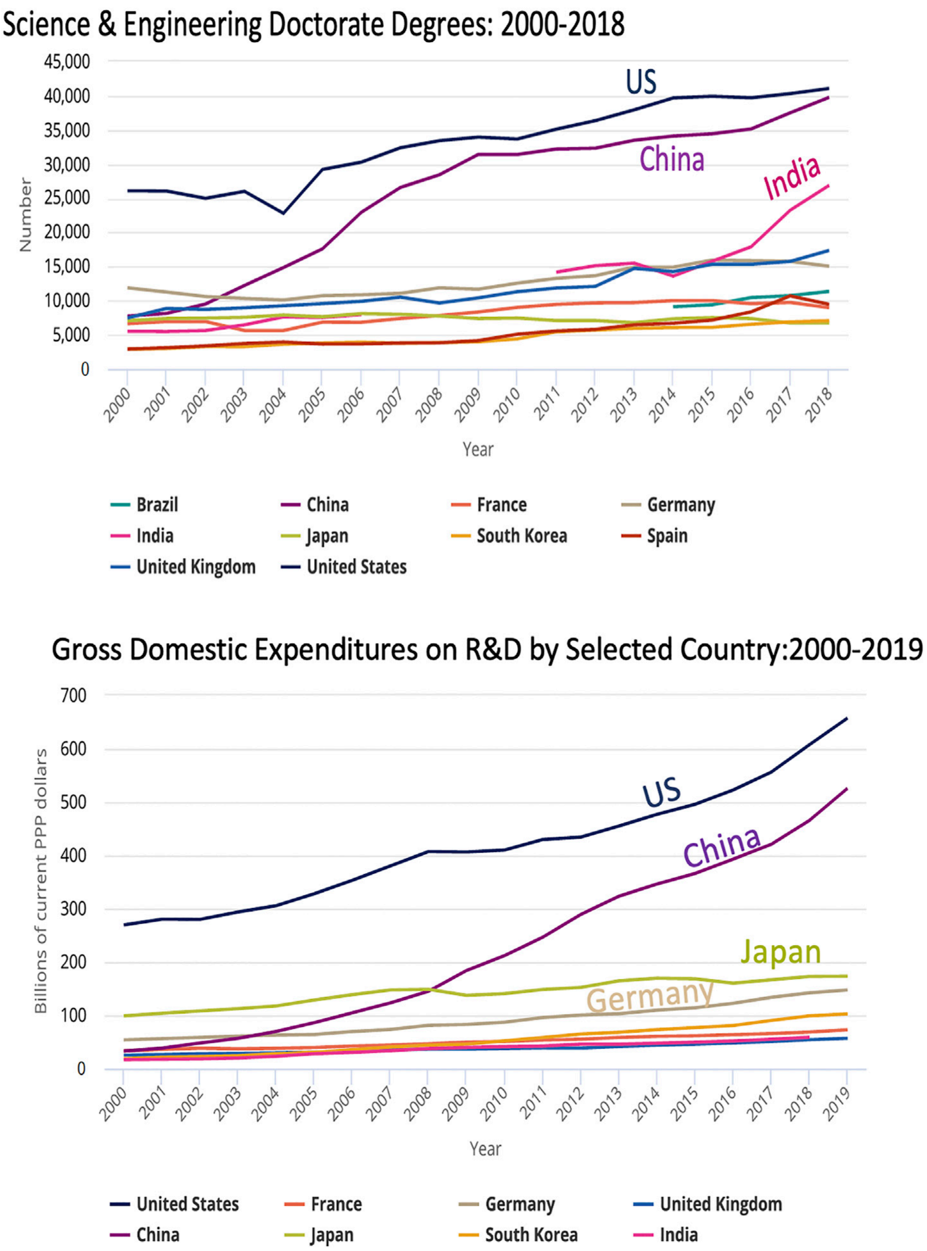

FIGURE 9
Top: Number of science and engineering degrees awarded to 10 countries. Bottom: Gross expenditures on science and engineering RandD. From National Science Board (2022).

While there have been benefits to centralizing public engagement in NASA's Science Activation Program Initiatives (Erickson, 2021), education and public outreach and engagement activities by members of the community have been left unfunded. Engaging URCs at the pinch point of high school to college and providing support systems (including introductory courses) to encourage and retain them along the path of Planetary Science and Astrobiology is going to be essential to create and grow a diverse community. For example, the opportunity to propose outreach activities as an optional extension to funded RandA grants would allow grantees to make a positive impact on community diversity and inclusion activities.

Recommendation: NASA's Planetary Science Division should regularly evaluate programs that enhance participation of students and faculty from URC's; fellowship programs that facilitate engagement of NASA funded planetary scientists and astrobiologists with faculty at URC institutions; and mechanisms for supporting education and outreach as an integral part of research *via*, e.g., the inclusion of outreach activities as optional add-ons to RandA grants, or as a requirement for missions or cooperative agreements.

The National Academies of Sciences, Engineering, and Medicine, 2022a study was charged with addressing the issue of diversity of the leadership of space missions but realized that considerable effort needs to be put into early career stages. Here are a couple (of 15) recommendations that support early involvement in missions:

> RECOMMENDATION 11: To engage and train diverse teams at all stages of professional talent development, NASA should offer mission-related research, mentorship, and training opportunities—ideally, integrated into actual NASA missions—through colleges/universities as well as NASA centers, that should start as early as first-year undergraduates and graduate students (e.g., internships), and extend to the ranks of postdocs (e.g., fellowships), and established scientists (e.g., participating scientists) as well as STEM initiatives centered on DEIA:

> RECOMMENDATION 14: In order to ensure a vibrant, next-generation pool of excellent and diverse talent for leadership in competed space missions, NASA Science Mission Directorate, in collaboration with the Office of STEM Engagement, should provide consistent and adequate funding for STEM initiatives that are explicitly centered on diversity, equity, inclusion, and accessibility, address recruitment and retention challenges in the Earth and space sciences, and support and expand opportunities for individuals from underrepresented groups. These investments should reflect a pathways approach spanning the academic and career continuum from post-secondary through post-PhD years in order to establish flexible and robust education-to-career trajectories into the Earth and space sciences workforce, and ultimately into principal investigator–led missions. A systematic process should also be in place to document measurable impacts of these investments.

In parallel with the National Academies of Sciences, Engineering, and Medicine, 2022a study of mission leadership, NASA commissioned a study of *Foundations of a Healthy and Vital Research Community for NASA Science* (hereafter National Academies of Sciences, Engineering, and Medicine, 2022b) that looked into ways NASA could evaluate the impact of their space science programs on the research community. The National Academies of Sciences, Engineering, and Medicine, 2022b's first recommendation is to gather key data to track trends in who and where gets funded:

> Recommendation: NASA's Science Mission Directorate should collect key data and trends representative of the research solicitation process and quality of the research produced by the science community. Key indicators and/or efforts.

– *Metrics of participation (center, type of institution, specific institutions, partnership);*
– *Metrics of innovativeness and research pedigree (completeness of topics, novelty). The assessment of the quality of research and science results is likely best handled by periodic peer review;*
– *Review of peer review effectiveness and data sharing of other division-unique initiatives;*
– *A dashboard that tracks the multi-objective nature of driving science while incentivizing and supporting change; and*
– *Trends that capture the ratio of basic to applied research funding and foundational investment as defined in decadal recommendations.*

The final recommendation involved supporting mentoring programs working with MSIs as well as with professional organizations:

> Recommendation: NASA's Science Mission Directorate (SMD) should develop a Mentor-Protégé Program for Minority Serving Institutions, including Historically Black Colleges and Universities, Hispanic Serving Institutions, Tribal Colleges and Universities, Asian American and Pacific Islander Serving Institutions, Alaska Native and Native Hawaiian Institutions, Native American Serving Non-Tribal Institutions, Predominantly Black Institutions, etc., to help them train and develop principal investigators and researchers. In addition, SMD should continue to work closely with outside professional societies—for example, the American Physical Society, the American Astronomical Society, the American Geophysical Union, etc., in development and expansion of mentoring programs. This will enable NASA to collect data and engage in longitudinal tracking of its research communities.

The National Academies' Institute of Medicine 2007 report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* presents a bold target for enhancing the US STEM workforce as a whole and recommend these 3 actions:

> Action A-1: Annually recruit 10,000 science and mathematics teachers by awarding 4-year scholarships and thereby educating 10 million minds.

> Action A-2: Strengthen the skills of 250,000 teachers through training and education programs at summer institutes, in master's programs, and in Advanced Placement (AP) and International Baccalaureate (IB) training programs.

> Action A-3: Enlarge the pipeline of students who are prepared to enter college and graduate with a degree in science, engineering, or mathematics by increasing the number of students who pass AP and IB science and mathematics courses.

While these actions may seem expensive, the report shows that such actions are key for the US economy. The 2020 *Perils of Complacency* report follows up:

> "The recommendations in the 2007 NASEM's Gathering Storm report pertaining to pre-K–12 education should be implemented, including creating each year 10,000 federally funded four-year scholarships in STEM fields to be competitively awarded to U.S. citizens in exchange for a commitment to teach STEM in a public school for at least five years following graduation."

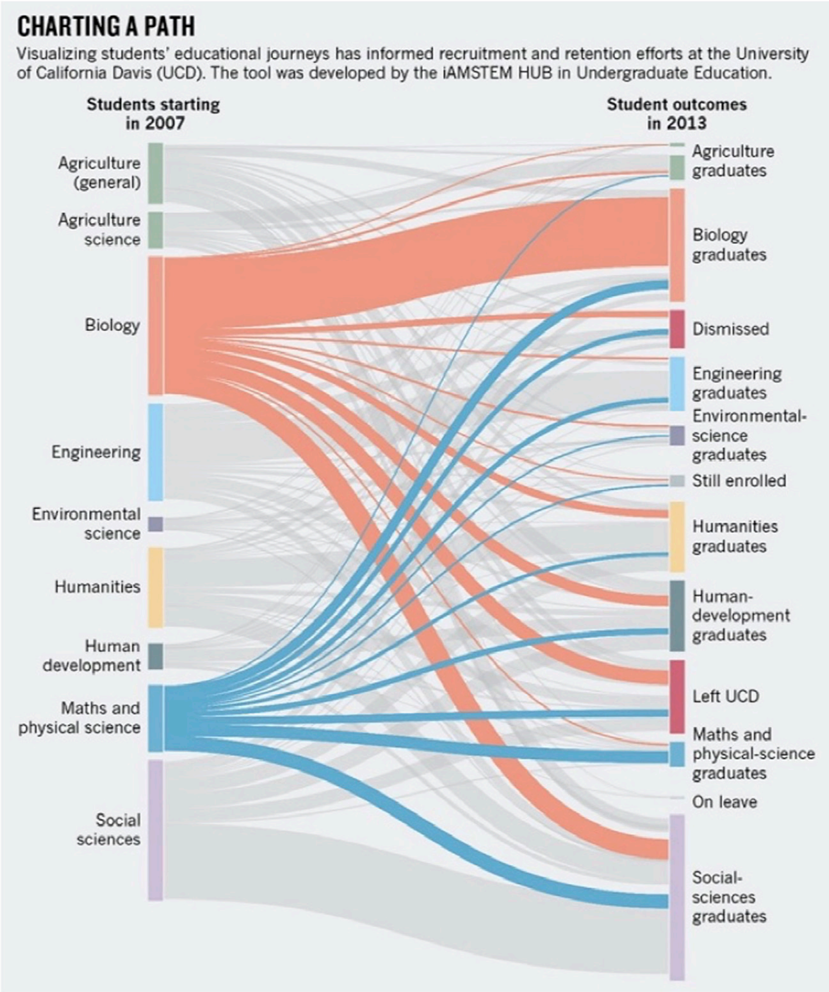

FIGURE 10
Results from a study of undergraduate degree outcomes *versus* incoming student interests, by field. From Bradforth et al. (2015).

Enough of these high-level viewpoints, what can we do to fix the problems locally?

Think global, act local: Undergraduate

To address the main factors that drive students to switch out of STEM majors (listed above), strategies need to be made at the departmental or institutional level. Bradforth et al. (2015) set out in a 3-page *Nature* some strategies from the bottom-up (for faculty) to top-down (for institutions) to enhance science education. We reproduce in Figure 10 their graphic (called a Sankey diagram) that illustrates for the University of California Davis (UCD) the flow of students from the subjects they choose on entry to their outcomes 6 years later. In contrast to other STEM disciplines like biology or social sciences, physical sciences were loosing ~90% of students arriving at UCD with an interest in those fields (2007–2013). Drawing on Bradforth et al. (2015), the TALR book, and personal experience, here are a some strategies.

- Regularly repeat to class and individual students "You can do this. We will help you pass the class—that's the most important thing—so you can do what you want in your career".
- In the classroom, focus on the students—what are they thinking? This might draw attention away from "How can I deliver as much as possible as quickly as possible".
- Training in effective teaching techniques:

1) Plug into teacher training provided by the local institution;
2) Develop a group of fellow teachers to share experiences and ideas;
3) bring in experts in Discipline-Based Education Research to give seminars;
4) Apply data tools to track when students switch vs persist (like Figure 10). Work with education or sociology departments to survey students on why they persist vs switch.

- Get the department to do a self-study to address:

1) Do we have introductory "weed-out" classes? If so, what is the goal? How do we change?

2) Could we address the impact of "grading on a curve" with other methods? Make introductory classes pass-fail?
3) Discuss how teaching is evaluated in faculty careers and ways to improve;
4) Consider hiring teaching faculty or instructors to focus on bringing evidence-based techniques to teaching the introductory classes (leaving research-focused faculty to teach the upper division classes);
5) Team with education department to make combined science + education degrees.
   - Set up study areas that are friendly, safe and open in the evening (perhaps even 24–7) near the student housing, with comfortable chairs, whiteboards, coffee and music. Pay upper-division majors to be informal mentors, helping students persist through their introductory classes.

If you are interested in researching how to improve undergraduate education in STEM, there's an NSF program called Improving Undergraduate STEM Education (IUSE) under the Directorate for STEM Education which

> "Supports projects to improve STEM teaching and learning for undergraduate students, including studying what works and for whom and how to transform institutions to adopt successful practices in STEM education."

This could be an opportunity to collaborate with a local group at an education or science department with faculty and/or researchers who are involved in education research.

Undergraduate research opportunities

The 2011 USSAP workforce survey showed "a steady increase in the proportion of undergraduate students participating in scientific research outside class assignments, with over three-fourths of the recent (2000+) bachelor's degree recipients report having done so" (White et al., 2011a). Undergraduate research experiences comprise traditional summer REUs (for groups of students) as well as individual projects, and are shown to enhance retention of STEM majors, particularly URM students (e.g., Russell et al., 2007). The National Academies of Sciences, Engineering, and Medicine, 2022a report made a finding that:

> "*Decades of educational research suggest that early and ongoing experiences with authentic research—experiences that engage students not only in learning about but actually doing research—is key to retaining students generally and URM students specifically.*"

All three Decadal Surveys made similar findings. While NASA and NSF do fund summer REU programs (and institutions are encouraged to apply, perhaps teaming with nearby MSIs or community colleges), there is also great value in part-time research projects during the semester. Solar and Space Physics researchers are encouraged, either individually or as a coalition of colleagues, to seek support (e.g., institutional or a grant supplement) to involve undergraduates in their research, perhaps forming a collaboration with a local college. Indeed, such efforts do take time away from one's own research, and institutions need to recognize the value of researchers getting involved in mentoring students doing authentic research.

Think global, act local: Graduate

Much less attention has been paid to graduate education, maybe because it is perceived to be less formal and the nature of a student's graduate work is "up to the adviser". But some relatively recent studies are worth reading. First, there are a couple books by Julie Posselt (2016, 2020) about the graduate admissions process. A major issue is that it is not straightforward to determine what are best predictors of success in graduate school. Several studies (including the Decadal Surveys; Posselt, 2014; Posselt, 2016; Posselt et al., 2017) have described how GRE scores are not reliable, particularly in developing a diverse population where other metrics are more effective. Quoting from Posselt's 2016 book:

> "*For example, the Fisk-Vanderbilt Master's-to-PhD Bridge Program, designed to provide underrepresented minority (URM) students a pathway to doctoral studies, added a question to its selection process to assess the applicants' understanding of their own grit and resilience. Since 2004, the program has demonstrated positive results, with 81 percent of those entering the program having gone on to enter doctoral programs.*"

Posselt's 2020 book summarizes the message on graduate programs in this succinct list of actions.

Recruitment

- Ensure online presence communicates commitment to diversity, equity, inclusion
- Engage with MSIs
- Attend to cues sent at campus-visit weekend
- Timely responses to email inquiries from prospective students
- Develop a Bridge Program
- Recruit undergraduates directly from their institution as appropriate
- Pursue diversity fellowships
- Coordinate with graduate school outreach and recruitment
- Create a climate in which current students gladly serve as ambassadors

Admissions

- Downplay or eliminate GRE
- Fine-grained read of transcript (not use of cumulative GPA)
- Value research experience
- Intentionally assess non-cognitive competencies
- Emphasize potential over absolute achievements
- Contextualize achievements
- Revisit committee composition
- Discuss meanings of criteria to check misperceptions
- Develop, refine, and use rubric to systematize valuation
- Define merit in relation to what makes program distinctive

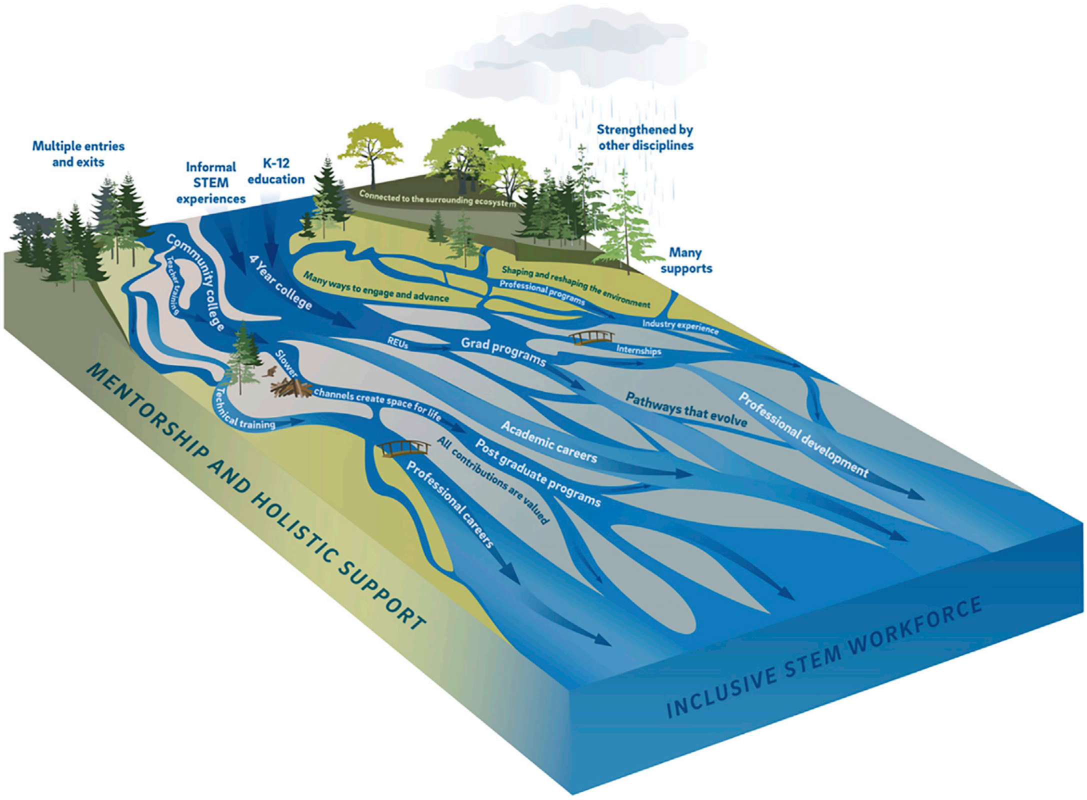

FIGURE 11
A braided river system illustrates a new, holistic STEM workforce career development model. Credit: Jennifer Matthews. From Batchelor et al. (2021).

Mentoring and Support

- Individual development plans
- Develop a lab manual
- Attend to quality of relationships
- Empower staff
- Same-identity faculty available for mentoring, even if not formal advising.
- Support student organizations
- Include students in faculty decision-making
- Appoint ombudsperson or means to report harassment, bias, and/or assault
- Encourage multiple mentors
- Make support and resources for mental health explicit

Creating Conditions Conducive to Equity

- Attend to social relevance of science
- Coordinate with university and disciplinary leaders, to leverage resources
- Create processes that support reform
- Shift from diversity champions to collective engagement
- Critical mass of women faculty and faculty of color
- Track program-level data, disaggregated by race/ethnicity and gender
- Empower a department diversity, equity, or inclusion committee

A second useful reference is the National Academies of Sciences, Engineering, and Medicine, 2018 study of *Graduate STEM Education for the 21st Century* which describes an ideal path through graduate school. The report then calls for systematic change from the top level of federal agencies down through institutions, departments, faculty, to the graduate students. Here are a couple notable recommendations, first addressing the need to regularly evaluate and modify programs:

> RECOMMENDATION 3.6—A Dynamic Graduate STEM Education System: The STEM education system should develop the capabilities to adjust dynamically to continuing changes in the nature of science and engineering activity and of STEM careers. This includes mechanisms to detect and anticipate such changes, experiment with innovative approaches, implement appropriate educational methods, and support institutional mechanisms on a larger scale.

- Faculty and graduate departments and programs should periodically review and modify curricula, dissertation requirements, and capstone projects to ensure timeliness and alignment with the ways relevant work is conducted and provide students with opportunities to work in teams that promote multidisciplinary learning.
- Professional societies and non-profit organizations should convene and lead discussions with graduate programs, employers, and other stakeholders and disseminate innovative approaches.
- Federal and state funding agencies, professional societies, and private foundations that support or conduct education

research should support studies on how different STEM disciplines can integrate the changing scientific enterprise into graduate education programs and curricula.
- Graduate students should learn how to apply their expertise in a variety of professional contexts and seek guidance from faculty, research mentors, and advisors on strategies to gain work-related experience while enrolled in graduate school.

Another recommendation is to consider how graduate programs could improve the research process:

> RECOMMENDATION 5.3—Structure of Doctoral Research Activities: Curricula and research projects, team projects, and dissertations should be designed to reflect the state of the art in the ways STEM research and education are conducted.

- Universities, professional societies, and higher education associations should take the lead in establishing criteria and updating characteristics of the doctoral research project and dissertation preparation and format.
- Students should seek opportunities to work in cross-disciplinary and cross-sector teams during their graduate education and *via* extracurricular activities and be incentivized by their departments and faculty advisors to do so.
- Graduate programs and faculty should encourage and facilitate the development of student teams within and across disciplines.

Three of the suggested actions for graduate students seem particularly valuable.

- Seek multiple mentors to meet their varied academic and career needs, such as information about potential career paths and employers.
- Learn how to apply their expertise in a variety of professional contexts and seek guidance from faculty, research mentors, and advisors on strategies to gain work-related experience while enrolled in graduate school.
- Engage in group activities and experiences outside of traditional academic settings to increase feelings of inclusion and to normalize feelings associated with negative phenomena, such as imposter syndrome, that can reduce productivity and success in the training experience and extend time to degree.

Finally, we encourage departments to develop online resources for both current students as well as recruitment of future graduate students. An excellent example is found at the University of Iowa (incidentally, the department of space physics pioneer James Van Allen) where the website has several links to resources providing advice to students (https://physics.uiowa.edu/graduate/advising).

Career development along braided pathways

Careers in STEM—and Solar and Space Physics is no exception—are complicated. Contrary to common folklore, few take a direct path from high school to university UG to grad school to post-doc to faculty or permanent jobs. Most weave a path that involves bends, turns, side loops—as illustrated in Figure 11 (from Batchelor et al., 2021). Each person must find what works for themself. Institutions need to recognize the damage of stereotyping career paths and assist people along their different pathways.

The need for training and mentoring all along the braided pathways of careers in the space sciences was emphasized in the National Academies of Sciences, Engineering, and Medicine, 2022a report. The National Academies of Sciences, Engineering, and Medicine, 2022a focuses on training of potential PIs of competed missions:

> RECOMMENDATION 12: Principal investigator (PI)-led missions present opportunities for aspiring PIs to gain invaluable experiences. NASA should expand resources (e.g., instructional materials, seminars, workshops) for aspiring PIs to gain leadership experience and connect with individuals with mission experience for mentorship opportunities. This may include.

- Integrating aspiring PIs as mentees in roles on mission teams, including the higher leadership positions. This could be achieved by including developmental positions in all missions (i.e., competed, non-competed, and instrument investigations), which may require increasing the PI-managed costs.
- Encouraging aspiring PIs to pursue entry points to mission leadership, such as proposing to smaller, low-cost mission opportunities (e.g., suborbital, SmallSats and CubeSats, instrument development, and hosted payloads).
- Expanding structured networking opportunities at relevant disciplinary conferences such as meet-and-greets where aspiring PIs can connect with collaborators and meet existing PIs, and participate in presentations and question and answer sessions led by NASA personnel about the proposal process.

. . . but similar advice applies throughout the space sciences—in research areas (e.g., data analysis, modeling, theory) as we as the more operational side (e.g., space weather prediction). Summer schools, workshops and conferences are vital opportunities to meet broader communities of scientists with various backgrounds, to learn about different fields, approaches and careers, and to tap into resources provided by professional organizations (such as APS, AGU, AAS). The larger conferences usually have booths where funding agencies display their programs, where you can ask the staff about opportunities such as post-doc, early-career, guest-investigator or participating scientist grants as well as find out about career opportunities at these agencies. Perhaps the simplest advice is to keep an open mind about potential careers, seek advice broadly, explore options, assess what extra skills are needed, and persist over bumps in the path.

Conclusions

We have presented the demographics data for the space physics workforce which we compared with other space sciences fields. Since the biggest change in demographics occurs in the high-school to college period, we focused on the early stages of college, and drew some lessons from looking beyond the US. We reviewed some of the studies from the National Academies, pulling out some relevant recommendations. Finally, we considered the actions that could be made locally by an institution or individually to enhance and diversify the career pathway through the space sciences. Our conclusions are summarized.

1) Space physics is pretty white and male. The percentage of women has been slowly improving but racial/ethnic diversity remains very small. Such demographics are similar to the physics profession overall.
2. The "pinch point" seems to be between high school and first year of college—when the percentage involvement of women in physics courses drops from 47% to ~20%. The percentage of physics degrees awarded to Hispanic Americans has been rising for the past decade to 10% (still below the national population) while the percentage of physics degrees awarded to Black/African Americans remains ~4%.
3. Studies of STEM entry-level college/university courses show common issues (e.g., poor teaching, "weed-out" culture, lack of support) with freshman math and physics classes for both those who switch and those who persist, across gender and race/ethnicity.
4. Concerted efforts have been made at various institutions across the country to improve retention of students in freshman STEM courses. These range from small, local efforts to improve teaching (e.g., more interactive classes, transparent and fair grading systems, student support, socially-relevant applications, etc.) to national sponsorship of internships, REU programs, bridge programs, teacher-training programs, etc. It is important to learn which programs are the most effective at promoting diversity and retention of STEM students.
5. Research suggests that early and ongoing experience with authentic research is key to retaining students generally and URM students specifically. Institutions are encouraged to develop research experience for undergraduates, during the semester as well as over the summer months.
6. For the past ~30 years roughly half of Physics PhDs in the US have been awarded to people who are born outside the US. While this has boosted the percentage of women getting Physics PhDs (since many other countries award a larger percentage of their physics bachelor's degrees to women) it means the STEM research and industry relies on imported talent which may not be such a secure source in the future. Besides, the US should provide education and career opportunities for all Americans.
7. In a national effort to enhance STEM careers, federal agencies and academic institutions need to a) gather data on the evolving STEM workforce; b) improve freshman math and physics classes; c) train more physics high-school teachers by providing combined physics + education degrees. Better pay for high school teachers would likely also help.
8. Attention is needed in improving and evolving graduate programs (with non-academic career advice, mentorship, multi-disciplinary experiences, involvement in missions, etc.), continued through post-doc and early-career support.

Marcia McNutt, President of the National Academy of Sciences, recently issued an editorial in *Science* magazine entitled "*Higher Education For All*", urging the nation to provide higher education for everyone in the US (McNutt, 2022):

> "It is time for educators to ask which innovations can be introduced and, importantly, sustained, to expand the accessibility of higher education to meet the needs of the 21st century."

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

The author declares 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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The importance of local long-duration STEM mentorship as a global mechanism for increasing diversity at all levels of education

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We begin with a brief review of the progress being made by the professional space physics community to increase diversity and inclusion. These efforts have been primarily centered on overcoming barriers that have inhibited existing underrepresented minority space physics professionals from being successful at all levels of academic, mission, and administrative achievement. While we find these remediations to be essential, we must recognize that our ability to achieve a diverse professional workforce representative of the US population depends on achieving a diverse population of researchers entering the field. That means the greatest gains can only be achieved by actions that reach into the educational system. We identify and discuss possible issues within the traditional formal education and developmental environment of young inquiring minds, including gaps in resources, the pressure to bring in income during secondary school and graduate school matriculation, and the cultural biases against research careers. We highlight the importance of local mentorship and age-appropriate research-like activities within all levels of education, including Kindergarten through bachelor's and advanced degree programs, as a means of overcoming barriers to becoming a respected contributing member of the space physics research community. We note these issues extend beyond space physics into all STEM fields. These activities can provide road maps into research careers, practice age-appropriate skills, and provide an avenue for current researchers to become mentors. Specifically, we advocate the development of a formal program of professional chapters for colleges and age-appropriate research-oriented programs for K-12 schools and encourage strong collaborative affiliations with other professional societies. At the core of this is the development and implementation of informed, persistent mentoring.

KEYWORDS

mentoring, diversity, inclusion, K-12 stem, higher education, attrition, leaky pipeline, braided river

1 Introduction

Significant strides are being made within the space physics workforce to improve diversity and inclusion (D&I). Gannon and Lugaz (2020) summarize a NOAA Space Weather End User panel discussion at the 2019 AGU fall meeting, where attendees discussed progress toward increasing diversity and inclusion in the space weather and space physics communities in the United States. The short article made the case that D&I is receiving broad recognition within the American Geophysical Union (AGU) and NASA, but much is yet to be done. Ford et al. (2018) show progress in bringing young women into these fields; however, persistent preference was shown for experienced male scientists for invited oral AGU fall meeting presentations when primary session organizers are male. Basic representation in these fields was shown to be profoundly lacking for African Americans, Hispanics/Latinos, Native Americans, and Pacific Islanders, who used the results of Ford et al. (2019) based on abstract submissions from 2014–2017. These minority ethnic and racial groups comprised only 7.7% of the total submissions, even though they comprise 31% of the United States population.

AGU's Space Physics and Aeronomy section has also taken an active role in addressing D&I. Diversity involving gender, geography, and career-stage has and is being sought for committees, such as the Fellows Committee, as reported by Gannon and Lugaz (2020). Jaynes et al. (2019) report on the work of Dr. Elizabeth MacDonald of NASA Goddard Space Flight Center who, in the fall of 2017, organized the Nomination Task Force within AGU's SPA section to create nomination packages for individuals from underrepresented groups. Three of the six nominated individuals received prestigious awards recognizing their outstanding achievements. One of the effects of implicit bias has previously led to a long-time lack of recognition through professional awards. Keesee et al. (2019) discuss progress and continuing shortfall in D&I through professional recognition by awards and prizes.

Similarly, much effort is ongoing within NASA Headquarters and at all field centers to advance D&I for recognized benefit across all organizational elements captured in the FY 2022–26 NASA Strategic Plan for Diversity, Equity, Inclusion, and Accessibility (DEIA). The effort is strongly represented in the public statement by NASA's Administrator Bill Nelson (2022): "We fully embrace DEIA as a strategic enabler of our safety and mission assurance. Our commonalities unite us as a team, and our differences strengthen our capabilities, including our talent, skills, knowledge, experience, innovation, perspectives, and ideas that optimize performance and mitigate groupthink, optimism and confirmation bias, complacency, normalization of deviance, and risk." Moreover, recent efforts have been made to evaluate DEIA in NASA's Space Mission teams and their Principal Investigators (PI) (NASEM, 2022).

The space physics community has shown a clear commitment toward advancing the goals of D&I and that there continue to exist systemic barriers that discourage advancement. It is vital that our profession continues to minimize the attrition of young researchers by limiting bias in proposal reviews, improving opportunities for professional society positions of responsibility, ensuring more opportunities for prominence at conferences, and removing bias in promotion and tenure. However, it is essential to recognize that our ability to achieve a genuinely diverse professional workforce representative of the United States population depends on maintaining a diverse set of researchers entering the field (Funk et al., 2021).

Estrada et al. (2011) and other works, discussed in Section 2, Section 3, Section 4 find that the broader STEM community falls short of nurturing young minds, failing to enable them to seek betterment, equity and positive reinforcement at all educational levels. While much of that work is narrowly focused on age ranges or specific types of institutions, some published research and active remediation efforts are immediately applicable for consideration. The lost youth from STEM education pathways has become known by the concept of a "leaky pipeline" (Estrada et al., 2011), where a much larger underrepresented population cannot traverse the hardships of socioeconomic and educational environments required to attain researcher status. They are lost from the educational "pipeline" at each step because their parents tell them, "that's not for people like us." They are lost because they visit a campus and do not see anyone like themselves or how they can fit in. They are lost because they have no STEM role model, no way to build self-efficacy, or sense of belonging within the STEM community (Estrada et al., 2011). Most recently Batchelor et al. (2021) has introduced the concept of "braided river" in recognition of the need to dismantle the overly simplistic imagery of a pipeline to instead embrace the many "on-ramps, pathways, and career pivots that real life induces" that the braided river model with its "numerous interwoven and changeable channels capture." The braided river concept fosters flexible and adaptable pathways as each person seeks their way to a STEM career, perhaps through a mentee-mentor relationship.

Both models begin after high school when students traditionally are first faced with making choices for their educational future. We find that the attitudes of many children toward potentially rich STEM careers are lost much earlier and that is where we begin our discussion in Section 2 to establish how children can remain in the braided river through mentoring. We highlight six key strategies that help overcome challenges. Section 3 is all about mentoring as a professionally learned skill that necessarily evolves with its application and a changing society. Section 4 discusses the professional organization's critical role. We conclude by encouraging professional researchers to take steps through their societies to help build an equitable and rich multicultural research environment.

2 The developmental significance and persistent fragility of self-efficacy

Eccles et al. (1983) developed an expectancy-value model of achievement-related choices, as applied to gender differences, in which students' decision on whether or not to continue in the STEM pipeline is determined by their expectations for succession and the relative importance they gave to the available options. Their expectations for success were dependent on their self-beliefs about their ability to succeed, referred to as self-efficacy. Eccles (2009) describes the relative importance to be represented by the subjective task value (STV), the importance of taking mathematics and science course in terms of four elements: (a) the utility value as related to the student's future goals, (b) the intrinsic value, (c) the attainment value (the consistency of mathematics and science with the student's identity), and (d) the cost, such as time taken away from other activities or the negative responses of the student's peers. Each individual assesses their STV based on what they gain from their culture, socializers, and experiences.

Andersen and Thomas (2013) apply the STV model (Eccles, 1983; Eccles et al., 2009) to investigate the plans of ninth-grade underrepresented minority (URM) students. They base their work on the assumption that all students stay in the STEM pipeline by default before high school. Their expectation was those students traverse different coursework or career preparation paths based on perceived ability, motivation, and opportunity, suggesting that this is the critical time for understanding the factors that affect students' plans to persist in STEM. They found that mathematics and science self-efficacy were not significant predictors of persistence plans, apparently because of perceived barriers to opportunities compared to those of white students. Andersen and Thomas (2013) mention the influence of deficits students face in taking advanced preparatory mathematics and science coursework at low-socioeconomic status high schools but acknowledge that it is often attributed to disinterest (Thompson and Lewis, 2005).

However, what appears as disinterest may have become an implanted self-belief or acceptance of the socioeconomic stereotype expressed by parents, peers, or even teachers (Ambady et al., 2001). Ambady et al. (2001) conducted a study involving elementary and middle school children where they activated positive and negative stereotypes for cognitive performance in kindergarten-grade 2, grades 3–5, and 6–8. They found that positive and negative self-relevant stereotypes can affect the performance of even very young children. Asian-American girls in lower elementary schools performed significantly worse than a control when their gender identity was activated and performed significantly better than the control when their ethnic identity was activated. The same-age Asian-American boys performed significantly better when both gender and ethnic identities were activated, also in accordance with stereotypes. The same was true for these groups in middle schools. Ambady et al. (2001) state that both younger and older girls and boys possessing an alternative identity associated with positive stereotypes, such as in math and science, might buffer girls from the negative stereotypes associated with their gender. The same susceptibility and protective buffering ought to be anticipated regarding other common negative stereotypes involving ethnicity, race, religion, or socioeconomic status.

The Ambady et al. (2001) study builds on that of Steele (1997), who more broadly discusses the achievement barriers women and African Americans face in school. These groups are usually identified with socioeconomic domains with negative stereotypes that, when activated, dramatically depress their academic performance. Steele (1997) reported studies from the 1980s–1990s showing that this stereotype threat had led to a crisis for African Americans. By the sixth grade, they had fallen two grade levels behind their white counterparts with whom they had been evenly matched when they started school. Steele (1997) reports a study showing virtually no differences between boys' and girls' performance in standardized math tests through elementary and middle school but trends toward a steady divergence of men over women in high school and beyond, with women leaving math-oriented fields at more than twice the rate as men.

Steele (1997) suggests what they call the "wise" strategy for supporting and guiding students who are stereotype threatened, listing:

1. "Optimistic teacher-student relationships." While stigmatized students worry that other students will doubt their abilities, the authority of potential-affirming adult relationships in a mentoring program provides critical motivating feedback and optimism about their potential.
2. "Challenge over remediation. Giving challenging work to students conveys respect for their potential and shows them they are not regarded through the lens of an ability-demeaning stereotype."
3. "Stressing the expandability of intelligence." Repeatedly advocating the expandability of intelligence to elementary school tutees to significantly improve grades counters the fixed-limitation ability stereotype inherent in one's group.
4. "Affirming domain belongingness. Negative-ability stereotypes raise the threat that one does not belong in the domain." Direct affirmation of their belongingness in the domain is important, and to base this affirmation on the student's intellectual potential.
5. "Valuing multiple perspectives." Explicitly value a variety of approaches to academic substance and the larger academic culture. "Making such a value public tells the stereotype-threatened student that this is an environment in which the stereotype is less likely to be used."
6. "Role models. People from the stereotype-threatened group who have been successful in the domain carry the message that stereotype threat is not an insurmountable barrier."

The generalized mentoring actions are noted in the summaries above and discussed in length by Steele (1997). A mentor, for example, is an authority figure for the mentee so by expressing optimism about the mentee's performance and ability to solve challenging problems the mentor has implemented the first two of the Wise strategies. By consistently showing the mentee respect, by challenging the mentee with increasingly more difficult problems, and listening to their ideas for solutions the mentee is implementing the Wise strategies 3, 4, and 5. By being honest, respectful, consistent, and successful member of the greater STEM community and looking like the mentee a mentor becomes a role model for the mentee and implementer of Wise strategy 6.

3 Sustaining self-efficacy through persistent mentoring

Mentoring is building a focused, intentional relationship between an established community member and someone new to the field. Positive mentoring relationships have been shown to increase the success and retention of students from underrepresented groups and to reduce stress, anxiety, and depression (Hund et al., 2018). A successful mentor is a trusted guide and advocate. In contrast, poor mentoring can lead to increased student stress, attrition, and decreased productivity. Hund et al. (2018) and cited papers also discussed the risk mentors face when they become blind to the power they hold over their mentee.

Hund et al. (2018) conducted a survey where 70% of responding mentors reported they "rarely" mentor poorly, while 39% of all respondents reported poor mentoring "frequently." Of the responding mentors, 69% reported no formal training, and 74% "little" training.

In addition to many available studies, Byars-Winston and Dahlburg (2019), hereafter the Report) declares that "mentorship is a skill that can be developed through intentional and reflective practice and cultural responsiveness." Several institutions have created professional mentor training programs, including through online interactive guides provided by this Committee, which the Report highly recommends.

The Report distills mentoring into two core functions: providing psychosocial support, which includes role modeling, and offering career support, which includes providing challenging work toward skill development. As noted, individualized practices of mentors promote successful extended relationships between mentor and mentee. Psychosocial support may include such things as encouraging problem-solving and active-listening techniques. It may include role modeling involving mentee behavior and professional values. Mentor-mentee interpersonal interactions can allow mentees to see themselves as future academics to the extent that they identify with the mentor. Career guidance can take the form of evaluating the mentee's strengths, weaknesses, and interests. Mentors can help mentees reflect and think critically about their goals, challenge their decisions, and realize their aspirations. Mentors should be trusted to acknowledge the achievements of mentees publicly and be their advocates. A mentor must maintain professional boundaries and ethics, including communication, providing objective feedback, not losing their temper, and respecting their mentee's privacy. Moreover, the mentor and mentee must have a dynamic changing relationship as each needs mature.

Mentoring at the elementary and secondary levels often focuses on the fundamental math and science skills. While mentoring at the undergraduate and graduate levels includes more in-depth discussion and exposure to research and career pathways in STEM fields. The Wildlife Society is one professional organization that is leading the way for students at the college level. They have developed a mentorship program[1], Leadership Institute, Student Development Working Group, and Student Chapters[2]. Lopatto (2007) notes that undergraduates who experience authentic research in the sciences have a positive impact on those pursuing graduate school. NASEM (2022) highlights the importance of mentoring at the graduate student level which is important for the development of diversity in NASA's Space Mission PIs.

1 https://wildlife.org/mentoring/.

2 https://wildlife.org/next-generation/student-benefits/.

4 Mentoring through organizations and professional societies

Barnes et al. (2021) bring attention to the scenario where national societies and "locally-based" institutional undergraduate student chapters provide atmospheres in which underrepresented groups can develop relationships and skills required for academic and professional careers in STEM. These societies and student chapters also combine to contribute to outreach STEM activities. Barnes et al. (2021) state that using underrepresented group (URG) student chapters of professional societies, at the undergraduate level, allows students to become active members of professional organizations while also receiving mentoring, support, and resources (e.g., leadership opportunities, scholarships, internships/jobs, and education opportunities[3]). They allow students to connect with the community directly by contributing student posters at conferences and being part of making a difference locally, for example, through student research internships and STEM outreach. The students also become part of something bigger, a pathway to the scientific world where they can develop leadership and mentorship skills of their own. Student chapters need to be created at primary, intermediate, and secondary levels to aid in slowing loss from the braided river by helping to promote equitable access to resources. The University of New Mexico has a Mentoring Institute which offers an annual conference and training.[4] These go beyond what AGU currently targets connecting professionals with undergraduate and graduate students and Early Career researchers in their Mentoring365 network.[5]

Mentoring can become a skill actively taught and shared as developed and demonstrated. Trained college-age chapter mentors could be incorporated into high school chapter functions. Trained high school chapter mentors could participate in primary and intermediate school chapters. This is ladder mentoring, which could become a new element in this context that would be designed to inspire and provide a supportive space to encourage young students to express their excitement in STEM activities. Trained, young mentors become a role model and consistent, familiar presence with younger mentees while always in the company of a supporting senior certified mentor (the research professional). However it would be implemented in the lower grades (K-12), it would need to be frequent enough to be meaningful but not be an unacceptable burden on those involved. Relatively frequent events for K-12 might become integrated with school science fairs, including sponsorship and judging. Within Regional Student Chapter Associations, Conclaves could be held, like Science Olympiads, which provide STEM field-specific knowledge competitions for junior participants, mentoring by senior professionals, and relationship-building between peers and professionals[6].

There are a lot of ongoing efforts within the STEM community to discuss, highlight, and provide training for D&I (e.g., Lunar Surface Science Workshop, 2022; NASA, 2022). NASA Science Mission Directorate Inclusion Plan Pilot Study requires researchers to specifically address how they will promote and foster inclusion within their teams as a key proposal element. The Planetary Science

3 https://wildlife.org/next-generation/student-benefits/.

4 https://mentor.unm.edu/conference.

5 https://mentoring365.chronus.com/.

6 https://wildlife.org/se-section/about/conclave/.

program, Payloads and Research Investigations on the Surface of the Moon (PRISM) is one of the participating programs (Watkins, Lunar Surface Science Workshop, 2022). More work can be done getting professionals to work on local scales. Moreover, no formal mentoring training currently exists. NASEM (2022) highlights D&I as important for successful teams for NASA Space Missions and their PIs. While formal mentoring training currently exists[7], this training has not become a part of mainstream PhD curriculum and likely needs to become a mandatory element of academic training, as was noted by Reuben (2020), "Scientists are not trained to mentor. That's a problem." Moreover, more work needs to be done getting professionals to work on local scales where large impacts are made.

5 Conclusion

From the beginning, we have established the perspective that fundamental progress toward the meaningful integration of underrepresented members of our society as successfully contributing partners in space physics and other STEM research fields requires our intentional and meaningful involvement in the motivation and self-efficacy of those who would become our partners beginning at a young age. Further, only using persistent and evolving encouragement and training experiences can we anticipate members of historically underrepresented groups to thrive in STEM fields. The scale on which this must occur requires a collective approach, which at a minimum, begins in our professional space physics societies. In truth, it requires strong collaboration and coordination across professional societies to enable a general society-wide awakening of STEM opportunities without socioeconomic borders.

The evidence we have highlighted strongly suggests that the youngest students begin with equal openness to experience everything their world has to offer. They seek to understand who they are, where they belong, and how everything works together. Each step they make will become positive or negative experiences that differentiate their academic expectations. If a students' progress is encouraged, they will build positive self-efficacy in STEM, solidifying the knowledge of potential success should they choose to continue. If a student's progress is discouraged, the opposite occurs, such that self-efficacy devolves, their inability to perform in STEM becomes predetermined, and they become part of the leaky pipeline. It is our perspective that we cannot passively wait and continue as researchers in our field without taking action to mitigate the issues that drive many away from STEM. Here we have discussed mentoring, particularly local long-duration mentoring at the university, and K-12 grades, as one important aspect that space physicists can participate in. Professional training in being an effective mentor can be useful for all, especially for existing mentors without formal training. Mentoring in the K-12 grades is essential to address the leaky pipeline of the STEM workforce. Professional organizations and societies can play an active role in providing mentoring training for professionals and avenues for these professionals to engage students locally with chapters at the university and K-12 grade levels.

Our past efforts to retain young women, African Americans, Hispanics/Latinos, Native Americans, Pacific Islanders, and other under-represented professionals from leaving space physics have come at the end of a leaky pipeline. A much larger population of potentially valuable contributing individuals were lost, not because they failed to have the intrinsic ability or interest, but because they felt out of place in the STEM world. There are D&I professional organizations with missions to provide safe environments for young under-represented students to thrive. Scientific societies are already working with those societies to integrate STEM themes into those environments. These efforts are experiential and mentor based. Our advocacy is for a strategy based within AGU to actively develop and/or promote mentor training in affiliated graduate programs, to include formal mentor rolls for graduate teaching assistants in their department programs. Next to broaden AGU's efforts to, where possible, coordinate with other professional societies to create college STEM chapters. From these chapters to adopt, foster, or create as necessary K-12 activities that routinely inspire, challenge, and guide young minds that seek a future in STEM. This can be a braided river framework that is built from within and sustaining. One where we can individually find worthwhile roles and contribute if we choose, from the local to the national level Eby et al., 2008.

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

SD wrote the initial abstract and authored the concept of the vision for mentoring societies. Also, SD provided much of the literature and contributed to the writing and editing of the text. HH contributed to the writing, editing, and concepts presented. DG authored much of the original text and review of the literature and is the corresponding author.

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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.

7 https://mentor.unm.edu/conference.

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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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Space physics guide to STRIDE: Strategies and tactics for recruiting to improve diversity and excellence

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The space physics research community is not diverse. This is especially true at the senior experience levels, but is even true for our student populations, which are also not matching the demographics of the general public. Striving towards a demographic shift to match the general population promotes equity and inclusion. In addition, diversity increases research productivity. Unfortunately, bias exists, including within the space physics research community, and this negatively impacts hiring practices and perpetuates the demographic mismatch. Yet there are many strategies and tactics that can be adopted to counter this problem. A number of these methods are presented and discussed, specifically those regarding the search process for hiring new research group members. The key methods for achieving an equitable search process are as follows: develop a holistic rubric early, even before the job ad is posted; slow down the downselect from the full applicant pool to the short list of finalists so that the rubric can be carefully applied to each candidate; make the interview process as equitable as possible by considering the ways in which it could be biased; and conduct a fair decision-making process that focuses on the job-relevant criteria and avoids global rankings until the final vote.

KEYWORDS

space physics, equity, DEI, NSF ADVANCE, hiring, demographics

1 Introduction

1.1 Diverse teams lead to better space physics

Research has been conducted to study the effect of homogeneity or diversity within teams. Diversity is defined broadly here: gender and gender expression, race, ethnicity, geography, cultural heritage, sexual orientation, disability, and life experiences, to name a few. The argument for the homogeneous team approach is that, because the members act similarly and come from similar backgrounds, they will "mesh well" and have less conflict and faster decision making. The argument for the diverse team approach is that, because the members come to the group with many different perspectives and life experiences, they will consider problems from a variety of angles and therefore reach better and more creative solutions to problems. Which of these two paradigms is supported by the research?

TABLE 1 AGU space physics section gender information from the 2018 membership demographics report.

	Student	Early career	Mid-career	Experienced	Retired
Aeronomy					
Female	29.4%	28.0%	16.9%	9.3%	2.7%
Male	70.0	71.1	82.1	90.1	97.3
Prefer Not to Answer	0.6	1.0	1.0	0.6	0.0
Magnetospheric Physics					
Female	32.4	26.4	17.5	9.2	3.6
Male	66.8	72.6	81.5	89.8	96.4
Prefer Not to Answer	0.8	1.0	1.0	1.0	0.0
Solar and Heliospheric Physics					
Female	34.9	27.9	19.1	8.5	5.6
Male	64.3	70.9	80.1	90.5	94.4
Prefer Not to Answer	0.8	1.2	0.8	1.0	0.0
Space Physics and Aeronomy					
Female	35.6	29.9	21.1	10.7	5.5
Male	64.2	68.5	78.3	88.3	94.5
Prefer Not to Answer	0.3	1.7	0.7	1.0	0.0

The vast majority of studies conclude that the latter situation—the diverse team—leads to better outcomes (Page, 2008). In fact, nearly a decade ago, a special issue of Scientific American was devoted to this topic, with all papers in it providing strong evidence for diversity as a benefit to the scientific endeavor (Guterl, 2014b). One article in particular from that issue (Medin et al., 2014) summarizes several examples of how diversity leads to better scientific outcomes, as well as counterexamples where a lack of diversity limited the findings. Specifically in space science, Moldwin & Liemohn (2018) conducted a survey of citations to papers published in the Journal of Geophysical Research Space Physics, finding that international teams are more highly cited than those from just one country. In a much more comprehensive assessment of publications across many Earth and space science journals, Lerback et al. (2020) found that citations to an article are, on average, significantly higher when the coauthor team includes researchers from two or more countries. As noted by Greenwald (2017), international teaming helps enable large-scale research projects, allowing for experiments and investigations beyond the scope of any one country.

Team diversity makes good business sense as well. Rock & Grant (2016) present a concise review of studies from the corporate perspective. Hunt et al. (2018) conducted a survey of over a thousand companies, finding that for every measure of economic success, diverse leadership made the companies (on average) better. A similar analysis of business performance was conducted by Herring (2009), finding overwhelming support for diversity as a harbinger of success. Ellison & Mullin (2014) combined performance measures with those of "social capital," finding that firms with homogeneous workforces tend to have higher cohesion but lower productivity. These are only a few examples in favor of diversity from a "business return" perspective.

While the case can be made that productivity and results improve with a diverse workforce, this alone does not have to motivate us into action. Burt et al. (2022) showed that the "business case" for diversity is misaligned with current attitudes of young professionals in both the Earth and space sciences and more broadly across science and engineering, in general. Rather than seeking only the benefits that diversification can yield for (primarily white, male) institutions, many are motivated by their interest in equity and inclusion (Haacker et al., 2022).

1.2 But space physics is not diverse

The field of space physics has a demographics problem. According to the 2018 report of the American Geophysical Union[1] (AGU), it was revealed that the subsections of the Space Physics and Aeronomy (SPA) section are heavily dominated by men, as seen in Table 1. This is not unique to AGU; these numbers are typical across sections of the American Astronomical Society (AAS), according to its 2019 workforce survey report.[2] Note that neither of these surveys asked about non-binary gender identification. Membership statistics by race show an overrepresentation of white people (see Table 2). Sexual orientation data is also shown in Table 2. For comparison, the US

1 The American Geophysical Union 2018 membership demographics survey results are available here: https://www.agu.org/-/media/Files/AGU_Membership_Demographics_2018.pdf

2 The American Astronomical Society 2018 membership demographics survey results are available here: https://aas.org/sites/default/files/2019-10/AAS-Members-Workforce-Survey-final.pdf

TABLE 2 AAS race/ethnicity and sexual orientation information from the 2018 membership demographics report.

Category	Percent	US population
Race and Ethnicity[a]		
White	82%	76%
Asian or Asian American	9	6
Hispanic or Latino	5	18
Black or African American	2	13
American Indian or Alaska Native	1	0.7
Other	2	2.4
Prefer not to respond	4	
Sexual Orientation		
Heterosexual or straight	85%	88.3%
Gay or lesbian	3	3.3
Bisexual	4	4.4
Other	2	4.0
Prefer not to respond	5	

[a]Note that the numbers do not add to 100% because some individuals may be reported in multiple categories.

Census Bureau[3] provides similar percentages, with the population for the country being 50.5% women, respectively, and the breakdown by race/ethnicity and sexual orientation shown in Table 2. The sexual orientation percentages are close to the US population as well as some of the racial numbers, but many race/ethnicity percentages are well below the general population, as is the gender split.

This diversity disparity in the scientific workforce has been recognized in numerous studies and reports. Moldwin & Morrow (2016) presented results from a demographics survey of the community conducted for the last Solar and Space Physics Decadal Strategy report, finding similar results to those in Table 1. Skewed demographics were found within recent space physics conference attendee and speaker lists (Jones and Maute, 2022). James et al. (2019) examined the leadership and award selections for 30 science societies, finding that, over time, representation in lower positions and awards is becoming more equitable but this is not the case for more prestigious positions and awards. While some counterexamples exist, the statistics of the top-most levels of research communities still heavily favor white men. Guterl (2014a) presented a survey of demographics across many scientific disciplines, noting large discrepancies from the general population.

An argument can be made that the demographics disparity is an issue to be solved earlier in the educational path, as women and minority students leave the physical sciences for other career and life options. One of the largest pinch points is in high school; Hodapp and Hazari (2015) noted that the gender participation breakdown in physics classes is 47% women in high school and only 21% women in college. Similarly, Bradforth et al. (2015) found that, at one university, only 10% of entering college students expressing interest in a physical science or math degree eventually get a degree in those fields. Yes, this "leaky pipeline" needs to be remedied, but problems exist within the space physics academic and research community, as well, as is visible by the comparisons to population-level data.

The demographics disparity is seen in funding trends. Bernard & Cooperdock (2018) found that racial disparity in funding rates by programs within the National Science Foundation (NSF) had not improved over the last 40 years, and the follow-on study by Chen et al. (2022) found that the situation regarding NSF funding rates for different racial groups has still not changed. A provocative call for action by Stevens et al. (2021) challenges racial disparities in grant awards by the National Institute of Health.

This demographics inequity is particularly noticeable in leadership positions. Centrella et al. (2019) conducted an analysis of Explorer-class astrophysics mission proposal principal investigators (PIs) to NASA, revealing that 3 of 61 unique PI proposers were female, and only 14% of the membership of the full science teams from the 102 proposals examined were female. That is, women are not being included on PI-led mission teams at the same level as men and therefore not receiving the experiential training to eventually propose their own mission as PI. This survey was followed by another from the National Academies of Science, Engineering, and Medicine (NASEM) of all the PI-led mission proposals to NASA (NASEM, 2022a). Of the 524 proposals to 32 Announcements of Opportunity for PI-led spaceflight hardware projects (from instruments to full missions) across all divisions of the NASA Science Mission Directorate, only 13% were led by a PI inferred to be a woman. These percentages are similar to the right-side

3 The US Census Bureau data can be found here: https://www2.census.gov/programs-surveys/popest/ and a graphical form of the LGBT data here: https://www.census.gov/library/stories/2021/11/census-bureau-survey-explores-sexual-orientation-and-gender-identity.html

columns of Table 1 on gender within the senior ranks of the research community, i.e., highly skewed in favor of men.

1.3 Homogeneity leads to bias

This diversity disparity creates a downwardly-spiraling feedback loop that has consequences for the research community. Specifically, the lack of diversity allows for the unhealthy development of a workplace environment that is negative or even hostile to historically excluded groups, a situation that drives people from the field and dissuades young professionals from entering it. Hurley (2014) noted that gender imbalance in a group setting has negative impacts on how women interact in a scientific discussion. Similarly, Kessel (2022) described her fortunate situation of having good mentors in her career, but often found herself being the only woman in the room. Clancy et al. (2017) detailed gendered and racial harassment for women of color in planetary sciences, Popp et al. (2019) found that women geoscientists experience negative bias at work more than twice as often as men, and a large-scale study confirmed these findings across many scientific research communities (NASEM, 2018). Lerback & Hanson (2017) found that editors of geoscience journals (including space physics) pick too few women as reviewers, thus denying them the career development opportunities from this experience. The AGU SPA section recently had several years with zero or one woman nominated to be an AGU Fellow (Jaynes et al., 2019). Furthermore, scientists in our field too often assume that their anonymous reviewer is male, choosing to use he/him pronouns instead of the broader they/them option (Liemohn, 2022), which can make women feel unwelcome or unrecognized. These are just a few recent studies and anecdotes of bias specifically documented regarding our research community.

Lack of diversity is a widespread problem across science and engineering disciplines. Using a "resume study" in which identical applications–except for the name–were evaluated for postdoctoral positions in physics, Eaton et al. (2020) found statistically significant differences in who was found "hireable." Faculty evaluating CVs exhibited both a gender bias in favor of presumed male candidates and a racial bias in favor of Asian and white candidates; black women and Latinx women and men candidates were rated the lowest. In a similar resume study, Correll et al. (2007) found that changing both the perceived gender of the applicant as well as the parental status with the inclusion (or exclusion) of a line about active involvement in a parent-teacher organization revealed diverging results for men and women. The parenthood bias that they found is that women experience a statistically significant "motherhood penalty," with potential employers questioning their commitment to the workplace, while men benefit from a "fatherhood bonus" in which they are perceived to be more stable. Another place for bias is with academic letters of recommendation. Within geoscience, Dutt et al. (2016) analyzed over 1000 such letters and found that letters for men are longer and with more superlative adjectives than those for women. Hiring committees are biased in how they consider gender and relationships, allowing these non-job-relevant issues to enter the discussions for women far more than for men candidates (Rivera, 2017). Academia has an institutional bias, as well, with one study finding that, for computer science, 25% of PhD-granting institutions produce 80% of tenure and tenure-track faculty (Clauset et al., 2015). Even citations are a skewed metric, with King et al. (2017) finding that men self-cite their own papers nearly twice as often, on average, compared to women. As a final point, once hired, retention is systematically lower for women (e.g., Dennehy and Dasgupta, 2017), although female peer mentoring and female role models help (e.g., Carrell et al., 2010). A lack of diversity perpetuates these biases, which then creates obstacles to increasing diversity in the field.

1.4 We can do better

In summary, systemic bias exists in scholarly research communities, including space physics. This is not unique to this field or science in general, but it is a problem that our community should collectively address. This bias has led to a lack of diversity in the field, and this homogeneity of input can lead to groupthink and continued bias. The evidence is clear that diverse teams are good for science, with a wide range of perspectives leading to creativity and innovation. While individual space physicists rarely intend to be biased, microaggressions occur and systemic bias within institutions and research community cultures perpetuates the problem, including Earth and space sciences (e.g., Rosen, 2017; King et al., 2018; Popp et al., 2019).

The good news is that we can use existing tools to begin addressing the lack of diversity. The authors have served on a University of Michigan ADVANCE Program committee called STRIDE (Strategies and Tactics for Recruiting to Improve Diversity and Excellence).[4] STRIDE, created with NSF funding and sustained *via* a university commitment (Stewart et al., 2007), equips faculty across campus to run equitable faculty searches. The committee analyzes the peer-reviewed literature on the topic and conducts workshops describing and promoting empirically-based best practices. This review summarizes some of the main highlights from STRIDE that are of particular relevance to the space physics community. It is intended to be applicable not only for academic faculty searches but for selection processes across our field, from choosing a new student researcher in your group to society leadership positions.

2 Steps to doing better

There are many evidence-based strategies and tactics that can be adopted to conduct equitable searches. A comprehensive review can be found in Stewart & Valian (2018). Specifically, based on U-M STRIDE activities and complementary analysis, Stewart et al. (2016) identified three major obstacles that impede change towards increased diversity: other priorities (e.g., traditional definitions of "excellence" being prioritized over diversity of perspective); unfavorable department climate (not wanting to talk about diversity, difficult personalities); and external factors (such as the "pipeline problem" or practices around dual-career hiring). In the

4 The University of Michigan STRIDE committee website can be found here: https://advance.umich.edu/stride/

sections below, several key processes are summarized that overcome these constraining factors.

2.1 Develop a holistic rubric early

You want to hire an excellent candidate for your open position. You seek the "best" person, but how do you judge who among the applicants is truly best? There are many attributes that could contribute to the characterization of best. Early in the process, even before you finalize the job posting, it is important to define the criteria against which applicants will be assessed. You should use an assessment rubric that includes not only the skills required for the job but also potential indicators of those skills.

The list of desired features should include all facets of the candidate that are vital for the position. One common answer for "best" is to consider the number of papers, especially first author ones, and the number of citations to those papers. Because candidate's careers may reflect the accumulation of bias or advantage (access to top labs as a graduate student, for example), and citation practices themselves can reflect bias (King et al., 2017; Hofstra et al., 2020; Kozlowski et al., 2022), "counting" is a poor proxy for quality. Assess the work directly–the innovation, the significance, the impact. Leadership positions are also regularly used as an indicator of excellence; here too, look for evidence of talent and leadership strengths even if not yet recognized with an official leadership position. Another criterion is a person's funding record, assuming that the position is senior enough to warrant that assessment. If it is a faculty position that will require teaching, then assessing their experience or potential for high-quality instruction should be included. This is much more than their ability to give a good research presentation; it includes their philosophy on teaching pedagogy and their willingness to adopt inclusive teaching tactics and active learning techniques in the classroom.

Don't stop there, though. The studies listed in Section 1.1 above provide clear evidence that those with different perspectives and experience bases are beneficial to the group, and beneficial to the mindset of those within the group. Therefore, when evaluating applicants, you might consider the background of each applicant, noting their educational and career trajectory and how this might bring new thinking into the group. This could be included in the applicant review as an evaluation criterion based on augmenting the existing group dynamics culture (as opposed to "fitting in").

It is not only what they personally bring but also the possibility of the doors that they intend to open for others and their potential to shift the field towards greater inclusion. Regarding this, it is equally useful to assess the candidate's philosophical approach to diversity, equity, and inclusion (DEI) and their history of commitment to DEI. One of the best ways to obtain this information is to request a diversity statement (Sylvester et al., 2019; Bombaci and Pejchar, 2022), but it can also be embedded in an applicant's cover letter, research statement, or teaching philosophy.[5] Moreover, the applicant's record of action in DEI areas could be a category of evaluation. From these inputs, you have information to assess the potential of the applicant to be a DEI advocate and role model, and the potential for the candidate to make positive contributions to the culture of the group (or department) and to organizational change.

Finally, it is useful to broadly define the research scope in the call for applicants. Studies show that expanding the search beyond the traditional center of the research field is useful for attracting a more diverse applicant pool (e.g., Stacy et al., 2018; Settles et al., 2022). Therefore, even if you are searching for applicants to fill a specific role in a funded project, it is beneficial to not limit the job ad to require experience in that particular niche within the research field. Rather, adopt a more capacious definition of the qualifications for the position. Here is example text of a rather narrow job description (a real posting from the lead author): "Perform basic research on magnetosphere-ionosphere-thermosphere dynamics and coupling using physics-based modeling with a focus on the generation and consequences of ionospheric upflow and outflow." It then went on to mention several specific numerical models. Simply stating the research focus as "geospace dynamics" would have been a more expansive description that likely would have yielded a larger and more diverse set of applicants.

The issue might arise regarding collecting enough information—from either the applicant or from letter writers—in order to adequately assess all candidates against your rubric of job-relevant criteria. The answer is to ask for it. When developing the job ad, ask for materials that will provide you with the content needed to assess applicants against all of your criteria. For letters, be specific in your request about the points that you want addressed in the letter. Another option is to not request open-ended letters at all but rather use a form with specific, criteria-related prompts.

2.2 Slow down the downselect

You will hopefully get many applications for your opening. This poses its own problem, though: we are busy and it is tempting to go fast through the initial screening in order to quickly get to a short list of finalists for the job. The key take-away for you is this—go slowly and methodically through them.

The human brain has two modes, one fast and one slow, as summarized by Kahneman (2011). The "fast brain" response—your reflex thoughts about a given stimulus—automatically provides an assessment, without you having to exert effort and often before we are even aware that an evaluative decision is needed. We cannot control what pops into our head. We can, however, control what we do with that initial thought. This is "slow brain" thinking, the deliberative thought process and the mindset that we consider as "our personality." This second response takes energy, and our brain is conditioned to minimize caloric expenditures, so we have to make a conscious decision to enter slow-brain mode and think about a situation.

This slow-brain thinking is what we need to do when evaluating applicants. When we allow fast-brain thinking to dominate, then we revert to schemas, which include negative stereotypes (see chapter 1 of Valian, 1999). Intentional slowness can overcome this problem. O'Meara et al. (2021) introduced the concept of equity checkpoints; these are specific times in the search process during which you deliberately stop and consider that step with respect to whether you

5 An excellent DEI rubric is available from UC Berkeley: https://ofew.berkeley.edu/recruitment/contributions-diversity/rubric-assessing-candidate-contributions-diversity-equity

TABLE 3 Appropriate and inappropriate conversation topics with job applicants.

Appropriate topics	Inappropriate topics
Education and past work experience	Physical appearance (height, weight, skin color, hair color, tattoos, piercings, gender expression)
Knowledge of the discipline	Personal finances (including credit rating)
Skills desired for the position	Personal relationships (marital status, children, sexual orientation)
Past activities regarding your evaluation criteria	Religious or political affiliations
Philosophical approach regarding your evaluation criteria	Age
If they have US citizenship, *only* if *required* to perform job duties (e.g., restricted hardware)	National origin, birthplace, cultural heritage, or ancestry
How applicant would handle job-related problems (i.e., leadership/management approach)	Details of an applicant's criminal record (can only ask if a record exists, only if all applicants are asked)

are engaging in inclusive processes that support equitable decision-making. Others have analyzed the effectiveness of equity advocates on search committees (Liera, 2020; Cahn et al., 2022), in which a person's role on the committee is to make sure the committee uses unbiased practices in advertising, assessing, interviewing, and selecting candidates. These studies show that these tactics work to significantly improve the diversity of the short list.

When conducting the downselect and applying your rubric, it is important to remember that many traditional indicators of scientific success are biased in favor of white men.[6] This skew has been shown to exist in citations to scientific journal articles (King et al., 2017), letters of recommendation (Dutt et al., 2016), teaching evaluations (MacNell et al., 2015) and annual performance evaluations (Bauer and Bates, 2002); the intersectionality of these issues non-linearly disadvantages scientists with multiple minority group identifications (Kozlowski et al., 2022). The systematic enhancement of these metrics in favor of white men should be taken into account when assessing a candidate's quality. This is especially critical when comparisons are made between applicants from different groups in order to finalize the list of interviewees.

2.3 Equitable visits

Once you have a short list of finalists, it is important to make the interview process as equitable as possible. For example, include breaks in the schedule and travel time between meetings so that candidates who need a little extra time to move around or gather their thoughts can be at their best; ask also about accommodations that may be helpful. Provide all finalists with the same information about the research group or department, institutional policies, and details of the surrounding area without asking about their personal situation (e.g., do not assume only women candidates want information about schools and do not ask finalists if they are parents). Develop a list of questions ahead of time and ask all interviewees the same set. Ask about pronouns ahead of time and distribute this to all interviewers. If in person, then pay for any travel expenses in advance. Consider the environmental cues that reflect on who "belongs" with respect to what will be seen during the interview (such as wall pictures of only white men as scientists). For the job talk, be as consistent as possible in the format. There are specific topics that are either illegal or inappropriate to ask of job candidates; Table 3 provides a list of in-bounds and out-of-bounds topics, distilled from the University of Michigan faculty hiring manual.[7] In short, focus the interview on job-relevant questions and topics of conversation (that is, your selection criteria) and make the experience as uniform as possible.

If virtual, do a dry run to check connectivity. Fiechter et al. (2018) found that remote interviews were negatively influenced when the connection was bad or the image quality was not ideal. Checking these ahead of time, with all applicants, allows issues like this to be resolved before the stress-filled day of the interview.

To further minimize bias, these equity-focused accommodations should often be orchestrated by someone not involved with the final decision. This could be an administrative staff person or someone outside of the hiring group. In whatever way it is handled, you should have these aspects of the visit done before the first finalist goes through the process, so that it is the same for all.

The job talk is a particularly important part of the finalist interview, so it is worth some extra advice on this issue. Studies have shown a systematic bias in favor of men compared to women with respect to the questions and interruptions they receive during job interview presentations (Blair-Loy et al., 2017; Dupas et al., 2021). Informing the audience to hold questions to the end and then, before taking any questions—i.e., remind the audience that this is a job interview presentation and that the candidate should be allowed to fully complete their prepared remarks—helps to mitigate this problem. Choosing a DEI-conscious moderator for the job talk can also be helpful.

6 More information on the bias in traditional indicators of scientific success are available at the U-M ADVANCE resources website, under the STRIDE heading: https://advance.umich.edu/resources/#stride

7 The University of Michigan faculty hiring manual is available here: https://advance.umich.edu/wp-content/uploads/2018/10/Handbook-for-Faculty-Searches-and-Hiring.pdf

2.4 Fair decision-making process

When it comes time to make the final decision, the biggest piece of advice that we have is to recenter your rubric. Whether in the committee or in a larger group setting, keep all discussions focused on the job-relevant criteria and cut off tangential or inappropriate remarks.

If many are participating in the evaluation of the finalists, then soliciting their feedback through an evaluation form is convenient. Make this form based on your search criteria and ask for supporting evidence for any ratings. Get this feedback quickly, preferably before the next candidate has their interview.

Postpone global rankings until the final vote. Any use of rankings earlier than this has an anchoring effect and biases further conversation about the candidates (Sensoy and DiAngelo, 2017). This is especially true if senior group members get to speak first, which can then intimidate junior members from giving a different assessment. Rather than an open vote in which people see or hear who is voting for whom, consider using ranked-choice voting with a secret ballot[8]. This method has been shown to be effective when there is close contention between several finalists (Santucci, 2018). Of course, talk about pros and cons of the finalists in relationship to your job-relevant criteria, and even rank within those criteria, but it is not necessary—or even desirable—to achieve consensus in an open forum.

After the offer is made, you should focus on actively recruiting the person. This is the time to ask the candidate what they would need to know more about to be able to accept the offer, including information relevant to their family and partner situation like dual career hiring considerations or local schools, and help them access that information or resource. Only after the offer is made—and the decision is now theirs on whether to accept—are these non-job-relevant topics permitted in the dialogue.

3 Discussion

The space physics research community is not diverse. This is especially true at the senior experience levels, but is even true for our student populations, which are also not matching the demographics of the general public. Striving towards a demographic shift to match the general population supports our commitment to equity and inclusion. In addition, diversity increases research productivity. Unfortunately, bias exists, including within the space physics research community, and this negatively impacts hiring practices and perpetuates the demographic mismatch. Stachl et al. (2021) notes that positive shifts can be achieved with "discussions grounded in our own data," thus the focus in this report on the demographics and perceptions within the space physics research community.

There are many strategies and tactics that can be adopted to counter this problem, though. Section 2 above details a number of these methods, and they are summarized in Table 4. This is a list of steps that address the broad definition of diversity and is not tailored to focus on any one historically excluded group. The recommendations in Table 4 are suggestions that could be adapted to better suit a particular hiring situation. One example of this is how excellence is defined for the position; the wording, rubric, and emphasis placed on each of your specific job-relevant criteria would result in different search outcomes.

Note that this review only covers the search and hiring process. In addition to recruitment, a complementary aspect of this issue is retention, another critical component of the NSF ADVANCE program (DeAro et al., 2019). This topic is expertly covered by, for example, Settles et al. (2006), Stewart and Valian (2018), Stachl et al. (2021), and Hughes et al. (2022). At the author's institution, this is specifically addressed by STRIDE's sibling committee, Respect In Striving for Excellence (RISE)[9], which offers resources and programming for academic workplace climates across campus (Linderman et al., 2022). A full coverage of this is beyond the scope of this review.

Despite the negative tone of Section 1, the space physics research community is already improving our discipline with respect to DEI. One example is with research-centered awards. After the years of very low nominations of women in the SPA section to be AGU Fellows, a special task force was created to remedy the situation (Jaynes et al., 2019; Keesee et al., 2022). A similar group started in the United Kingdom (Walach et al., 2022). This has resulted in a marked increase in the diversity of nominations for not only AGU Fellows but also other awards. Halford et al. (2022) offers a perspective from the fellows' selection committee, detailing the process and offering advice on creating a good nomination. A second example is the creation of the Equitable Letters in Space Physics project (Burrell et al., 2021), from which many tips have been compiled for writing a good recommendation letter (Burrell et al., 2023). Regarding gender, Table 1 shows improved percentages at the earlier career stages, suggesting that our field may become more diverse with time—if we provide the opportunities and support to these newer investigators.

Our community has also shared advice on moving towards a more diverse field, a more inclusive culture, and a more equitable structure of interaction and engagement. A comprehensive review by Bagenal (2022) offers several suggestions for enhancing diversity in the space physics community. Jones et al. (2022) provides an excellent presentation of actions to improve inclusivity in space physics, while Kenny et al. (2022) and Halford et al. (2023) also include action item lists to achieve this goal. Liemohn et al. (2021) postulates that this positive shift in the diversity of the space physics community will result in many new discoveries, and Liemohn (2022, 2023) offers advice on achieving this shift. Palmroth (2022) shares a success story in achieving a dream, with the advice of striving for something 10+ years out to enable a paradigm shift in thinking as well as celebrating each other's victories and accomplishments. Palmroth (2022) encourages us to more proactively support each other and welcome new people into the group.

8 More on ranked-choice voting: https://www.fairvote.org/rcv#how_rcv_works

9 The University of Michigan RISE committee website can be found here: https://advance.umich.edu/rise/

TABLE 4 Summary of suggested remedies to possible equity issues during the hiring process.

Hiring step	Potential issue	Possible remedy
Developing applicant evaluation strategy	Too focused on publications and funding record	Consider all aspects of "excellence" for the position
Developing the job ad	Too narrowly focused	Intentionally generalize the wording
Request for application materials	Entirely focused on research experience	Specifically ask for information on other experiences, including DEI philosophy and action
Initial evaluation of full applicant list	Reading too quickly and applying schemas	Intentionally clear ample time with no distractions
Rating applicants	Bias within traditional measures of success	Adjust individual evaluations based on known biases of metrics
Selecting finalists	Applying artificial cutoffs on numeric evaluations	Use broad rating categories instead of rankings
Finalist visits	Inequitable experiences	Brainstorm for potential issues and preemptively address them, ask interviewers to prepare a list of questions they ask everyone
Interview seminar	Aggressive interruptions for some speakers	Clearly state "rules" for job talks before each presentation
Finalist visits and internal discussions	Asking inappropriate questions or discussing such topics during evaluations and deliberations	Distribute the list of off-limits questions, actively cut off talk of non-job-relevant topics
Final discussion	Ranked list that "anchors" some at the top, hard to refute and redirect the conversation	Don't calculate a global ranking, but rather separately discuss each criterion and each candidate
Final decision	Anxiety about publicly voting differently than senior group members	Use ranked-choice voting with a secret ballot

Beyond our immediate research cohort, others have also been striving for a more equitable space physics research community. Lewis et al. (2022) encourages Earth and space scientists to embrace committee work as an opportunity for "regenerative gatekeeping," using the service role as a chance to implement policy change within your institution or society. Hamden et al. (2022) describe the intent and format of the NASA PI Launchpad Workshop, a program designed to increase the diversity of leaders ready to propose a spaceflight mission concept to NASA's Science Mission Directorate. Williams et al. (2017) detail the role of AGU in increasing diversity and inclusion in the field, including making ethics violations equivalent to scientific misconduct and grounds for dismissal from a leadership position or award selection. Atherton et al. (2016) offer six recommendations for ensuring equity for physicists across the spectrum of gender presentation and sexual orientation. The NASEM (2022b) report on creating the proper conditions for a vibrant research community recognizes the problem of inequity in science disciplines and offers a long list of suggested actions for us to undertake to address it. Quite a few resources exist, accessible to space physicists and ready for implementation.

In summary, we urge the space physics research community to adopt these best practices for equitable hiring. These techniques should lead to a more diverse cohort of new members in our discipline, which will yield benefits for our science, our community members, and for humanity.

Author contributions

The writing of this paper was led by ML with equal, smaller contributions from all other authors. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

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HUG Initiative: Overcoming roadblocks on a research career roadmap of individuals from historically marginalized or underrepresented genders

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The underrepresentation of students of Historically marginalized or Underrepresented Genders (HUGs) in STEM departments results in the low representation of HUG researchers in the space science community. This paper reviews relevant literature to explore the potential barriers that prevent HUG students from staying in STEM fields, including few opportunities to develop STEM identities, experiences with professional devaluation, and chilly campus climates. Thus, HUG students are more likely to feel excluded in STEM programs. To address the disparities, our HUG Initiative, a student-led research initiative, is proposed and piloted at a large research institution. This initiative promotes the pursuit of research careers among students who self-identify as HUG in the department of electrical and computer engineering. By holding panel discussions, interactive workshops, and networking luncheons, HUG Initiative aims to demystify what it means to be a researcher and provide resources on research opportunities and support for HUG students. The influence on the HUG students' career choice and their accessibility of information will be evaluated by pre-study and post-study surveys. The research outcome will offer suggestions to create a safe and supportive departmental environment for HUG-identifying students to pursue research careers.

KEYWORDS

research career, gender minority, initiative, chilly climate, STEM identity

1 Introduction

The field of space physics is interdisciplinary, combining both engineering and science. Researcher affiliations include departments of planetary science, physics, astronomy, and electrical engineering among others. Demographics of Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) community presents a drastic decrease in women populations from students (38.7%) to early career scientists (17.9%), implying that women are more likely to leave the space physics field once obtaining the degrees (Jones Jr and Maute, 2022). The result is aligned with the AGU Section Membership Demographics report in 2018, which indicates that the percentages for women students, early-, mid-, and senior-career scientists in the section of Space Physics and Agronomy are 35.8%, 29.86%, 21.05%, and 10.73% respectively (AGU, 2018). The phenomena might be partly explained by "the leaky pipeline" (Seymour and Hewitt, 1997; Lovitts, 2002; Grogan, 2019), which will be detailed in the following section.

Over the past several decades, while there have been multiple efforts to study the systemic gender biases women face in STEM fields, the binary gender narrative does not include the people who are non-binary, genderqueer, genderfluid, *etc.* Moreover, women-only spaces often exclude transgender and non-binary people, especially with anti-trans rhetoric of trans-exclusionary radical feminists (TERFs) on the rise since the start of the COVID-19 global pandemic (Pearce et al., 2020). The experiences of people who identify as lesbian, gay, bisexual, transgender, and/or queer (LGBTQ+) in STEM are seldom addressed in studies and reviews (Kersey and Voigt, 2021; Maloy et al., 2022). For instance, all the surveys American Geophysical Union (AGU) distributed before 2019 only had three choices, "female," "male," and "prefer not to answer." It was not until 2021 that AGU Diversity and Inclusion Advisory Committee officially updated the gender categories to include "non-binary" (AGU, 2021). While few efforts have focused on analyzing the academic and workplace experiences of transgender scientists (Kersey and Voigt, 2021; Maloy et al., 2022), prior studies have shown that queer and transgender students and professionals in STEM face various microaggressions in academic settings, such as being subjected to cis-normative language or incorrect pronouns (Campbell-Montalvo et al., 2022b). Moreover, transgender and non-binary students are often forced to use their deadname—the birth name they no longer use—due to interpersonal or institutional reasons, leading to increased mental health issues (Russell et al., 2018; Cooper et al., 2020). In addition, STEM fields often present a chilly climate to women and people who identify as LGBTQ+ (Settles, 2014; Campbell-Montalvo et al., 2022b), and the prevalence of cisgender culture within STEM that alienates those who identify as LGBTQ + as well as cisgender women (Miller et al., 2021).

For a more comprehensive coverage of genders, this study includes individuals of Historically marginalized or Underrepresented Genders (HUGs), including cisgender women and anyone who identifies with transgender and non-binary groups. In this paper, we review past efforts in understanding the difficulties and potential solutions for STEM students and professionals of underrepresented genders. We also provide a framework, HUG Initiative, for supporting and motivating HUG students in pursuing research careers. **Section 2** discusses the obstacles HUG students face in research and proposes possible solutions to mitigate the barriers. **Section 3** details the workings of HUG Initiative, including a pilot study survey, panel events, and a student mentoring program. **Section 4** concludes the paper.

2 Obstacles and possible solutions

The underrepresentation of HUG students in STEM fields is possibly caused by the lack of awareness of diversity when recruiting HUG students as well as the fact that HUG students have higher attrition rates than non-HUG students, so called "the leaky pipeline," as shown in **Figure 1**. While numerous studies focus on the recruitment of HUG students in STEM fields, this section discusses why HUG students leave STEM fields. In this section, we explore the possible barriers HUG students face when pursuing STEM degrees along the career research roadmaps. While studies have shown that non-binary and transgender people have similar experiences as cisgender women, they face augmented difficulties (Blackburn, 2017; Conrad et al., 2021; Miles and Naumann, 2021; Campbell-Montalvo et al., 2022a). Challenges and compounding difficulties will both be addressed in this section.

2.1 Lack of opportunities to develop STEM identity

STEM identity is a quantitative indicator for measuring students' behaviors on educational and professional persistence in STEM field (Carlone and Johnson, 2007; Hazari et al., 2010, 2013; Unfried et al., 2014). This indicator is developed based on four dimensions, including interest, competence, recognition, and performance, and was found to accurately predict students' intentions to complete and choose a STEM career. HUG undergraduates have lower STEM identities when compared with non-HUG peers, and thus they had lower interests in STEM careers and did not recognize themselves as engineering or physics students (Hazari et al., 2010; Godwin et al., 2013). The Persistence Research in Science and Engineering (PRiSE) survey project on undergraduate identities showed that 50% of men considered themselves as physicists, compared with only 30% for women (Hazari et al., 2013). One factor contributing to this disparity is identity regulation. Students are more likely to connect with disciplines that fit their actual or desired identity and avoid areas that they consider different from themselves. Since STEM fields are often associated with masculinity (Master et al., 2016; Cheryan et al., 2017), HUG students are often perceived as being a misfit between their gendered self-concept and the image of STEM (Kessels et al., 2014). Another factor for low STEM identity is due to the low self-efficacy beliefs of HUG students, that is, they possess lower confidence in their ability to conduct a STEM project or research (Miles and Naumann, 2021; de las Cuevas et al., 2022; Andrews et al., 2021). Women in physics class have lower science self-efficacy than their men counterparts. Moreover, women with "A" grades often had comparable physics self-efficacy perceptions to men with "C" grades (Marshman et al., 2018).

The fact that HUG students possess lower STEM identity and efficacy beliefs is most likely due to the lack of opportunities to develop their STEM identity. HUG students tend to be more passive in answering questions during lectures and are less likely to be encouraged to become researchers by faculty (Hazari et al., 2010). Kahle et al. (1993) indicated that men students engaged more in the typical classroom interactions, such as asking and answering questions. Thus, women typically received less attention and recognition from lecturers, and had fewer prior experience on conceptual understanding than their men counterparts (Kahle et al., 1993; Chambers and Andre, 1997). In addition, negative stereotypes play a key role in the students' motivation to pursue a STEM career. For instance, women students' self-confidence is likely to be influenced by beliefs that men generally perform better in STEM than women (Maries et al., 2018). Therefore, women students are more likely to assume that they need to make extra efforts to succeed in STEM fields and undergo stress to demonstrate their skills in order to be valued equally as men students (Marshman et al., 2018).

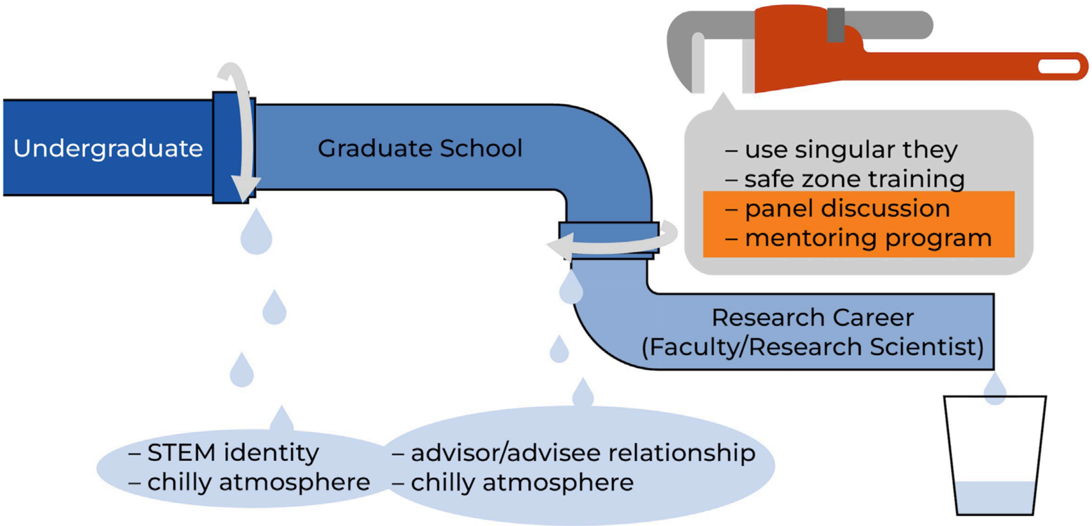

FIGURE 1
Conceptual diagram of obstacles HUG students face while pursuing a research career. The highlighted text under the pipe wrench indicates the scope of HUG Initiative.

2.2 Chilly climate

Department climate is shaped by the nature and quality of interactions between students, faculty members, and staff. The "chilly climate" refers to the inequities that may seem trivial, but frequently occur. However, cumulatively, these inequities can lead people to doubt the value of their contributions (Lee and Mccabe, 2021). HUG students usually face additional difficulties of integration with their academic community and experience chilly department climates. They—especially those who do not fit in the cisgender binary—experience more harassment, discrimination, and professional devaluation in their departments (Cech and Waidzunas, 2021). STEM departments seldom provide the environment for students to feel safe to be out about their gender identities, including the lack of gender-neutral bathrooms and binary gender options (man or woman) on school forms (Woodford et al., 2017). Moreover, since STEM is primarily dominated by cisgender men, the nature of cis-normative language within the department causes people from underrepresented groups to make additional efforts to blend in or resist the culture (Miller et al., 2021). An interview study revealed that HUG students felt uncomfortable about gender-specific language, such as often addressing each other as "bro," "dude," or "guy" in casual conversations and having male-dominated jokes (Vaccaro, 2012). HUG students further reported that they tend to dress less feminine to avoid harassment from their peers, and believed this made them easier to fit in to the departments (Miller et al., 2021). Overall, this unwelcoming and chilly atmosphere and pressure to conform gives HUG students the impression that "STEM is not for me." The failure of integrating with the academic community decreases the motivations of HUG students to stay in STEM fields.

The difficulties HUG graduate students face are similar to HUG undergraduates. However, advisor–advisee relationship is one of the aspects that differs between HUG undergraduate and graduate students. Unlike undergraduates, graduate students have few opportunities to meet peers through lectures and student organizations. Instead, they spend more time and effort being involved in professional organizations, participate in seminars, and on- or off-campus social events. Since these activities vary between research fields, the research career roadmaps of graduate students are typically guided by their advisors. Building a strong and bonding advisor–advisee relationship introduces additional opportunities and interactions to integrate with the academic community and helps keep HUG graduate students in the STEM field. Studies have shown that students who are advised by a faculty member with close research interests or who share similar personal interests tend to form more successful advisor–advisee relationships (Lovitts, 2002). Since HUG faculty members are also underrepresented in most STEM departments, they usually spent 2 hours more per week on mentoring students than their colleagues (Misra et al., 2011). Therefore, HUG students have difficulties finding an advisor who has the time and experience to help them overcome the challenges they face.

2.3 Result: Lack of psychological safety

The lower STEM identities of HUG students and their experiences with a chilly atmosphere lead to HUG student difficulties in constructing their research career roadmaps when pursuing STEM degrees. These roadblocks also limit their opportunities to build their networking villages in departments, professional organizations, and meetings throughout their research careers. Therefore, HUG students may feel disappointed by the learning experiences and explore opportunities outside STEM fields. Moreover, HUG students were reported to experience health difficulties, including insomnia, stress from work, and depression, more frequently than their non-HUG peers due to chilly atmosphere (Cech and Waidzunas, 2021). HUG students felt less like they "fit in" in STEM fields as they faced more severe, frequent, and often invisible microaggressions when interacting with others, such as professional devaluation, additional harassment, and discrimination during conversations (Campbell-Montalvo et al., 2022b). Consequently, HUG students exhibit lower persistence and sense of belonging to STEM fields than their non-HUG colleagues. For example, around 30% of HUG students and faculty were not comfortable with STEM department climates, and seriously considered leaving their institution due to negative experiences and perceptions (Farrell et al., 2017; Conrad et al., 2021). Moreover, non-binary and transgender students were 7% more likely to transfer to non-STEM programs (Hughes, 2018), and a longitudinal survey study on the degree completion of graduate students showed that HUG graduate students in the typically-men PhD programs (with less than 38.5% women students in the average cohort) are ~12% less likely to graduate from the PhD program than men students (Fouad et al., 2017; Bostwick and Weinberg, 2022; Maloy et al., 2022).

2.4 Additional impact during global pandemic

The COVID-19 pandemic placed additional challenges on HUG students because of online learning and working environments. During the pandemic, HUG students, especially LGBTQ + students, were constantly discriminated against and harassed by their peers due to the rise of TERF wars (Pearce et al., 2020), or isolated with their unsupportive families (Fish et al., 2020). However, access to supportive systems within the university, such as interaction with affirming friends, therapists, advisors, teachers, and student organizations, largely decreased (Thanawala et al., 2022). For example, 30% of HUG students felt unsafe and missed at least 1 day of school monthly, according to a School Climate 2022 survey, and suffered from psychological distress four times greater than non-HUG students (Salerno and Boekeloo, 2022). Furthermore, women reported more disruptions to publishing academic papers and focusing on their research studies than men due to their expected family responsibilities (Shah et al., 2021). They are likely to cut their work hours to take care of sick family members or help their children with homework and keep them focused during school hours (Modestino, 2020). Studies showed that the research productivity of women, especially early-career HUGs, has been affected more than non-HUGs (Squazzoni et al., 2021; Paul et al., 2022). The proportion of first authors who are women on COVID-19 related papers was 20% lower than on papers published before the pandemic in medical journals (Andersen et al., 2020). This phenomenon has not been observed in the space science community yet, and may require additional statistical analysis in future studies (Wooden and Hanson, 2022).

2.5 Possible solutions: Take actions

Considering the challenges that HUG students face when pursuing a career in STEM fields and the additional burdens caused by the COVID-19 pandemic, it is extremely important for us not only to detail the disparities between HUG and non-HUG students, but also to implement pragmatic solutions and take actions for a more inclusive and supportive environment in our academic community. These actions should take place not only at events held by professional organizations, departments, and student organizations, but also at lectures and during office hours. Liemohn (2022) suggested stopping using bro language and stoping having male-dominated jokes in casual conversations. Instead, we use gender-neutral language, such as using "singular they" in publications and presentations.

Several other actions were recommended in supporting HUG students, including panel discussions, safe zone training, and mentoring programs. Surprisingly, Hazari et al. (2010) pointed out that inviting HUG speakers and introducing HUG scientists during lectures had little impact on the increase in STEM identities. It would be beneficial to have an explicit discussion of the issues of underrepresentation faced by minorities in HUG, such as the gender-bias experienced by HUG scientists (Hazari et al., 2010). A mini workshop series of panel discussions was reported to have a significant impact on underrepresented students by providing resources and opportunities that were not accessible individually (Artiles et al., 2021; Connor et al., 2021). Furthermore, holding safe zone training sessions within departments or professional organizations educates people about terminologies of gender minorities and the biases they experience, as well as the coming out process (Farrell et al., 2017; Miles and Naumann, 2021). The training sessions are meant to engage everyone to be aware of the difficulties HUG students face and form a supportive structure and culture of allies for HUGs (Miller et al., 2021). In addition, students who used support and mentoring services were found to have lower attrition rates (Madara and Cherotich, 2016). Meeting with a STEM professional who shared similar backgrounds greatly encouraged HUG students to pursue a STEM career, and helped them feel like they belonged in their academic community (Kricorian et al., 2020).

3 Plan of action: HUG Initiative

To close the knowledge and resource gaps between HUG and non-HUG students while providing a sense of community for HUGs, the HUG Initiative is formed to promote the pursuit of research careers among both undergraduate and graduate students of historically marginalized or underrepresented genders alike in the Department of Electrical and Computer Engineering at the University of Illinois Urbana-Champaign (ECE Illinois). This student-led research-based initiative includes a pilot study that identifies the difficulties HUG students in ECE Illinois face compared to their non-HUG counterparts, and addresses the roadblocks through panel discussions and student mentoring. Our plan of action and research outcome provide a framework for how to motivate HUGs to involve in the space science community and create a safe and supportive environment to continue their research career pathways.

There are 327 women undergraduate and 117 women graduate students in ECE Illinois, which are ~15% and 17% of the total ECE student populations. The HUG Initiative aims to help these HUG students develop their researcher identities and attain research positions. We envision three key elements that lead to a

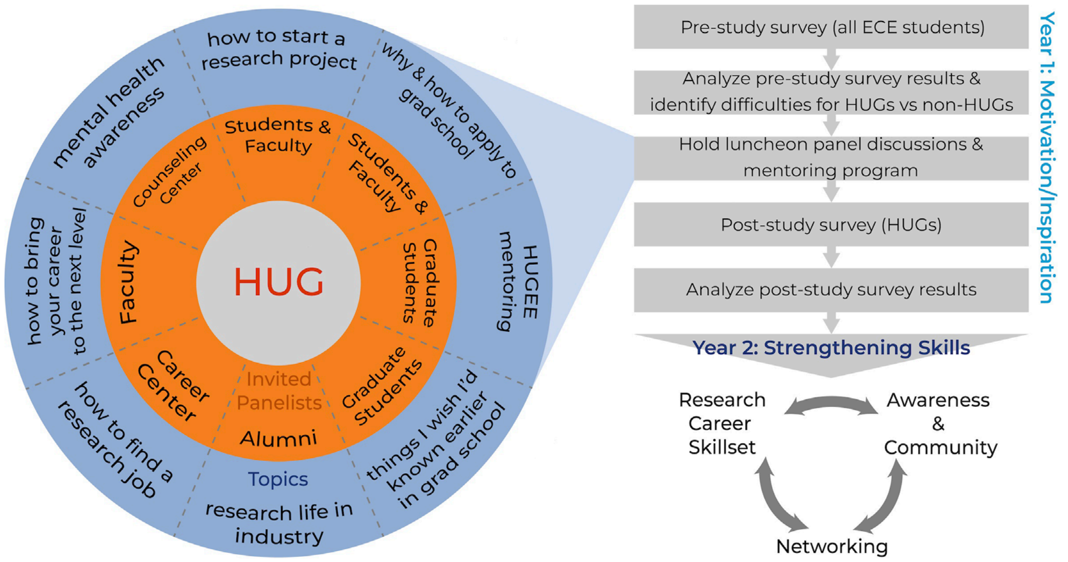

FIGURE 2
Diagram for HUG Initiative makeup and activities.

successful HUG researcher: research career skill sets, networking, and community awareness. These elements are meant to help HUG students construct their research career roadmaps while pursuing their STEM degrees, and provide additional opportunities for them to integrate with the academic community. A flowchart for HUG Initiative is on the right side of Figure 2.

3.1 Pre-study survey

We distributed an institutional review board approved pre-study survey to all ECE students in the first week of the Fall 2022 semester to identify the difficulties HUG students face compared to non-HUG students. The survey is designed to collect students' current states regarding their STEM and research identities, knowledge of available research resources and opportunities, attitudes toward STEM careers, and psychological safety in the department. Results will provide the department with insight into how to better direct HUG students towards STEM research careers. To evaluate the impact of the HUG Initiative, a similar survey will be distributed to HUG students at the end of the academic year to assess how the panel discussions and networking events impact their understandings of research career pathways.

3.2 Event planning

HUG Initiative will hold panel discussions, mentoring program, and town hall meetings, which will accommodate 20–30 students at each event. During the panel discussions, HUG Initiative will invite panelists to give advice on how to find research opportunities, and share their experiences in research skill development, especially the challenges they have encountered before. Various topics, including undergraduate research opportunities, graduate school application, graduate student orientation, research job searching in academia and industry, and mental health will be addressed. Planned topics and corresponding panelists are detailed on the left side of Figure 2. These panel discussions aim to help HUG students gain understanding and motivation toward having research careers, and further build connections with panelists for future opportunities of advancement. Similarly, the mentoring program was launched during the semester to pair graduate students with undergraduates for one-on-one near-peer mentoring on graduate school applications and research experiences.

4 Conclusion

HUG undergraduates are suggested to be 10% more likely to leave the STEM field compared to their non-HUG peers, while HUG graduates are suggested to be 12% less likely to complete a PhD program. This high attrition rate of HUG students may be credited to the fact that they experience additional professional devaluation and chilly campus climates. Therefore, they suffer from low psychological safety and feel excluded from STEM programs. To address the disparities, we designed the HUG Initiative to increase the representation of historically marginalized or underrepresented genders in STEM research through community building and informative workshops. The initiative not only investigates in why HUG students are more likely to leave STEM field, but also takes actions by holding panel discussions and mentoring program for HUG students and studying how to better support their pursuit of research careers. The survey findings and event evaluations will provide insights on how to increase gender representation in the space science research community from the students' perspectives.

A student-led research initiative is critical to promoting a more diverse research community. It is necessary to include voices from different stages of education level to construct a career roadmap. The experience of education research strengthens students' research skillsets and gives them additional chances to interact with administrative staff in the departments as well as their peers in the academic community. The entire research team of HUG Initiative is led and operated by graduate and undergraduate students from ECE Illinois, and thus, a good example. With the support from experienced faculty members and the Institute for Inclusion, Diversity, Equity and Access in The Grainger College of Engineering, HUG Initiative can conduct educational research that focuses on the experiences of students in the department, in addition to their technical research projects.

5 Citation diversity statement

Recent work in several fields of science has identified a bias in citation practices, such that papers from women and other minority scholars are under-cited relative to the number of such papers in the field (Maliniak et al., 2013; Mitchell et al., 2013; Caplar et al., 2017; Dion et al., 2018; Bertolero et al., 2020; Dworkin et al., 2020; Chatterjee and Werner, 2021; Fulvio et al., 2021; Wang et al., 2021). Here we sought to proactively consider choosing references that reflect the diversity of the field in thought, form of contribution, gender, race, ethnicity, and other factors. First, we obtained the predicted gender of the first and last author of each reference by using databases that store the probability of a first name being carried by a woman (Dworkin et al., 2020; Zhou et al., 2020). By this measure (and excluding self-citations to the first and last authors of our current paper), our references contain 43.94% woman (first)/woman (last), 14.91% man/woman, 25.72% woman/man, and 15.43% man/man. This method is limited in that a) names, pronouns, and social media profiles used to construct the databases may not, in every case, be indicative of gender identity and b) it cannot account for intersex, non-binary, or transgender people. Second, we obtained predicted racial/ethnic category of the first and last author of each reference by databases that store the probability of a first and last name being carried by an author of color (Ambekar et al., 2009; Sood and Laohaprapanon, 2018). By this measure (and excluding self-citations), our references contain 9.64% author of color (first)/author of color (last), 18.21% white author/author of color, 13.65% author of color/white author, and 58.50% white author/white author. This method is limited in that a) names and Florida Voter Data to make the predictions may not be indicative of racial/ethnic identity, and b) it cannot account for Indigenous and mixed-race authors, or those who may face differential biases due to the ambiguous racialization or ethnicization of their names. We look forward to future work that could help us to better understand how to support equitable practices in science.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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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MAVEN mission perspectives and approaches to inclusion

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The Mars Atmosphere and Volatile Evolution mission (MAVEN) is a NASA spacecraft that has been orbiting Mars since 2014. The Mars Atmosphere and Volatile Evolution mission team has established a current set of best practices to strengthen Diversity, Equity, Inclusion, and Accessibility (DEIA) initiatives; there are numerous axes of diversity, and this paper does not focus on one specific aspect of diversity but rather focuses on mission-specific approaches to inclusion. We present the past and present approaches as well as future initiatives and areas of improvement to continuing our efforts towards maximizing inclusion and engagement on the Mars Atmosphere and Volatile Evolution mission team and its working environment. The approaches presented in this paper are applicable to the space physics and planetary science communities, as well as any large-scale science or mission teams.

KEYWORDS

diversity, early career, Mars, mission, inclusion

Introduction and timeline

The Mars Atmosphere and Volatile Evolution mission (MAVEN) is a NASA satellite that was launched on 18 November 2013, and entered orbit around Mars on 21 September 2014. The mission's primary goal is to explore the planet's upper atmosphere, ionosphere, and interactions with the Sun and solar wind to provide insight into the history of Mars' atmosphere and climate, liquid water, and planetary habitability.

The MAVEN proposal was submitted to the Mars Scout Program in 2006 by the original mission Principal Investigator (PI), Dr. Bruce Jakosky (University of Colorado, Boulder), and was down-selected for flight development in 2008. PI Jakosky led the MAVEN mission until 2021 when he recommended Dr. Shannon Curry (University of California, Berkeley) to succeed him as MAVEN PI.

The following perspectives will focus on 1) our practices to maximize inclusion on the MAVEN team and 2) recommendations and areas of growth. The perspectives will focus on recent actions under PI Curry, who assumed leadership during Phase E (primarily the science phase), as well as past actions under PI Jakosky. It should be noted NASA prohibits soliciting demographic information from the MAVEN team regardless of whether it is volunteered, so team demographic data is not available at any point during the mission. However, peer reviewed literature on more general demographics within the fields of planetary science and space physics is available and included in the discussion below.

TABLE 1 MAVEN approaches for inclusion.

Approaches	Actions
MAVEN Early Career (EC) Visibility and Opportunities	Appoint ECs as session leads at science meetings
	Appoint ECs as Deputy Leads for all Instruments
	Provide Research Experiences for Undergraduates (REUs)
	Promote Dedicated Early Career Group
MAVEN Management and Leadership	Represent diversity in Senior Leadership
	Represent diversity in Science Advisory Board
MAVEN Mission Tone and Culture	State culture expectations in Rules of the Road
	Provide presentations on mental health and diversity at science team meetings
	State culture expectations in verbal Code of Conduct
Communication and Accessibility	Use uniform gradient of brightness in colorbars
	Use accessible fonts and HTML
	Include alt text to accompany publicly available images

MAVEN best practices: Approaches and initiatives for inclusion

Early career visibility and opportunities

One of the largest efforts towards increasing and maximizing MAVEN team inclusion and engagement has been in the area of early career visibility. Early exposure and visibility for scientists in the beginning of their careers can have a profound effect on the collaborations, networks, and resources they can seek out to achieve success later on. Walach et al. (2022) and Bol et al. (2018) discuss this topic, specifically referencing the Matthew effect: "early successes increase future success chances." Bol et al. (2018) found that mid-career scientists who had already won a grant accumulated over twice as much funding as their peers who had not won a grant in their early career, even with nearly identical proposal ratings. Effectively, the study found that early career scientists who experienced early success were much more likely to be successful later on, even with similar abilities and qualifications. In this spirit, the MAVEN team has made a concerted effort throughout the mission to improve early career visibility and success (as summarized in Table 1).

One approach is through leadership of our science meetings. When MAVEN's primary mission began in 2014, the science team held ~4 "all person" science meetings, or Project Science Groups (PSGs), per year to discuss the latest results. Initially, the results were organized into science sessions, and the senior scientists on the team would chair and curate those sessions. However, within the first 18 months from MAVEN's launch, a number of postdoctoral fellows and graduate students joined the mission to analyze the huge volume of new Martian data. By early 2016, PI Jakosky made a concerted effort to have graduate students and postdoctoral fellows leading science sessions, all of whom were also encouraged to apply for their own grants and funding sources. The current MAVEN PI, Dr. Curry, was one of these postdocs.

Another concerted effort that the MAVEN team is making towards increasing early career visibility is having each of the nine MAVEN instrument leads select deputy leads. This provides an avenue for succession planning as well as allowing the deputy instrument leads to gain experience working on an active instrument. The deputy leads present many of the weekly and monthly instrument status updates and thereby gain experience presenting to different audiences. Three of these deputy leads later moved to roles as the current instrument leads.

MAVEN also continuously provides opportunities for undergraduate and graduate students, who are a critical demographic to introduce to Science, Technology, Engineering and Math (STEM) research. We have had Research Experiences for Undergraduates (REU) students every summer at many institutions performing research with the MAVEN datasets. Additionally, MAVEN's primary institution—the University of Colorado Boulder's Laboratory for Atmospheric and Space Physics (CU LASP)—trains and certifies undergraduates to work in its Mission Operations Center.

Finally, a dedicated MAVEN early career group is composed of self-identified MAVEN team members and meets at PSGs and conferences throughout the year. Platforms such as Gathertown and other virtual co-hort building tools temporarily helped until in person meetings resumed, and currently the mission supports the MAVEN early career group to meet at PSGs as well as conferences throughout the year.

Management and leadership

An important aspect of inclusion and progress for the MAVEN mission is representation within the management team. In this journal issue, Hamden et al. (2022) wrote extensively about expanding the base of potential principal investigators across space sciences. They noted that "obstacles are borne out by the demographics of both PIs and Science team members for selected and proposed space missions, which tend to be both very male and very white." This observation was in part based on Centrella et al. (2019), who did a study using gender as a marker of diversity during the period 2008–2016 in NASA's Astrophysics Explorer-class missions. Over 8 years, 9 solicitations were issued, and during that time 102 Principal Investigators (PIs) submitted Explorer-class proposals, but only four of these PIs were women. The National Academies also recently released a report, "Advancing Diversity, Equity, Inclusion, and Accessibility in the Leadership of Competed Space Missions" (National Academies of Sciences, 2022a) with a number of relevant findings including opportunities for mentorship (Guiding Principle 4) and work-life balance including parental leave (Guiding Principle 5).

The current MAVEN senior leadership includes:

- Principal Investigator (PI): Dr. Shannon Curry
- Project Manager: Rich Burns
- Co-Deputy PI: Dr. David Mitchell

- Co-Deputy PI/Project Scientist: Dr. Gina DiBraccio
- Science Advisory Board lead: Dr. David Brain

Before Dr. Curry became the MAVEN PI, Dr. Janet Luhmann served as Deputy PI from 2008–2020. While gender is only one axis of diversity, female leadership on the MAVEN team has been a step forward on a Discovery class mission (note that MAVEN is part of the Mars Scout program but had a budget similar to that of a Discovery mission). Additionally, both Dr. Curry (PI) and Deputy PI (Dr. DiBraccio) have taken parental leave (multiple times) while in these roles and have been fully supported by the mission team.

The MAVEN Science Advisory Board (SAB) is another area where diversity is critical for providing a robust set of recommendations. Board membership is designed to capture the broad array of scientific expertise within the team, while keeping other axes of diversity (e.g., career level, institution, gender, race, etc.) in mind. Additionally, the board has a permanent seat for an early career representative. With this diverse set of perspectives, the SAB advises the PI on journal special issues, science working groups, science team meeting organization, relevant collaborations, communications/science products for both NASA HQ and the public, and other relevant science initiatives.

MAVEN mission climate and culture

Many of the examples to improve DEIA within the space physics and planetary science community are concrete; however, it is important to discuss the general tone, culture and working climate within a mission team (a formal recommendation by the National Academies of Sciences, 2022b, and finding from Fernando et al., 2022).

One example of setting expectations for MAVEN's mission culture is our Rules of the Road, codifying how data is shared amongst the team and across instruments. Since the primary science mission began, all MAVEN datasets are available as soon as possible to the entire science team, defined by MAVEN Co-Is and their direct research groups and students, along with NASA-selected Participating Scientists. This has been effective in creating a collaborative and inclusive atmosphere and removing territorial tendencies that have often plagued larger missions.

Another approach to creating an inclusive climate is the simple act of discussing DEIA within the team. Within MAVEN's mission wide science team, there are meetings every other week for 60–90 min to review mission status, relevant team and instrument updates followed by a 30–45 min science talk. Recently, we have expanded our science talks to include invited talks on explicit DEIA efforts, mental health and inclusion and accessibility practices within the STEM field.

We also clarify in the beginning of science meetings and PSGs that everyone in the room has the right to voice a question or comment and that we have a zero tolerance for bigotry in any form. Mission environments that are more collaborative, positive and respectful are the most successful in attracting and retaining under-represented and marginalized people (Advancing Diversity, Equity, Inclusion, and Accessibility in the Leadership of Competed Space Missions).

Communication and accessibility

Communication and presentation of scientific and mission/operational content is an important aspect of accessibility. Everything from figures in presentations to the text in written documents can affect how other members of the community can absorb the material. Below are specific initiatives that the MAVEN team has taken to.

Colorbars

Many plots in presentations and journals default to a rainbow colorbar. However, MAVEN has made a concerted effort to encourage team members to switch to more accessible alternatives. This switch is not only based in the science of human vision but address significant accessibility issues: 1) colormaps without a uniform gradient in perceived brightness are unintelligible in grayscale reproduction (potentially limiting the audience), 2) about 1 in 12 men are red/green colorblind, making rainbow colormaps less legible or illegible for a significant fraction of scientists. Use of perceptual colormaps with a uniform gradient of brightness makes graphics accessible to sighted people regardless of their color vision. The following link is commonly used on the MAVEN team to adopt this: https://github.com/planetarymike/IDL-Colorbars.

Readability

The MAVEN team has taken steps to improve media accessibility by applying best practices for font size and face, use of HTML tags used by screen readers, and exclusion of potentially disruptive or triggering website content. These adjustments are more inclusive of seniors, vision-impaired and screen reader users and include more accurate <title> tags in the HTML, using the font Lato (or Helvetica if the browser can't load Lato), increasing body font size from 13px to 15px and text line height, as well as removing flash content.

Alt text

Images play a large part in social media engagement, especially when sharing science results, but are not accessible to someone with a vision disability. Alternative text, a physical summary of an image, is a way to make images accessible by accurately describing it to a user. Alternative text, or "alt text," serves two major purposes:

- For anyone using assistive technology such as a screen reader or text-to-speech program, alt text is crucial to access digital content because it's meant to accurately describe images to the user. Oftentimes these users are blind or have a severe vision disability.
- Second, if an image on a webpage fails to load, the alt text will also indicate what the missing image was.

Since October 2021, MAVEN's social media posts have had alt text when appropriate. This is to help make MAVEN science more accessible and inclusive to users. Our communications team is always looking for materials to learn more about how to make content accessible, including better writing practices for alt text.

MAVEN areas of improvement and recommendations

Diversifying mission teams and promoting scientists and engineers from underrepresented backgrounds can be difficult due to challenges in both the recruitment and retention of diverse community members in the field (Walach et al., 2022; Davies et al., 2021). In the following recommendations we shift focus toward retention and improving the professional experience of our community members. These recommendations and areas of growth are for MAVEN, other space missions as well as the planetary, space physics and scientific community at large.

Areas of improvement: Underrepresentation and the burden of service

The most recent Planetary Decadal Survey, Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032, found that Latinx/Hispanics represented 8% percent of all physical science jobs, while representing 17% of the United States workforce. Even more pronounced was the finding that Black/African Americans represented 6% of physical science jobs while representing 11% of the United States workforce and there was insufficient data on Indigenous researchers. This disparity needs to be addressed at every level—K-12, undergraduate, graduate, postdoctoral, etc.,— but the onus to implement change should not fall upon those communities who are least represented. The Planetary Decadal Survey, National Academies of Sciences, 2022b, released a finding highlighting this issue: “Community service and administrative duties are important contributions, but ones that tend to be distributed inequitably. This places a disproportionate burden on URC members and women by virtue of their smaller numbers and other responsibilities (e.g., number, culture/family, etc.).”

A recommendation to help bridge this gap at the mission level would for be for missions to participate in programs such as NASA’s Here to Observe Program (H2O), Louis Stokes Alliances for Minority Participation (LSAMP) and the NSF’s Organizational change for Gender Equity in STEM Academic Professions (ADVANCE). These are programs that cultivate partnerships with non-traditional institutions to pair students with NASA missions and research by:

(1) Providing access for undergraduate student observers.
(2) Supporting meaningful mentorship activities.
(3) Encouraging peer cohort-building at the institution level.

Areas of improvement: International collaboration

In addition to addressing DEIA in outreach programs, mission teams can improve on inclusion with international collaborators. A subtle and often overlooked issue is the marginalization of international scientists who work on missions with fewer resources or who have no direct mission involvement at all. Research from foreign scientists must be given objective consideration. Politics and cultural differences can contribute to inadvertently alienating or excluding team members without connections to more established institutions that have direct mission involvement. This can and does happen inadvertently, so we note that this is an area of improvement for all of us to consider as it often goes unaddressed.

Recommendation: Mission proposals

Another recommendation at the mission level to ensure that leaders of planetary and space physics missions are actively thinking about inclusion is through NASA Announcements of Opportunity (AOs). AOs could include a DEIA or mission culture plan that clearly defines the principles by which mission team members can operate in an inclusive and equitable environment. Examples include language describing a “code of conduct” and Rules of the Road for missions, inclusive succession plans and practices, leadership expectations, etc.

Conclusion

The MAVEN mission has made significant effort towards maximizing inclusion and engagement on the team and fostering a positive working environment. These efforts are applicable to the space physics and planetary science communities, as well as any large-scale science or mission teams. Specifically, we have found that providing as many opportunities for early career visibility and experience as possible has been a powerful tool for retaining and improving the professional experience of our whole team. We have also found that defining and maintaining the MAVEN mission culture has also served the mission well, including efforts such as implementing Rules of the Road that make data available to the whole team, diversifying our science advisory board and addressing DEIA and mental health issues during team meetings. The MAVEN mission has also made efforts to improve upon communication and accessibility practices through things like uniform gradient brightness colorbars, accessible fonts and alt text.

However, as a mission we need to keep listening and keep trying to improve in our efforts to engage more diverse sectors of our community. We plan to participate in the NASA H2O program to expose and include underrepresented students to working on a planetary mission by shadowing our science team meeting for a week each year. We also plan to produce a written code of conduct, with input from the whole team, to continue and codify our expectations for a positive and inclusive mission culture. As a mission, we can also take these lessons forward to future missions in development, encouraging them to develop a DEIA or mission culture plan. Finally, now and moving forward, we can continue to work with our international colleagues regardless of their mission experience to broaden the planetary community.

MAVEN launched almost 10 years ago and has provided exceptional science from an exceptional team, and much of this success can be attributed to an inclusive and positive mission team environment. We do not have all of the answers to solving DEIA issues within our community but hope some of the approaches and initiatives here can motivate others to take concrete approaches towards inclusion.

Data availability statement

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

Author contributions

The main author, SC is the PI of the MAVEN mission and primarily wrote the article with the inclusion of feedback from the mission team.

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The author declares 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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Perspectives of interpersonal interventions at conferences to promote broader inclusion

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Conferences require a variety of interpersonal interactions starting with conference inception, leadership development, and progressing through organization, the dynamics of invitation, and participation. Thoughtful reasoning along with social connections at the interpersonal level are exemplified in the conference setting where ideas are exchanged and knowledge is shared. This engagement within a welcoming (warm) climate that promotes all voices being heard is essential in broadening inclusion for developing and recognizing a diverse cadre of scientists. Broader inclusion at the interpersonal level can be examined by applying the framework of the social cognitive theory, which considers interpersonal interactions based on many individual personal factors while engaging in an environment and impacting behavior. In this perspective, we share anecdotal experiences from our own involvement hosting (together with colleagues) four small, topically focused Chapman conferences between 2011 and 2016 as part of the American Geophysical Union (AGU). To promote broader inclusion and ethnographically observe outcomes in the conference environment, we look retrospectively at interactions of organizing leadership and participants with respect to diversity, e.g., geographical and cultural diversity, perceived gender, ableism, and disability. Focusing on interpersonal relationships within the conference environment, we highlight where interpersonal interactions and the climate that results can impact inclusive behavior. It is through observation and recognizing the successes and pitfalls that we identified potential key intervention targets.

KEYWORDS

interpersonal relationship, diversity and inclusion, intervention, conferences science, equity

Introduction

Conferences require a variety of interpersonal interactions starting with conference inception and progressing through organization, invitation, and participation. There are increasing calls to promote broader inclusion of diversity in sciences[1, 2, 3, 4] (Puritty et al., 2017; Else, 2019; NSF, 2021), including conferences with broader demographic reporting. Identifying key areas at each interaction that can be targets for intervention to improve inclusion begins with observation followed by action. At each interaction with others, these interpersonal relationships play an important role in individual development. Based on Vygotsky's work, self-development involves the reflective and psychological process of the individual through thoughtful reasoning along with social connections at the interpersonal level. Together, with others, ideas are

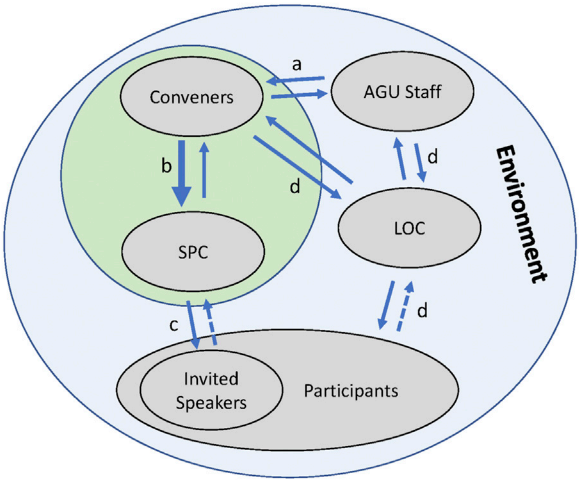

FIGURE 1
The three factors of the SCT (interpersonal, environment and behavior) are applied to our depiction of the conference within the context of AGU organizational structures supporting Chapman conferences. The environment is the large (lightly shaded ellipse). Within, and part of, this environment are the members (in smaller darker shaded ellipses) and their interpersonal interactions (shown with arrows). Within the environment, the convener team engages with leadership (label a), the centralized leadership of conveners invites science program committee (SPC) (label b) and together the team invites speakers (label c). Arrows as interpersonal factors of individual cognitions can be weighted with unidirectional selection or bi-directional interplay and with dashed lines showing potential development. With increased interpersonal engagement at intervention targets, AGU Chapman staff with variable engagement in the environment relying on local organizing committees (LOC) (label d) become more involved forming networks with bi-directional arrows representing interplay within teams. All parts of this environment impact the resulting behavior (inclusion) while engaging individuals in interpersonal interactions to promote diversity.

exchanged and knowledge is shared (Vygotsky, 1962; Vygotsky, 1978) which is exemplified in the prime setting of a scientific conference. When engaging individuals within a collective, broader inclusion can be promoted; thus, these relationships are prime targets.

This development of interpersonal relationships is also shaped by the environment. In this context, the environment is not just the location but encompasses the people with whom one interacts. Abilities to engage in communities, such as a scientific conference, can be examined under the framework of the social cognitive theory. This theory explores the dynamic interpersonal interactions based on many individual personal factors while also examining how engaging with others socially in an environment impacts behavior (Bandura, 1986). Fundamental to engaging interpersonally is the influence of dynamic interactions between individuals through the process of observation, imitation, and modeling with learned cognitions eliciting behavior change. For our purposes, the conference setting and interpersonal interactions within provide the environmental factors that shape those involved at different levels of the conference, i.e., leaders and participants (Figure 1). To broaden inclusion, we must recognize how the diverse makeup of engaged members contributes to these interactions and that many of the outcomes sought are only achievable in a collective (Bandura, 2000).

We need diversity at the leadership levels to improve the collective. Evidence supports that engagement in interpersonal relationships aids in advancing diverse scientists and that collective intelligence with more diverse teams improves scientific outcomes (Woolley et al., 2010). Collaboration is paramount for scientific rigor and the development and retention of diverse scientists with a variety of perspectives and identities (Nielsen et al., 2018). The collaborative context can be within a team in research or co-authorship in publication (Hanson et al., 2020). Networking helps build scientific career advancement (review Hall et al., 2018). There is a need for cross-gender social ties in teams to prevent exclusion from the benefits gained professionally (Cyr et al., 2021). A welcoming culture and warm-climate promoting all voices is essential for inclusion to happen (Biggs et al., 2018), and this is achieved at the interpersonal level. Particularly as the scientific society moves to promote inclusion, this social exchange within the environment of scientific conferences is a key point to observe what has worked and what falls flat in fostering an interpersonal culture where scientists share and develop scientific knowledge. Then, interventions can target key gaps.

Likewise, until the recruitment and retention of diversity of the collective is addressed, we will continue to have lower numbers of women and other underrepresented groups in the talent pool that could move into the leadership roles (Seymour and Hewitt, 1997; Seymour et al., 2019). We see from the AGU data that from recruitment of STEM majors in colleges/universities, attrition begins as early as the first transition point to early-career scientists and at each subsequent step in the career pathway.[1,5] The top-down model of diverse leadership is not fully supported until the bottom-up model is addressed to increase the pool of talent. This pool of individuals can be over-tapped if the pool remains limited raising this as a key AGU strategic goal.[4] Regardless, increased recruitment and retention must be addressed at all levels as broader diversity benefits the collective.

Building on the SCT, which focuses on individual and interpersonal exchanges, another model, the social ecological model (SEM), provides a broader framework to explore how the lower levels of individual and interpersonal relationships fit within a broader structure (McLeroy et al., 1988). Within this multilevel framework, the interpersonal level is a key intervention point for behavior change (Golden and Earp, 2012). Taken together, it is especially useful for both models to document observations including anecdotal reports and then develop and implement interventions targeting a key determinant to change behavior within the conference environment. While what we observed can apply to many different types of conference settings, we focused on those of the American Geophysical Union (AGU) with their small, topically focused Chapman conferences.

Since AGU is committed to promoting an inclusive environment with a focus on diversity, equity, and inclusive (DEI) practices and policies, this search for understanding lies within AGU's strategic diversity plan.[4] This involves tracking demographic data[5] for members and other means since 2014 to understand our demographics, including scientists with global affiliation and international perspectives from 147 countries.[1]

Another goal is to educate membership about broader objectives in diversity, equity, and inclusion.

Here, in this perspective, we share anecdotal experiences from our own involvement hosting (together with colleagues) four AGU Chapman conferences between 2011 and 2016. To better understand broader inclusion and better outcomes in the conference environment, we look retrospectively at interactions of organizing leadership and participants, e.g., perceived gender (woman/man and other LGBTQ identities), geographical and cultural diversity, ableism and disability, and noted challenges faced even when inclusive efforts were made. From within, we ethnographically explored the roles of engagement and dynamic interplay that is possible at the interpersonal level of conference leadership and organization with steps to develop a culture and create more welcoming climates as being critical in retention of diverse participants. Since conference participation and networking, and more so, invitation to participate on the science program committee (SPC) or as an invited speaker are linked to recognition in tenure and promotion (Kalejta and Palmenberg, 2017; Klein et al., 2017; Hall et al., 2018), the conference environment that impacts diverse participation is a significant area to investigate.

Through this process, we identified points we considered successful, as well as instances where the conference environment fell short and potential key intervention targets for the future. We focused on interpersonal relationships encompassing the SCT personal factors (interpersonal), environment, and impacts on behavior. This conference environment continues from conference inception, leadership development, invitation dynamics, and participation with the various players involved. It not only includes the structural location but also encompasses the people who make up the environment, their interpersonal interactions, and the climate resulting from these interactions.

Inception and convener leadership

At the level of conference inception by a convener, or convener team, proposals are made to AGU Chapman. Some interpersonal interactions at this level include discussions among the AGU committee for selection of proposals. Exactly how the larger organization selects proposals, approves how many they can support in a given year, and seeks locations for hosting the accepted proposals could be intervention targets. Different models exist for the level of exchange between the supporting administrative staff and the convener leadership (Figure 1, label a). It could be at this point that some intervention training could take place for conveners. For example, the proposal onset is a good time for AGU administration to start by building rapport and trust with the proposing convener(s), understanding the levels of inclusivity with which the conveners are familiar, and presenting opportunities for training against bias. Enhancing relationship building between administrative and convener levels could already promote inclusion. For example, simply raising awareness, providing resources, and helping conveners consider their next steps in selection could be an intervention target to promote diversity. Offering resources and training is one approach, but better interpersonal interactions would play a greater role in the information being perceived by conveners as supportive rather than top-down demands. This is especially true if the proposal has less diverse representation than would be recognized as being inclusive. In this case, nudging from the administrative level for the conference leadership team to be more inclusive and diverse may be needed, e.g., seek more balanced gender or racial/ethnic representation on the SPC.

Through observation, imitation, and modeling of how to counter bias and reach beyond for a more diverse team, the leadership team develops cognitions which results in behavior change as applied to Bandura's SCT. As an example, suggestions could be better received if the conveners have ideas of how to counter bias and learn and think about their choices of invited SPC, and ultimately the team's decision would also impact the diversity of the speaker roster. If a convener makes all top-down decisions, then there may be more potential for bias and for missing out on all the creative ideas a diverse team collective could bring. If a team is diverse and made aware of bias, this also could enhance greater accessibility. However, interpersonal connections with AGU staff are also valuable. If the relationships break down between these organizing levels, efforts for inclusion can disintegrate. For example, conveners themselves may have carefully planned efforts for inclusion that do not go forward when administrative oversight fails to support them, e.g., accessible locations, icebreaker activities, on-site access, and funding support distribution. In either case, this impact on inclusion and diversity comes through interpersonal interventions.

What is meant by inclusion can vary. From our perspective, as part of organizing teams for all four Chapman conferences, we inherently knew that enhancing diversity was important but still this involved a learning process. Through our growing experience, we saw the value of understanding how key environmental and structural factors such as geographic location, cultural (racial/ethnic) diversity, range of gender representation, and on-site universal access accommodations for those who identify as disabled would benefit inclusion of diverse participants. Recognizing the global reach of the space physics community, we sought locations that would support broad geographic and cultural diversity, representing the diversity in our scientists from around the global community.

Thus, as part of our convener proposals, specific structures within the conference environment were planned with interpersonal interactions as represented in Figure 1, labels a–d. Conference locations were proposed after we had already inspected them with the local organizing committee (LOC). Not all conference models use this process of site selection or fully support networking activities as proposed, but the interpersonal interaction therein is part of the structural environment in the SCT. Furthermore, within the SCT, the structural environment included interdisciplinary scientific participation among solar and heliospheric scientists, and magnetospheric and ionospheric scientists for Earth and other planets. By bringing together scientists from three interdisciplinary areas, unique relationships could be built. Conveners representing different interdisciplinary fields were invited. With this merging of these distinct areas, icebreaker activities were planned as necessary in building interpersonal interactions across disciplines. Often these activities included excursions, cultural programs at banquets integrated from the different geographic regions the conference would take place, and at our most recent Chapman conference, even specific inclusive learning opportunities were proposed and implemented. The LOC engaged with conveners and participants to facilitate both individual needs and interpersonal interactions.

We proposed and intuitively incorporated accessibility in various ways, such as collective access transport arranged for those in need but available to all. However, as society was progressively learning more, we were also learning more and increasingly felt the need to be more intentional in our efforts toward inclusive efforts for diversity. What might have initially been wishful thinking for inclusion produced more happenstance leadership teams, diverse in some ways but lacking in others. The process of invitation now involved a closer look at inclusion of more women, diverse speakers and participants from geographic locations and cultures, provision of access for disabilities, and conference construction to promote a warm climate for all intersectional identities including racial, ethnic, gender, and sexual identities identifying as non-binary or LGBTQ. Knowing we could always learn more, and even now in the midst of organizing a fifth Chapman conference, observations were made and strategies employed as each conference posed new challenges and ways that interpersonal interventions could be used to promote inclusion of diverse participants.

Certainly, as the administrative host is engaging with the initiating convener and the developing convener team, this is a key interpersonal target. Even as inception may begin with one convener and the invitation and merging of ideas results in a convener team, one must observe how this interpersonal process occurs to be aware of, and perhaps prevent, homophily with an all-one-trait leadership team and downstream, homogenous speaker rosters from occurring. Not only is the phase from proposal acceptance a key time for education of the initiating convener, but also anti-bias training of all conveners and their whole leadership team. These early steps are key interpersonal interactions worthy of intervention.

Convener selection of the science program committee

The recruitment of scientists to develop the SPC and the interpersonal relationships within while developing the science program are key intervention targets. AGU Chapman conferences follow a centralized model (Figure 1, label b). This is centralized in the sense that conveners invite SPC and together the leadership team invites conference speakers, as opposed to a decentralized model at a larger meeting with many teams, and each separate convener team is independent in decision-making inviting their own speakers. Together the conveners with the SPC form the conference organizational leadership and act as a decision-making team. Through team effort, the SPC assisted with the scientific theme, identified and invited speakers, later selected speakers and created the program, and often acted as chairs conducting the session. This is a key intervention point to not only enhance interpersonal relationships between leadership team members themselves but also increase diverse representation and promote all having a voice when working on the program development task which will ultimately impact the downstream participants.

Within this structure, interpersonal relationships between these leadership levels could create interplay with all voices heard and on task to enhance inclusion. We applied the SCT framework to Figure 1 to suggest with bi-directional arrows that interpersonal relationships at several key points in conferences can be key targets for interventions. For inclusion to occur, we advocate that steps could be taken to build community first before the task of selection occurs. At this stage, we advocate for training in anti-bias selection for greater diversity and inclusion.

At this stage of convener invitation of SPC, it is easy to fall into the pattern of thinking first of those one knows. This includes work colleagues, those who rub elbows at conferences, by referral from someone else, or simply by a paper read recently which could additionally lead into the trap of falling into citation bias in which underrepresented groups may have lower acceptance rates and fewer citations (Lerback et al., 2020). Inexperience may lead one to think that selection is solely based on merit and is sufficient but could be problematic in resulting in its lack of diversity since these systems are flawed in bias as well. Based on a modeled heuristic by Tversky and Kahneman (1973), this selection choice results simply by who comes to mind first and can result in a form of bias. When faced with many choices, the natural instinct is to simplify the decision. Since demographically, fewer underrepresented choices exist, the probability is higher that the person making the choice defaults to their more likely choice of someone like themselves and homophily perpetuates (Lazarsfeld et al., 1954; McPherson et al., 2001). In addition, the higher probable number of choices who come to mind are increased by the frequency of repetitions of encounters. Known as the *Matthew effect*, those who get invited to speak more, are cited more, gain more fame, and are invited more. This results in a positive feedback pattern that perpetuates when scientists with advantage and success tend to have more advantage and success over time and a widening gap with those having more initial disadvantage (Merton, 1968). To counter this bias at the stage of invitation to SPC or invited speakers, proactively creating ranked lists of expert, speaker, and potential reviewers can help (Nielsen et al., 2017; Nielsen et al., 2018; Vallence et al., 2019). Lists can highlight those in the community with strengths and consider many more qualified possibilities for invitation that can often be overlooked if selection is made based on those who come to mind first.

Since the scientific leadership plays a key role in achieving diversity/inclusion goals, this convener/SPC relationship is an important target. If a community culture is developed in which all team members have a voice and are tasked with responsibilities, then together while determining programming and creating a warm climate, inclusion of diversity can be better achieved. This social structure is central to Bandura's SCT that behavior is influenced by the interpersonal interactions and the environment making it another key intervention point. Key steps in building interpersonal relationships can include starting a collaboration with conversations of identity, work styles, and communication styles to build community. In starting the conversation (Smith-Keiling et al., 2020), some identities may still remain hidden, but it is helpful to know if any additional accommodations for disability are needed such as extra time on tasks with migraine, visual screen readers, or other needs. Sometimes identities are shared upfront, such as being the primary childcare or eldercare provider, but sometimes identities remain hidden. By knowing work/life constraints that people are more willing to share, such as teaching semesters or grant deadlines, timing can be better planned. In the case of working teams, starting the conversation about projects, identifying strengths and weaknesses in certain tasks, and recognizing the biases we hold are useful to increase community.

The SPC also needs to have a level of understanding of bias as well as strategies. Tying in Bandura's theory of the individual to the interpersonal, each SPC member's individual level of increased knowledge and increased skill in reducing bias becomes an intervention target. Interventions at this SCT level target not only the level of individual training and knowledge of bias but also the self-efficacy (ability) of the individual to act (Bandura, 1986). Training in how to be more inclusive, recognize and resist bias, and create inclusive interpersonal communities can increase knowledge in an individual, but through teams, the social support enhances the collective ability to increase inclusion. Thus, if training is introduced in the form of an interpersonal intervention, then as the team together attempts to broaden inclusion while working on the task of program development and invited speaker selection, the challenge of inviting a broader diversity of speakers can seem less daunting. Building interpersonal relationships includes crossing cultural boundaries—especially since inclusion and bias can have different understandings in different cultures.

Cross-cultural, anti-bias, and inclusive training, not described here, is beyond the scope of this perspective, yet even here we recognize that we felt ill-equipped to provide this training ourselves early on and a diverse leadership team was not as fully realized as one would hope. For example, while our convener and SPC leadership teams were diverse in some sense of geographical and cultural makeup, the number of women was lower than hoped. Of our four Chapman conferences, only one had a woman convener. Efforts to increase women on the team often fell flat. We also encountered cases when we lost a woman as convener, or lost women SPC members on the leadership team after recruitment. We questioned ourselves. Had the team built more community at onset, perhaps this would have prevented loss. Alternatively, women as underrepresented members were simply over-recruited and became over-committed. As often happens in populations that are in the minority, being over-tapped can lead to lower acceptance of speaking presentations or other opportunities when invited (Else, 2019). Even when the leadership team was prompted to seek additional women, it was not enough to simply ask the team to think of more women to invite without providing tools in how to do so. Again, earlier intervention is essential.

Of the leadership including SPC, not all of our four Chapman teams had women. One with no women at all was the earliest planned team and fell into the homophily trap of inexperience and inviting those the convener knew. The other three (and a fifth currently being organized) had increasing numbers of women, but still lacked certain ethnic representations. Without having any firm data for comparisons at the time for gender, we were limited to how our gut feeling target and our average number of women of approximately 20% might fit with the true demographic. Knowing there was literature on attrition of women in space science, even these numbers were based on perceptions (only considering binary man/woman gender perceived woman, or female presenting) since we had not asked identities at the time. Because of lack of self-reported identity, only perceived binary gender, racial ethnicity, and other demographics were inferred by name and by our personal contact at our conferences. Demographic data were not collected for Chapman conferences. This lack of self-identified data is within a changing paradigm with an imminent need for better identity-based data collection. Current omission leads those of non-binary gender identities and racial/ethnic identities to often feel excluded, and even violated. Certainly, we advocate for the changes now being made to rectify this erasure, and many scientific societies have begun to identity collection as anti-racism and anti-othering approaches to inclusion (Segurra-Totten et al., 2021; Burnett et al., 2022).

Before 2014, gender and other demographic data were neither collected by AGU, nor for Chapman. Numbers based on the AGU membership 2018 section demographics report,[5] as referenced by the Honors Diversity Report,[6] provided us the best snapshot to compare our retrospective analysis with current demographic data of self-identified women. With AGU membership (2014–2018) of approximately 60,000 members, women make up between 26% and 30% in both Earth and Space sciences and range approximately 23% in space sciences (early career students to experienced career stages) with attrition increasing with advancing career stage. For example, attrition from the mid-career stage (18%–23%) to experienced women (around 9%–13%) shows significant drops in the fields of Planetary sciences, Solar and Heliophysics, and Magnetospheric physics, representative of the Space science fields that attended our Chapman conferences. For our four conferences overall, women matched membership data of approximately 20% for participants and scientific organizing committees but not always for invited speakers and not at the convener level. This step in invitation is a prime interpersonal intervention target.

As we examined some of the challenges faced in engaging and retaining a number of women above this 20% mark for our own conferences, we recognized the career stage with lower proportions of experienced women (9%–13% in areas) was the pool from which we would invite. With the disproportional attrition of female scientists in space physics fields as academic rank progresses, this "leaky pipeline" (Alper, 1993; Popp et al., 2019) helped us better understand why we often struggled to get more women involved at the leadership levels and suggested looking toward invitation from the higher proportion pool of early-career scientists. Another factor playing a role in interpersonal relationships is the concept of reaching "critical mass" with sufficient numbers of underrepresented identities to promote social support. Teams need more than simply the 'token' numbers of underrepresented peoples. Even if we reach critical mass for effective teams between 15% and 30% (Cain and Leahey, 2014), the collective intelligence of the team is lower if a few people dominate rather than turn-taking (Woolley et al., 2010). Sometimes having enough overall diversity can circumvent feeling like the token representative, but if, for example, all members are white-presenting regardless of other identities such as gender or non-binary gender representation, then this also poses a gap in diversity along the ethnic/racial identities. Needless to say, we found difficulties in reaching numbers of women and other identities that would either reach critical mass or reach an equitable mark of AGU membership. Just as we continue to build inclusion and grow our community to be closer in equity of women and other underrepresented scientists, we will hope that as the community grows, so will our pool of available leaders as conveners and SPC members who will continue to act as mentors for the ongoing and future generations. Again, we suggest building early-career networks as a target. Evidence for supporting early-career networks lies not only in the benefits of mixed teams but also in the benefits of long-lasting impacts of networks (Lerback et al., 2020). The 2018 data[5] for the AGU section of space physics and aeronomy reporting (female students of 35.57% to male students of 64.18% in space physics) suggests lower recruitment, and taking into account the attrition of experienced women who are more likely in leadership roles while recognizing the higher participation of women students at the transition point to early career suggests the need to promote early-career interventions for their retention. Thus, interventions increasing women leadership participation is vital now to provide the mentoring needed for retention and is a key interpersonal intervention point at conferences for future invitation and growth of our leadership talent pool.

We questioned how our leadership gender distribution compared to other Chapman conferences. Investigating 60 Chapman conferences (spanning 2007–2019), which included our four conferences, we found that the presence of women conveners leads to more women present on the SPC (Keiling and Smith-Keiling, 2023). When there was at least one woman as a convener, it increased the number of women SPC members and the likelihood of all-men SPC was reduced. On average (perceived binary gender by name), the women proportion was less for conveners (17%) than for the SPC (24%). On average, mixed convener teams, as opposed to all-men convener teams, selected more equitable women representation among the SPC members. It was shown in another study that looking at invited speakers in a decentralized model, where many sessions at a larger conference were independently organized by different convener teams, more women in the SPC led to more women in the invited speaker roster (Casadevall and Handelsman, 2014). Taken together, one can see that the interpersonal leadership levels are a key target.

Perhaps 20% of the self-identified women in the leadership would indeed be representatives of equity based on membership data, but this is a far cry away from parity 50:50, nor would this take into account other non-binary gender demographics and other underrepresented groups with varied intersectional identities (Cech, 2022). Diversity of the SPC included members representing global, cultural, gender, and other diversity. It can be advantageous to have people in your team you know, but it can be equally rewarding to have people in your team you do not know. We advocate for the latter to reach the unexpected and to increase the collective intelligence, and take advantage of the trickle-down effect of more women and other diverse groups at the top conference leadership impacting downstream efforts in inclusion.

Leadership team selection of invited speakers

As selection of the SPC by the conveners creates a positive, welcoming "warm" climate of the team, this invokes an interplay or two-way exchange of ideas and can reduce bias within. Subsequently, their actions in the selection of invited speakers also increases diverse representation and participation downstream (Figure 1, label c). Since the number of women comprising the conveners appears to impact the composition of the number of women on the SPC (Keiling and Smith-Keiling, 2023), and when there were more women on a selection team, more invited women speakers resulted (Casadevall and Handelsman, 2014), then the broader impact of the team on downstream effects is important. Despite both studies only looking at proportions of women based on perceived gender and binary man–woman scale, these data demonstrate how important the training is in early stages of formation and potential for bias in the invitation of speakers.

Numerical proportions are one way to consider these impacts but another is to consider the interpersonal dynamics within the team. Just because women are on the team, does not mean there is no bias, or that by increasing the number of women on the organizing team, all would have a voice. It is also important to specifically give each responsibility and power to complete the task to find speakers. For example, since our SPC represented global, cultural, gender, and other diversities, as well as represented the interdisciplinary conference themes, shared voice was especially important. Conveners asked SPC to invite speakers from their respective fields. Conveners alone did not always have sufficient expertise and ability to pull together a diversely represented program alone. Hence, the centralized model utilizing the expertise of a multidisciplinary scientific program committee was invaluable, and it was vital to have leadership team members who could strongly lead to knowing their respective communities, invite speakers, and develop the program with inclusion in mind.

Just as a non-gender-biased speaker list can be valuable in inviting leadership, a methodological approach with lists could be employed for invited speakers (Nielsen et al., 2017; Nielsen et al., 2018; Vallence et al., 2019). However, we may still hit roadblocks of reaching equity with the same challenges in lower numbers of speakers that we saw in leadership. For example, sometimes, even when the convener asked the program committee for broader gender representation, we only gained a few more names at most. Sometimes, the invitation went to women, but our anecdotal evidence stems in the lack of positive response and even retracted commitment and withdrawal by women to act as conveners, SPC, and invited speakers who outweighed responses compared to men. Another example when conveners requesting input from the SPC and continuing not to hear any emails back, may indicate that some were no longer participating, resulting in discussions for their removal from the SPC list. Again, community-building may have mitigated this loss. Several studies document that some underrepresented groups tend to be invited less, but also some when submitting abstracts, tend to request posters over talks (Ford et al., 2018; Else, 2019; Ford et al., 2019). We considered who in our conference programs had declined invitations or withdrew participation, and primarily they were women as an underrepresented group.

Thus, as with leadership selection and interpersonal team development, then selection of invited speakers could also be an intervention target by enhancing mentoring. This is represented in Figure 1 with a bi-directional dashed line as those in the leadership role model positions could act as *de facto* mentors in new interpersonal relationships. Since conference participation and networking are beneficial for career advancement and retention, several studies have reported on this level for intervention (Casadevall and Handelsman, 2014; Kalejta and Palmenberg, 2017; Klein et al., 2017; Ford et al., 2018; Hall et al., 2018; Hanson et al., 2020; Zellner et al., 2022). All of the interdisciplinary fields represented at our four conferences were comparably limited in the numbers of mid-career to experienced women. AGU demographic data provided some reasons why gender balance was a struggle to get higher numbers from the pool of experienced women scientists. The invitation of early-career scientists would help solve this challenge of attrition, making it easier to find speakers, which also provides an opportunity for early-career scientists' career advancement. These experiences showed how valuable the SPC was in inviting diverse speakers for inclusion, but we posit that interventions enhancing knowledge and skills, and that all have a voice will achieve the impacts we seek in broader inclusion and greater diversity. This begins at the early student recruitment stage, increased student and early-career funding to conferences, and promoting interpersonal networking opportunities to support their next transition.

Interpersonal engagement of the local organizing committee

Conveners and SPC themselves build their own interpersonal relationships along with administrative staff and local organizing committee (LOC) consisting of non-AGU staff who are all part of the environment (Figure 1, label d). The LOC helps integrate the conference into the physical environment of place and the cultural setting in which the attendees will engage. We, acting in this role, along with local representatives, provided pre-conference support by providing insights into the inner cultural workings of the society in which the conference was being held. We acted on-site in an interpersonal manner with participants. When brought into the conversation about inclusion, some LOCs have been instrumental in planning inclusive events and providing access accommodations that promote inclusion as a key intervention point. Interpersonal strategies at our four conferences included icebreaker activities with an icebreaker event, shared meals, and specific scientific social hours for networking. These interpersonal interventions targeted all participants.

How might the LOC in charge of local logistics improve inclusion can vary with the level of experience and what is being asked. For example, conveners can request accessible locations. To pre-ascertain conference participant needs, a pre-survey at registration that helps prepare for case-by-case accommodations, e.g., bus transport, lactation room, and gender-neutral bathroom, as is typically carried out for dietary needs but could be expanded. We employed the concept of universal design with collective access. For example, bus transport planned for everyone in case of rain was valuable even for individuals with limited walking ability who used it but still provided collective universal access for all while also reducing stigma for the person with disability. In cases where larger buses did not need to be arranged in advance, then smaller shuttles and taxis were pre-planned in case of need. One cannot always plan for everything, such as surprises in the case for mandatory Ebola monitoring or additional measures for COVID-19, both of which we encountered. The LOC as part of the environment through interpersonal interactions can provide several intervention points to broaden inclusion and diversity.

Summary: tying together the interpersonal within the environment

Diversity at conferences cannot always be happenstance and should take a more concerted inclusive effort as we learned firsthand with each conference having different challenges with successes and pitfalls. Several examples within the SCT have been presented for how all these interpersonal interactions within the conference environment can impact behavior. The structures, the people involved, and the processes of communication all play a role. Even with the best intentions, goals are not always realized.

One may attempt to promote diversity of underrepresented groups by being inclusive, but while having success in one manner, fall short in another. In one of our own conference examples, when it was recognized that we had no woman convener or woman SPC member, then at any point an intervention could have prompted conveners to keep looking for more diversity and promoting inclusive practices. This unfortunate lack of representation at the leadership was actually the earliest conference proposal made by the lead conveners who at that time were focused on broader inclusion of a new geographic cultural location and their first time hosting this magnitude of conference. Due to this change of location and focus on cultural diversity, the focus on gender diversity on the leadership team was missed. Moreover, homophily played a strong but unintentional role in invitation. Although there were still women invited speakers comparable to our other conferences, it was clear that conveners were so focused on geographical and cultural diversity, that gender was missed at leadership levels. Thus, at these early stages of conference planning, when there was no AGU Chapman staff oversight nor policy in place, an intervention would have helped.

Likewise, sometimes the focus on gender inclusion can obscure other inclusivity even when attempts are made to include diverse voices. For example, in another conference series (with which the first author has great familiarity), the Society for the Advancement of Biology Education Research (SABER), the organizers were so focused on including women and inclusive LGBTQ identities in leadership, that ethnic and racial identities were missed. This conference society was initiated primarily to address a gender gap. With more women in leadership and participation, this was a great boon in addressing gender disparities compared to many other societies (M. P. Wenderoth, personal communication, 10 July 2022). However, even while the leadership at its 2010 inception of this new scientific society strived to incorporate diversity from a range of career stages, editors, and a wide US geographic range for input, some inclusion was missed. The group of 29 initially invited scientists comprised over 70% women (Offerdahl et al., 2011), looking good on the surface. This initiative may have countered the lack of representation of women found in other scientific societies; however, it also raised awareness that all members of these early conversations of the organizational meetings were white-presenting (with no individual ethnic or racial identities). This recognition of the lower ethnic and racial diversity in the growing membership of this new conference society, along with dramatic 2020 societal events, further propelled demands for broader inclusion and justice for other marginalized groups, leading to a response by taking an anti-racist approach to greater inclusion (Segurra-Totten et al., 2021). Thus, while here we are raising issues focusing on women, and even raising up the need to be more inclusive to all genders, this example highlights similar challenges that other STEM fields face. Even when focusing on one aspect of inclusion but overlooking another, this gap in cultural humility awareness no longer provides an excuse if we are mindful at the onset of these traps in not addressing broad inclusion.

It is important to consider gender-presenting proportions with the available data, despite still lagging even as identity-based data collection increases. Analyses based on limited gender data available is a starting point, but we need to emphasize the importance in taking the next steps in data for promoting broader inclusion of underrepresented groups. In addition, AGU has extended gender identities and other demographics in membership data[1]. Lessons learned for participation of women can be more broadly applied toward inclusion of non-binary gender identities and racial and ethnic underrepresented groups and provide universal collective access that benefit those who identify with disability but access available to all even if identities are not disclosed. The bigger picture considers all racial, ethnic, and cultural representations on a global scale and takes anti-racist approaches (Ali et al., 2021).

This perspective highlighted key points where intervention strategies could help meet several goals and conferences overall develop more inclusive measures at the level of interpersonal interactions. It may be that what one remembers from a conference is the science, but more so, it includes the interpersonal interactions experienced combined with the feeling and knowing that they belong. However, without an inclusive system promoting the equitable sharing of diverse viewpoints, many creative ideas and perspectives are lost to the broader community. We need broader participation, and we propose that by enhancing interpersonal relationships, increased inclusion and diversity will follow in attempts for equity.

1 American Geophysical Union. (2022). AGU's Diversity, Equity and Inclusion Dashboard. Retrieved from https://www.agu.org/-/media/Files/Learn-About-AGU/AGU_DEI_Dashboard_2021_baseline_demographic_snapshot.pdf
2 Retrieved from https://www.nsf.gov/od/oecr/diversity.jsp
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Data availability statement

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

Author contributions

BS-K and AK documented anecdotal observations. BS-K was the primary author and led the conceptual application of theory for the manuscript. Both co-authors contributed to editing and refining the document. All authors contributed to the article and approved the submitted version.

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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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Diversity in the space physics community: an overview of collaborative efforts led by The University of Alabama in Huntsville

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The field of Space Physics has significant recruitment potential. Almost everyone has been fascinated by space in one way or another since their early childhood. From this perspective, Space Physics might be expected to exhibit considerable diversity as a discipline. Regrettably, as in many STEM fields, the reality is quite different. Numerous reasons have been advanced about why the reality and the expectation diverge but one observation we have made over the years stands out, and, that is, that when students are given the opportunity, they are very eager to learn about Space Physics and enthusiastic about working on space physics projects. At The University of Alabama in Huntsville, we have developed a series of outreach programs, including summer programs, that are aimed at bringing students not typically exposed to space physics into the Space Physics community through working on real research projects that have the potential to produce journal publication results. These programs have been very effective in creating interest in Space Physics and have led to the recruitment of students that have been underrepresented historically into our research programs. In this paper, we summarize the various summer programs that the Center for Space Plasma and Aeronomic Research and Department of Space Science at The University of Alabama in Huntsville have been organizing in Space Physics for years and how these programs have contributed to increasing diversity in the field.

KEYWORDS

space physics, diversity, summer programs, ALPIP, ALREU, CIPPTA, ISWC, REU

Abbreviations: ALPIP, Alabama Plasma Internship Program; ALREU, Alabama Research Experiences for Undergraduates; ASU, Alabama State University; CIPPTA, Corporate Internship Program on Plasma Technology Applications; CPU2AL, Connecting the Plasma Universe to Plasma Technology in AL; CSPAR, Center for Space Plasma and Aeronomic Research; DEI, Diversity, Equity, and Inclusion; DLR, German Aerospace Center; FTPP, Future Technologies and Enabling Plasma Processes; HBCU, Historically Black Colleges and Universities; ISWC, International Space Weather Camp; MSFC, Marshall Space Flight Center; PPPL, Princeton Plasma Physics Laboratory; REU, Research Experience for Undergraduates; SANSA, South African National Space Agency; SPA, Department of Space Science; SULI, Summer Undergraduate Laboratory Internship; UAB, The University of Alabama at Birmingham; UAH, The University of Alabama in Huntsville.

1 Introduction

Diversity, Equity, and Inclusion (DEI) metrics in the Space Physics research community have been documented by the American Geophysical Union (AGU) which is the world's largest society in geophysics. According to the AGU's DEI Dashboard[1] that is, based on self-reported demographic data of AGU members in 2020, AGU members predominantly consisted of white men. The specific breakdown is 60% male and 28% female, based on self-reporting, with 54% white, 6% Asian American, 4% Hispanic Latino, and ~1% black; and 50% between the ages of 30 and 59, and ~18% under the age of 30 years old. These demographics data are based on AGU members from 146 countries with the following distribution: 61% United States, 16% Asia, 15% Europe, 6% Africa and the Americas, and 2% from Oceania. The latter data shows that the majority of AGU members come from the United States, Asia, and Europe. **Figure 1** is a graphical representation of AGU diversity and gender breakdown. These pie charts provide a more global perspective of the demographic data that we present below in analyzing the demographic and gender results from our summer programs. If we wish to look at demographic data at a national level, Europe's biggest, and the world's third biggest, contributing country to AGU publications in 2020, the United Kingdom, is a good choice. The report entitled "Demographics of the United Kingdom Space Sector"[2], published in 2021, presents the first comprehensive demographic statistics for the United Kingdom space sector. United Kingdom women and ethnic minorities are again significantly underrepresented, corresponding to 29% and 11%, respectively, in the space sector population. These two representative datasets illustrate that women and ethnic minorities are significantly underrepresented in the Space Physics national and international communities. A question frequently raised but not typically addressed very concretely is how an individual institution such as a university or a small coalition of university and laboratory partners makes a difference to DEI in, e.g., space physics. As we discuss further below, we take this question and try to build a strategy for addressing DEI at the local level instead.

While the question of DEI in a particular discipline, be it space physics or plasma science and engineering (PSE), is self-evidently important when considered nationally or internationally and has attracted considerable discussion, our experience, particularly that of the second author, is that discussion focused largely at a national level does very little to address problems on the ground that a typical department chair faces in trying to actually increase the number of woman faculty or diversify the student body. For example, we have found neither the American Physical Society Bridge Program[3] nor the AGU Bridge Program[4] particularly useful in improving DEI for the Alabama university consortium discussed in this paper. Accordingly, we have adopted very practical approaches in trying to improve diversity in our local and rather small part of the world, and identified what needs to be done to achieve a desired DEI outcome.

Support for our DEI and outreach efforts derives from two National Science Foundation (NSF) programs, an NSF Research Experiences for Undergraduates (REU) grant and two successive NSF EPSCoR Track-1 grants. The first of the NSF EPSCoR RII Track-1 grants was entitled *CPU2AL: Connecting the Plasma Universe to Plasma Technology in AL: The Science and Technology of Low-Temperature Plasma*. The NSF EPSCoR Project[5] CPU2AL aimed to enhance low temperature plasma research (including important elements of space plasma physics) in Alabama by building a partnership comprising nine universities and a research corporation in Alabama (Alabama A&M University, Alabama State University (ASU), Auburn University, CFDRC, Oakwood University, Tuskegee University, The University of Alabama, The University of Alabama at Birmingham (UAB), UAH, and University of South Alabama). CPU2AL is led by UAH (G.P. Zank is the principal investigator on the grant). A new NSF EPSCoR RII Track-1 grant was awarded in mid-2022 entitled *Future Technologies enabled by Plasma Processes (FTPP)*[6], also led by UAH with the same consortium of AL universities and principal investigator.

To set sensible goals and make meaningful progress, we began with a baseline assessment of the state of DEI in our CPU2AL and FTPP consortium institutions. The baseline assessment included faculty, researchers (including post-docs), and student participation in PSE-related fields. In this paper, we focus on the recruitment of the youngest members of the Space Physics research community, viz., undergraduate and graduate students in STEM fields (additional goals of both CPU2AL and now FTPP were/are, e.g., to increase the diversity of the faculty in our universities, which has proved very successful but this is a separate discussion). One of our major goals with the three NSF programs was to make measurable sustainable improvements in the gender and ethnic diversity of the STEM pipeline and workforce in Alabama, as well as educating the AL general public about PSE. Demographic data from the AL consortium (Alabama A&M University, Alabama State University (ASU), Auburn University, CFDRC, Oakwood University, Tuskegee University, The University of Alabama, The University of Alabama at Birmingham (UAB), UAH, and University of South Alabama) was tabulated in terms of gender, underrepresented minorities (URM), including African American, Hispanic, first-generation, and female, for faculty, researchers, and students alike. The baseline assessment provides an understanding of the immediate local demographics, which enabled us to develop a specific set of five-year quantitative individual diversity goals (URM and female) (first for the CPU2AL and now for the FTPP program). These goals were based on assuming 1) an ~10% growth in graduate and undergraduate populations, and 2) an additional 10 undergraduate and 10 graduate positions attracted by a proposed set of AL-wide five new faculty hires (this equally important component of diversifying the faculty resulted in the UAH Department of Space Science increasing their woman faculty from 0% to 33% of the Department in the 5-year period of our NSF EPSCoR CPU2AL program). For example, our FTPP goals are to increase the number of undergraduate students working with PSE-related faculty at the 9 FTPP-associated universities from a total of 57 to ~69, increasing

1 https://www.agu.org/-/media/Files/Learn-About-AGU/AGU_DEI_Dashboard_2020_baseline_demographic_snapshot.pdf

2 https://spaceskills.org/public/docs/SSA%20Demographics%20of%20the%20UK%20Space%20Sector%202021.pdf

3 https://www.aps.org/programs/minorities/bridge/bridge-inst.cfm

4 https://www.agu.org/bridge-program

5 https://www.uah.edu/cpu2al

6 https://alabamaphysics.com/

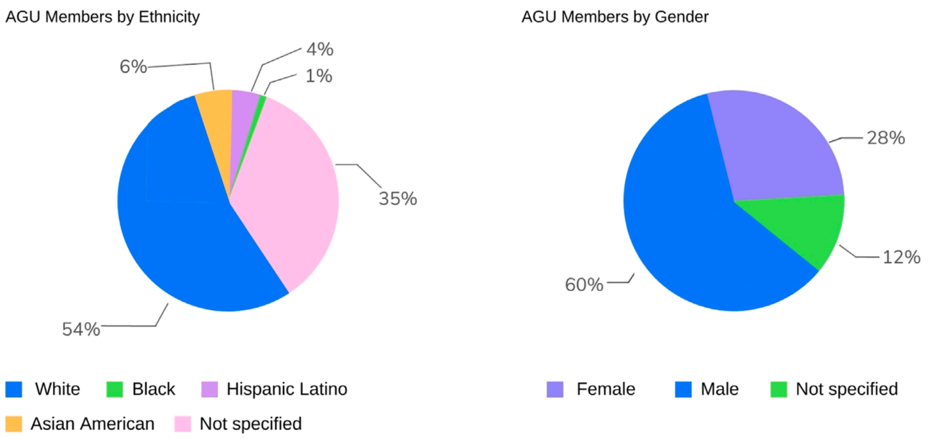

FIGURE 1
Summary of demographic and gender data for the American Geophysical Union (AGU) according to their DEI Dashboard[1].

the number of African American undergraduates from 11 to ~13, Hispanic undergraduates from 0 to ~2, female from 18 to ~22, first-generation from 17 to ~19 with the balance of 2 from expected growth. A similar analysis was performed for our graduate students.

Our goals are to have our summer programs 1) increase the female and URM undergraduate student population in AL PSE and space physics, and 2) transition a significant fraction of that undergraduate student population to graduate PSE-related programs to increase both the number and diversity of our AL graduate student population. The diversity goals enumerated above are realistic given the challenge facing PSE as documented in a February 2021 report from the American Institute of Physics (AIP) on Current Trends in Physics PhDs (Mulvey et al., 2021). The two fields central to PSE, plasma physics and materials science, were ranked 10 and 7, respectively, out of 16 identified subfields in terms of the total number of graduating PhDs averaged over 2 years (2017/18). Together, these two fields produced 130 out of 1900 (6.8%) Physics PhD degrees nationwide. When combined with the low representation in the Physics profession of women (~19%) and underrepresented groups (2% Hispanic and <1% African American), clearly a significant national effort is necessary. We cannot address this problem nationally but we can address the problem locally within Huntsville and AL, and the program outcomes summarized in this paper reveal that our prior award was very successful in increasing the number of women faculty in AL PSE (5 out of 6 new faculty hires were women), increasing the ratio of women to men faculty to 25% from 6% (the CPU2AL consortium began with only 2 female faculty). This ratio clearly exceeds women representation in all of physics and certainly in PSE nationally. The prior CPU2AL grant also resulted in a female and under-represented student make up of ~22% and 20% respectively, the former of which is a little better than the national average (19%) and the latter exceeding (~3%). The goals of our new program, FTPP, are to further impact the production of PSE researchers through new PSE faculty hires, student training, outreach activities, and workforce development. Despite the prior success, our greatest challenge is in attracting URM faculty, researchers, and graduate students to PSE since the annual national average for URM physics PhDs conferred is <3%. The Plasma 2020 Decadal Report (National Academies of Sciences-Engineering-Medicine, 2021) observed that PSE is particularly challenged with respect to Diversity and Inclusion nationally, and this is even more so in AL. The 2017/18 NSF Science and Engineering State Profiles report for AL (the most recent complete profile available[7]), showed there were 7,650 Science, Engineering, and Health (SEH) PhDs employed statewide in AL, a population of 8,714 SEH graduate students, and 414 Science and Engineering degrees awarded, of which 34 were in the Physical Sciences. If our quantitative goals for increasing diversity in our student PSE population are achieved, they will make a meaningful impact on the diversity of those students being awarded degrees in the Physical Sciences.

The Center for Space Plasma and Aeronomic Research and Department of Space Science (CSPAR/SPA) at The University of Alabama in Huntsville (UAH) offer five summer programs that are supported by grants from the National Science Foundation (NSF) to undergraduate and/or graduate students in STEM fields. These programs are

1. Research Experience for Undergraduates (REU) Site in Solar and Heliospheric Physics[8] which is jointly organized by CSPAR/SPA and NASA Marshall Space Flight Center (MSFC).
2. The Alabama Plasma Internship Program (ALPIP)[9], which is led out of CSPAR/SPA and organized by an NSF supported consortium of 9 research-focused universities in Alabama.
3. Alabama Research Experiences for Undergraduates (ALREU)[10]. This too is led out of CSPAR/SPA and organized by an NSF supported consortium of 9 research-focused universities in Alabama, as is the

7 https://www.nsf.gov/statistics/states/interactive/show.cfm?stateID=53,1&year=0
8 https://www.uah.edu/cspar/research/reu
9 https://www.uah.edu/cpu2al/career-opportunities/alpip
10 https://www.uah.edu/cpu2al/career-opportunities/alreu

4. Corporate Internship Program on Plasma Technology Applications (CIPPTA)[11].
5. The International Space Weather Camp (ISWC)[12] is supported by an international consortium of CSPAR/SPA, Germany through the Deutschen Zentrum für Luft- und Raumfahrt (DLR) site in Neustrelitz, and the South African National Space Agency (SANSA) site at Hermanus, and partially by an NSF supported consortium of 9 research-focused universities in Alabama.

Except for the NSF REU program, which has been supported by a series of NSF REU grants, the other summer programs were/are supported by the CPU2AL/FTPP grant. ISWC is/will be supported at Huntsville in alternate years by the CPU2AL/FTPP grant, and in the between years by support from the CSPAR and the UAH Office of the Vice President for Research. The international segments of the ISWC are supported by our international partners in Germany and South Africa.

In Section 2, we provide an overview of each of these programs and their contributions to the demographics of the Space Physics research community.

2 Summer programs

2.1 The NSF REU program

2.1.1 Organization

For the past 10 years, we have hosted a successful REU site at UAH CSPAR/SPA, and NASA MSFC. From its inception, we set three goals for our participants: First, we wanted to provide students an engaging research environment with projects that appealed to a wide variety of students and skill levels and that had far reaching applications to other science, technology, engineering and math (STEM) fields. We accomplished this by focusing projects on solar and heliospheric physics and recruiting mentors with projects that include hardware development, data analysis, theory and modeling, and computer simulations. Second, we wanted to recruit minority students and young (freshmen and sophomore) students to participate in the program. Studies have shown that inclusion in research improves retention in STEM fields; this is particularly true for minority students (Russell et al., 2007). Our recruitment activities and student selection process are geared to meet this goal. Finally, we wanted to provide the students a life-changing experience, not just by providing excellent research projects and mentors, but also by providing engaging social and extra-curricular activities, seminars on preparing for their future, and a network of peers and advisors that can provide additional support after the program is completed.

Every summer, 10 students selected from a highly-competitive applicant pool of undergraduate students in STEM fields who are enrolled at universities and colleges across the US are invited to the UAH campus to work on cutting-edge research projects in solar and heliospheric physics. Each student is supervised by one or more UAH and NASA scientists for 10 weeks over summer. We offer a wide range of projects covering topics in theory/modeling, data analysis, computer simulations, and hardware development. While working on their projects, the students participate in an intensive scientific lecture program in solar and heliospheric physics given by UAH and NASA scientists. The students are required to attend professional development sessions organized by UAH for all the summer programs offered throughout the campus.

At the end of the REU program, the students prepare posters about their project work and results, and present them to the UAH and NASA MSFC communities. One goal of our REU is to make a measurable impact on our REU students by engaging them in research with significant scientific merit. One gauge for this is that we expect the student research to be of a caliber to be presented at a major international scientific meeting and possibly produce a refereed scientific publication. REU students are required to submit abstracts to the AGU Fall Meeting or American Astronomical Society (AAS) Winter Meeting and are provided partial travel support to attend these conferences and present their work. In addition, we organize an REU poster competition at the end of the program where the posters are judged by the UAH and NASA scientists according to various evaluation criteria and the winner of this competition is given the opportunity to attend and present their work at an international conference. Travel expenses for the international conference are fully supported by our REU program. The winner of the REU poster competition in summer 2021 participated in the 44th COSPAR Scientific Assembly held in Athens, Greece, and the winner of the REU poster competition in summer 2022 was a student who attends a non-research college in Iowa (Grinnell College). This is a measure of the effectiveness of our mentorship.

2.1.2 Our philosophy towards undergraduate research and training

REUs have become highly competitive, making it increasingly difficult for students from small universities and those without much exposure to undergraduate research to be accepted into REU programs. About half the students accepted into our program have only 1 or 2 years of college training. This requires us to first bring them up to a standard suitable to manage the projects they have been assigned. We achieve this by, firstly, providing computer skills training and solar and heliospheric physics lectures at an introductory and mid-level range. Most importantly, we select a mix of students with, on average, ~50% having prior research or computational skills and 50% being completely or largely inexperienced. This ensures that students have peers with some prior knowledge and skills that can be shared communally. Since the students share a common workplace, they assist each other, an approach that works surprisingly well. Finally, we select mentors willing to spend more time with less experienced students. We regard careful student-mentor pairing as key to ensuring that both obtain the maximum return from the program. In addition, the PI, Co-PI, and Coordinator (the “Management Team”) serve as “shared” or “group” mentors, and check on the student group daily during the first several weeks and are available to support students throughout the summer.

11 https://www.uah.edu/cpu2al/career-opportunities/cippta

12 https://www.uah.edu/cspar/iswc

2.1.3 Programmatic goals

The primary goal of our NSF REU program is to increase minority participation in STEM fields. Minorities are underrepresented in all levels of the physical sciences, including space science, from undergraduates to senior level scientists. One problem is geography. Although 54% of African Americans live in the southeast region of the US, the vast majority of heliophysicists are from outside the southeast. This is true of the 81 Historically Black Colleges and Universities (HBCU's) ranked by United States News, of which half are located in the southeast. The heliophysics group in Huntsville is a notable exception having created a Department of Space Science at UAH, having CSPAR, and having the Solar Physics, Gamma Ray, and X-ray astrophysics groups at the co-located NASA MSFC. Furthermore, Huntsville possesses a large industrial research park with a heavy emphasis on aerospace. Huntsville is therefore ideally situated to enhance minority recruitment in heliophysics, and indeed to provide employment opportunities in related fields. Our program has been highly successful in recruiting minority groups through our proactive recruitment strategy that includes school visits and the use of personal contacts with student advisers.

A second goal motivating our program is to improve the retention of students in STEM majors. A sizable fraction of STEM majors do not graduate with STEM degrees, with most leaving the STEM fields during freshman and sophomore years. In addition to the equality in race and gender of the students, the recruitment strategy of our REU program targets freshman and sophomore students, along with students from non-research intensive colleges and universities that do not offer a graduate program. We have been rather successful in helping these "diamonds in the rough" graduate with a STEM degree. We attribute the success of our students to our focusing on recommendation letters and their own letters of interest during the selection process (these letters help us match the students with the mentors who offer projects in line with the students' interests), and to our ability to both train them using the intensive scientific lecture program and the tutorials corresponding to the software that they use in their projects and, perhaps most importantly, excite them in undertaking original research.

Based on our previous experience in recruiting REU cohorts during the past 10 years, our target is to recruit 50% women and LGBTQ+ community, 30% minorities, 15% freshman and 40% sophomore students, and 40% from universities with low research activity, community colleges, and HBCU's. These demographic numbers are much higher than the current demographics in the PSE/Space Physics research community presented above, and as we show below, the program is meeting or exceeding our quantitative targets derived from PSE demographic data.

2.1.4 Outcomes

The demographic breakdown of applicants and participants is illustrated in **Table 1** and a corresponding breakdown of the participants is illustrated in **Figure 2** and **Figure 3** for the period 2016–2019. **Figure 3** focuses on minority applications and participation over the period and summarizes the results in the figure caption. We chose this period since it was prior to the disruptions of in-person camps and programs created by the COVID pandemic. Note that we achieved parity of men and women participants in the past 2 years. We note parenthetically that the post-COVID period, although certainly not yet over, may be beginning to return to some form of normalcy since we recruited a cohort of 70% women and LGBTQ+ community vs. 30% men in summer 2021. This is the highest rate of minority participation in our program in terms of gender since 2012. However, it may take some years before the effects of the COVID-19 years no longer affect our statistical analyses. The goals of the REU program were to promote minority participation and retention in STEM fields, especially in solar and heliophysics, through research experience. Seventeen of our former REU students are attending/attended graduate school. The research projects are tailored to the range of skills and background that the students bring, allowing us to accommodate students with just 1 year of tertiary education. The students were drawn typically from physics, computer science, and engineering backgrounds, and worked on projects in theory, simulations, data analysis, and hardware development. We have drawn students from institutions with limited STEM research opportunities (see **Figure 2**).

In conclusion, we note that we follow up with our REU program alumni after the program in an endeavor to maintain long term relationships, using Facebook and "annual follow-up" emails. This reminds the students of their time with us, and the connection that they maintain with the program and their mentors. Mentors (and the REU Program Coordinator that oversees the entire program) frequently provide reference letters for former students applying to graduate school. Several past participants have indicated that a strong letter from an eminent scientist who speaks highly of their research capabilities has contributed to their acceptance into prestigious schools. Mentors sometimes continue to work with students after the REU program, especially when a student's work is suitable for publication. Altogether, ten of our REU students were coauthors on ten refereed journal publications over the past 10 years. The publication of a research paper in an international journal makes an enormous impact on a student and we regard

TABLE 1 Breakdown of applicants and participants over the 3 years 2017–2019. Note the gender balance in the past 2 years, and that in 2019 there were more women than men applicants. In each category, the first number indicates the number of applicants in that category separated by "/" from the second number which indicates the number of participants in the same category.

Demographics(Applicants/Participants)	2017	2018	2019
Total Number	95	80	106
African-American (non-Hispanic)	6/2	4/1	6/1
Hispanic or Latino	13/2	11/2	9/1
White (non-Hispanic)	57/6	52/6	70/5
Asian or Pacific Islander	4/0	7/1	10/0
Native American/American Indian	0/0	1/0	1/1
No Response (Ethnicity)	15/0	5/0	10/2
Women	39/4	35/5	52/5
Men	56/6	43/5	51/5
From UAH (home institution)	0	0	0
No Response (Gender)	0/0	2/0	3/0
Minority Participation	40%	40%	30%

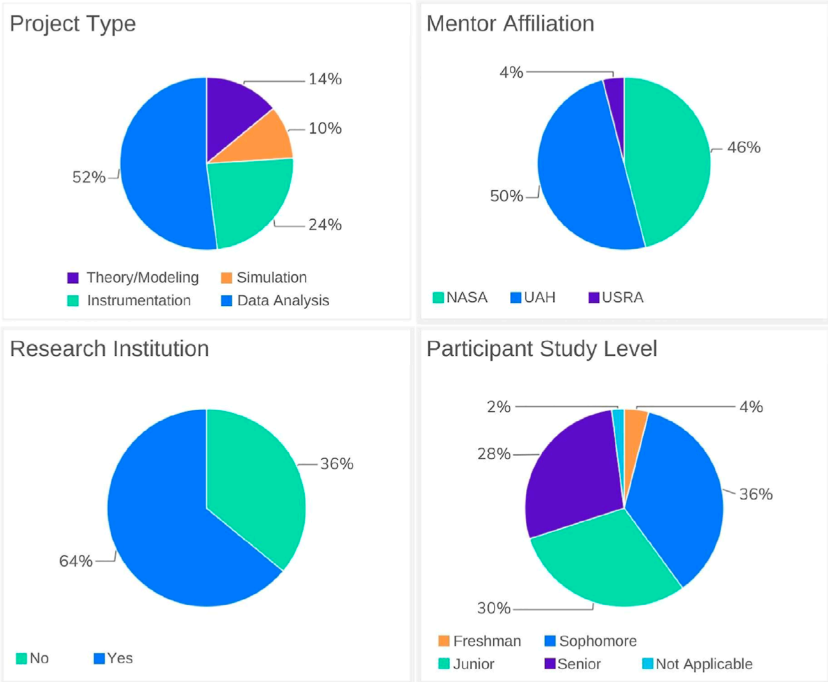

FIGURE 2
Cumulative pie charts for the NSF REU program during the 2016–2019 period showing a breakdown of the project type (top left), the mentor affiliation (top right), the fraction of students from colleges with a PhD program in Physics (yes/no) (bottom left), and the participant study level (bottom right).

this as one of our most satisfying accomplishments with the REU program.

2.2 ALPIP program

2.2.1 Organization

ALPIP has been offered since the summer of 2019 and is a 10-week summer internship program for undergraduate students (in particular, rising juniors and seniors in STEM fields). Recruitment of students was initially focused on students attending Alabama institutions and since been expanded to encompass the NSF EPSCoR southeastern states (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, South Carolina, West Virginia, the United States Virgin Islands, and Puerto Rico). The program was supported by an NSF EPSCoR RII Track-1 grant entitled CPU2AL: Connecting the Plasma Universe to Plasma Technology in AL: The Science and Technology of Low-Temperature Plasma and now by the FTPP program.

2.2.2 Programmatic goals

The goal of the program is to promote plasma physics as a discipline, which obviously includes space physics and plasma astrophysics. Another goal is to recruit students in the southeastern United States into plasma physics-related programs in Alabama, to increase diversity in plasma-related programs, and to bring plasma physics into the AL HBCU research programs. Since many of the students that attend the ALPIP program have little or no knowledge of plasma physics, CPU2AL provides a mandatory on-line plasma physics introduction developed by plasma physics graduate students and post docs that includes some simple quizzes. Thereafter, the ALPIP students attend an in-person intensive one-week summer program given by Princeton Plasma Physics Laboratory (PPPL) as part of the Department of Energy (DOE) Summer Undergraduate Laboratory Internship (SULI) program. ALPIP students participate in lectures, laboratory experiments, and short classes in plasma science. Although not especially technical, the required on-line plasma physics introduction that the ALPIP students take prior to the PPPL courses provides a good overview of plasma physics. This is important because most of the ALPIP students have had little or no exposure to plasma physics, electricity and magnetism, or statistical physics.

After attending the introductory plasma physics program at PPPL, our ALPIP students return to one of the Alabama CPU2AL partner universities for 9 weeks to work on a research project with one or more mentors. The students choose a project prior to the camp from a selection provided by the CPU2AL universities. The projects range from computational and theoretical to data analysis in space and laboratory plasma, while others address the application of plasma to the life sciences. The projects culminate in an in-house poster session and thereafter all the ALPIP students attend the Annual CPU2AL meeting where they exhibit their posters and awards are provided for the best posters. Several projects have resulted in journal publications with their mentors.

2.2.3 Outcomes

Illustrated in **Figure 4** is a table illustrating the demographic breakdown from 2019–2022 with a COVID pandemic break

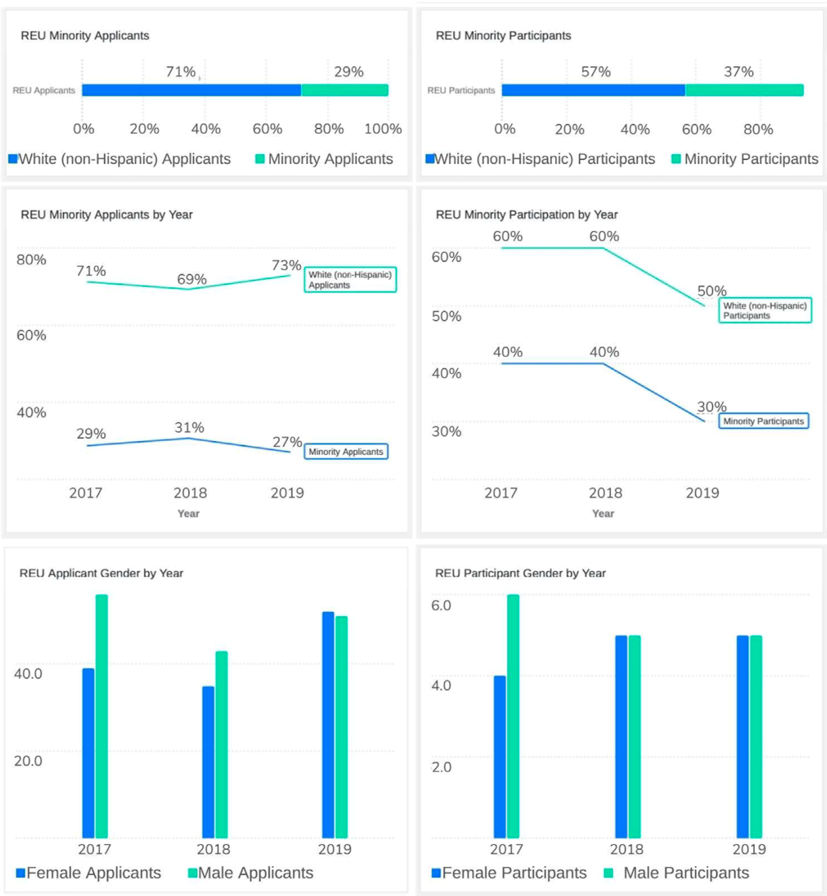

FIGURE 3
Left (top two panels): The REU program recruited women and minorities, obtaining the following breakdown: 29% minority applicants, 46% female applicants. Right (top two panels): Almost half of REU participants were women and over a third were minority, with the following breakdown: 37% minority participation and 47% female participation. Left (bottom): Female REU applicants increased by 33% between 2017 and 2019 with a breakdown of 54% male, 46% female. Right (bottom): REU participant gender is nearly equal with 53% male and 47% female. All averages are over a 3 year period (2017–2019).

during 2020 and a virtual camp during 2021. ALPIP 2022 was the resumption of the in-person program although, notably and importantly, with the PPPL component being offered only virtually. Both the completely virtual 2021 and the 2022 virtual PPPL component had a notable impact on our application numbers which were well below the 2019 numbers. We caution the reader that the complications of the pandemic make it difficult to draw reliable conclusions from the numbers in Figure 4 but some trends are apparent. In 2019, ALPIP support 4 African-American students, 1 Hispanic or Latino student, and 1 Asian or Pacific Islander student, and 6 white (non-hispanic) students for a total of 12 participating students or corresponding to the demographic percentages presented in Section 1, 33%, 8.5%, 8.5%, and 50%, respectively. Of the 12, they were split equally between men and women. The virtual ALPIP camp of 2021 after the canceled 2020 camp had a 60% decline in applications. Despite this, the number of minorities participating was 6 of 13 (2 African-American, 1 Hispanic or Latino student, 2 Asian or Pacific Islander, and 1 Native American student or 15%, 8%, 15%, and 8%, respectively). The split between women and men was the same, 6 and 7 respectively. As illustrated, the demographic breakdown achieved here well exceeds the baseline targets scribed in Section 1. The semi-virtual 2022 ALPIP camp saw a marked decline in the number of minority and women applications. It is unclear as to what the decline can be ascribed. One possibility is that the COVID pandemic affected the return of minority and women students to campuses more than white male students. However, we are unaware of detailed college post-COVID return demographic statistics so this is speculative.

Despite the complications of understanding the demographic data during the COVID pandemic years, a problem less acute for our NSF REU program, Figure 4 illustrates the potential for significant recruitment and engagement of minority and women students in the broader field of plasma physics. This program is continuing with new NSF support via an entirely new program *"Future Technologies and Enabling Plasma Processes"* (FTPP). The engagement of ALPIP students at both the PPPL and the individual AL universities participating in CPU2AL and now FTPP allows the students to become part of a larger, national plasma science student cohort, learn about opportunities in plasma science, and be exposed

ALPIP	2019		2021				2022			
	Applic.	Partic.	Applic.	Appl. Incr/Decr	Partic.	Partic. Rate	Applic.	Appl. Incr/Decr	Partic.	Partic. Rate
African-American (non-Hispanic)	No Data Available	4	14	N/A	2	14%	4	-71%	1	25%
Hispanic or Latino	No Data Available	1	6	N/A	1	17%	3	-50%	1	33%
Asian or Pacific Islander	No Data Available	1	5	N/A	2	40%	5	0%	1	20%
Native American/American Indian	No Data Available	0	1	N/A	1	100%	0	-100%	0	N/A
Minority Participation	**No Data Available**	**6**	**26**	**N/A**	**6**	**23%**	**12**	**-54%**	**3**	25%
White (non-Hispanic)	**No Data Available**	**6**	**22**	**N/A**	**7**	**32%**	**26**		**12**	**46%**
No Response (Ethnicity)	**No Data Available**	**0**	**1**	**N/A**	**0**		**1**		**0**	
Total Number	**127**	**12**	**49**	**-61%**	**13**	**27%**	**39**	**-20%**	**15**	**38%**
Women	**No Data Available**	**6**	**25**	**N/A**	**6**	**24%**	**8**	**-68%**	**3**	**38%**
Men	**No Data Available**	**6**	**24**	**N/A**	**7**	**29%**	**31**	**29%**	**12**	**39%**
No Response (Gender)	**No Data Available**	**0**	**0**	**N/A**	**0**	**N/A**	**0**	**N/A**	**0**	**N/A**
Total Number	**127**	**12**	**49**	**-61%**	**13**	**27%**	**39**	**-20%**	**15**	**38%**
From non-CPU2AL institution	**No Data Available**	**5**	**25**	**N/A**	**4**	**16%**	**8**	**-68%**	**2**	**25%**
Percentage		**42%**	**51%**		**31%**		**21%**		**13%**	
Freshman	**8**	**0**	**1**		**0**		**0**		**0**	
Sophomore	**31**	**2**	**17**		**4**		**7**		**2**	
Junior	**64**	**6**	**23**		**6**		**23**		**10**	
Senior	**24**	**4**	**8**		**3**		**8**		**2**	
Graduate Student	**0**	**0**	**0**		**0**		**1**		**1**	
Research Institutions	**95**	**11**	**31**		**9**		**30**		**12**	
Non-research Institutions	**32**	**1**	**18**		**4**		**9**		**3**	
Incomplete Applications	71		17	-76%			8	-53%		

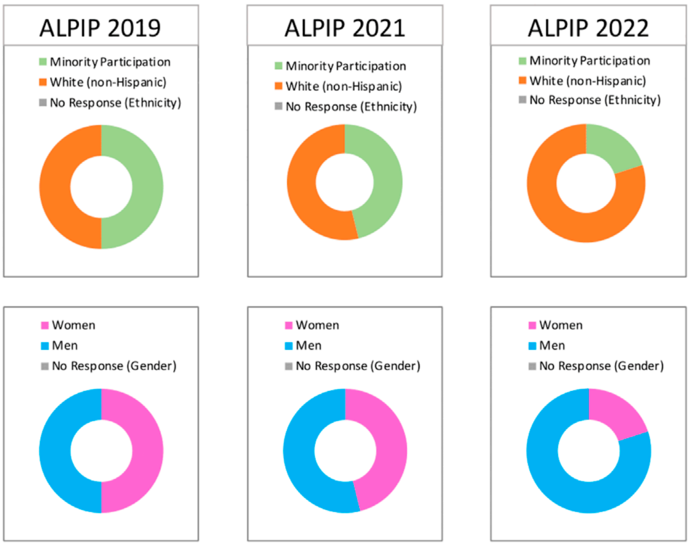

FIGURE 4
Top: Table listing the demographic information, the number of participants, and the number of accepted participants for the ALPIP program for the 3 years 2019, 2021 and 2022. The program was suspended during 2020 because of the COVID lockdown, 2021 was fully virtual, and 2022 was hybrid (part virtual, part in-person). Note that the participant rate is different from the number of participants, being calculated from the ratio of participants to applications. *Bottom*: Graphical representation of the diversity information (top row is the minority participant and the bottom row the gender participant breakdown) for each of the 3 years.

to the research environment of a national laboratory for plasma physics.

2.3 ALREU program

2.3.1 Organization

The State of Alabama has currently three NSF REU programs that are related to space and plasma physics. One is the UAH program discussed above. Both ASU and UAB host NSF REU programs (ASU NSF REU Site *"Research & Training in Multidisciplinary Field of Regenerative Sciences for Undergraduates"*, and UAB NSF REU Site *"Regional Initiative to Promote Undergraduate Participation in Experimental and Computational Materials Research"*, respectively) that are led by Principal Investigators that are part of the CPU2AL and now FTPP NSF EPSCoR grant. As we noted above in Section 2.1, students face increasing competition and challenges to be accepted into REU programs around the nation, particularly when they apply from non-research intensive universities and cannot demonstrate undergraduate research experience. This is especially true of

ALREU	2019		2021				2022			
	Applic.	Partic.	Applic.	Appl. Incr/Decr	Partic.	Partic. Rate	Applic.	Appl. Incr/Decr	Partic.	Partic. Rate
African-American (non-Hispanic)	No Data Available	4	8	N/A	3	38%	7	-13%	3	43%
Hispanic or Latino	No Data Available	0	0	N/A	0	N/A	0	N/A	0	N/A
Asian or Pacific Islander	No Data Available	0	1	N/A	0	0%	0		0	N/A
Native American/American Indian	No Data Available	0	0	N/A	0	N/A	0	N/A	0	N/A
Minority Participation	**No Data Available**	**4**	**9**	**N/A**	**3**	**33%**	**7**	**-22%**	**3**	43%
White (non-Hispanic)	**No Data Available**	**0**	**3**	**N/A**	**0**	**0%**	**0**		**0**	**N/A**
No Response (Ethnicity)	**No Data Available**	**0**	**0**	**N/A**	**0**	**N/A**	**1**	**N/A**	**0**	
Total Number	**19**	**4**	**12**	**-37%**	**3**	**25%**	**8**	**-33%**	**3**	**38%**
Women	**No Data Available**	**2**	**6**	**N/A**	**3**	**50%**	**6**	**0%**	**2**	**33%**
Men	**No Data Available**	**2**	**6**	**N/A**	**0**	**0%**	**2**	**-67%**	**1**	**50%**
No Response (Gender)	**No Data Available**	**0**	**0**	**N/A**	**0**	**N/A**	**0**	**N/A**	**0**	**N/A**
Total Number	**19**	**4**	**12**	**-37%**	**3**	**25%**	**8**	**-33%**	**3**	**38%**
Freshman	**1**	**0**	**0**		**0**		**0**		**0**	
Sophomore	**7**	**3**	**6**		**1**		**1**		**0**	
Junior	**7**	**1**	**3**		**1**		**4**		**2**	
Senior	**4**	**0**	**3**		**1**		**3**		**1**	
Graduate Student	**0**	**0**	**0**		**0**		**0**		**0**	
Research Institutions	**14**	**3**	**12**		**3**		**4**		**1**	
Non-research Institutions	**5**	**1**	**0**		**0**		**4**		**2**	
Incomplete Applications	10		5	-50%			2	-60%		

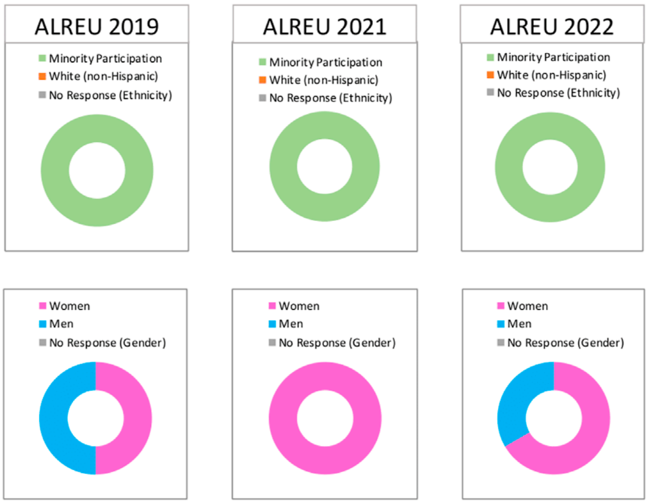

FIGURE 5
Demographic data presented in the same format as Figure 4 for ALREU for the same 3 years 2019, 2021, and 2022.

many HBCU students. Accordingly, as part of the CPU2AL and now the FTPP program, we piggyback off our three successful and existing independent Alabama-wide NSF REU programs by setting aside CPU2AL funds to support the attendance of three HBCU students at an REU camp of their choosing. With FTPP, this effort has expanded to include students enrolled at HBCU institutions across the southeastern United States (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, South Carolina, West Virginia, the United States Virgin Islands, and Puerto Rico). Not only does CPU2AL/FTPP provide the funding for the students but our CPU2AL/FTPP recruitment team advertises the program, the AL REU or ALREU program, across a broad spectrum of HBCU institutions.

2.3.2 Programmatic goals

Offered since summer of 2019, the ALREU program is a 10-week summer internship program for undergraduate students (in particular, rising juniors and seniors in STEM fields) by leveraging off our existing NSF REU programs in AL. The program provides students with quality research experiences at CPU2AL/FTPP partner institutions in a broad spectrum of PSE/Space Physics disciplines. The ultimate goal of the program is to engage a diverse, educated, and skilled pool of scientists and engineers to promote long-term relationships between students and investigators to enhance the Alabama plasma-related workforce. As more FTPP partners capture NSF REU programs, we anticipate expanding the ALREU program to include more students.

2.3.3 Outcomes

As with the preceding figure, Figure 5 shows a table illustrating the demographic breakdown from 2019–2022 with a COVID pandemic break during 2020 and a virtual camp during 2021. ALREU 2022 resumed the in-person program. Despite the completely virtual 2021 camp, the number of ALREU 2022 applicants roughly mirrored the 2021 numbers. Again, we caution the reader that the complications of the pandemic make it difficult

CIPPTA	2019		2021				2022			
	Applic.	Partic.	Applic.	Appl. Incr/Decr	Partic.	Partic. Rate	Applic.	Appl. Incr/Decr	Partic.	Partic. Rate
African-American (non-Hispanic)	No Data Available	2	5	N/A	1	20%	5	0%	0	0%
Hispanic or Latino	No Data Available	0	0	N/A	0	N/A	1	N/A	0	0%
Asian or Pacific Islander	No Data Available	2	1	N/A	1	100%	6	500%	1	17%
Native American/American Indian	No Data Available	0	0	N/A	0	N/A	0	N/A	0	N/A
Minority Participation	**No Data Available**	**4**	**6**	**N/A**	**2**	**33%**	**12**	**100%**	**1**	**8%**
White (non-Hispanic)	**No Data Available**	**3**	**13**	**N/A**	**3**	**23%**	**8**	**-38%**	**2**	**25%**
No Response (Ethnicity)	**No Data Available**	**0**	**0**	**N/A**	**0**	**N/A**	**1**	**N/A**	**0**	
Total Number	**44**	**7**	**19**	**-57%**	**5**	**26%**	**21**	**11%**	**3**	**14%**
Women	**No Data Available**	**1**	**7**	**N/A**	**2**	**29%**	**4**	**-43%**	**0**	**0%**
Men	**No Data Available**	**6**	**12**	**N/A**	**3**	**25%**	**17**	**42%**	**3**	**18%**
No Response (Gender)	**No Data Available**	**0**	**0**	**N/A**	**0**	**N/A**	**0**	**N/A**	**0**	**N/A**
Total Number	**44**	**7**	**19**	**-57%**	**5**	**26%**	**21**	**11%**	**3**	**14%**
Freshman	**2**	**0**	**0**		**0**		**1**		**0**	
Sophomore	**8**	**1**	**4**		**0**		**4**		**0**	
Junior	**17**	**2**	**7**		**0**		**8**		**2**	
Senior	**9**	**2**	**3**		**1**		**6**		**1**	
Graduate Student	**8**	**2**	**5**		**3**		**2**		**0**	
Research Institutions	**41**	**6**	**17**		**3**		**16**		**3**	
Non-research Institutions	**3**	**1**	**2**		**0**		**5**		**0**	
Incomplete Applications	25		6	-76%			5	-17%		

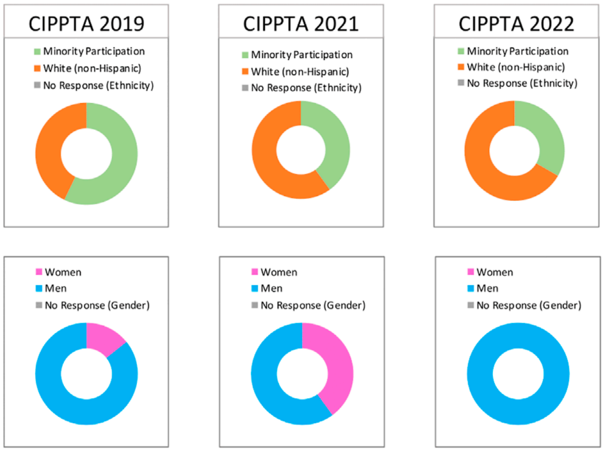

FIGURE 6
Demographic data presented in the same format as Figure 4 for CIPPTA for the same 3 years 2019, 2021, and 2022.

to draw reliable conclusions from the numbers in Figure 5 but some trends are apparent. In 2019, ALREU supported 4 African-American students, split equally between men and women. The virtual ALPIP camp of 2021 after the canceled 2020 camp had a 37% decline in applications and we supported 3 African-American students, all of whom were women. The 2022 ALREU camp saw a modest decline in the number of minority and male applications. It is unclear as to what the decline can be ascribed or if it statistically meaningful.

Despite the complications of understanding the demographic data during the COVID pandemic years, Figure 5 illustrates the potential for significant recruitment and engagement of minority and women students in the broader field of plasma physics. Evidently, ALREU has been successful in leveraging existing supported NSF REU programs in AL to increase exposure of minority undergraduate students to PSE/space physics who would otherwise never have had access to learn about or engage in research on PSE-related topics. As described already, this program is continuing with new NSF support via the FTPP program. The engagement of HBCU students from the southeastern states introduces them to opportunities in plasma science that most of whom have been unaware.

2.4 CIPPTA program

2.4.1 Organization

One of the important Workforce Development-related components of the NSF EPSCoR-supported CPU2AL program was the building of industrial and commercial links to the AL Statewide plasma academic program. An approach that we developed was a 10-week, typically summer, program in which CPU2AL (and now FTPP) sponsors a Corporate Internship Program on Plasma Technology Applications (CIPPTA) (https://www.uah.edu/cpu2al/career-opportunities/cippta) for students pursuing degrees in STEM fields. The program provides students at CPU2AL partner institutions with quality experiences on applying plasma technology at private AL companies. This is an internship in which a STEM undergraduate or graduate student chooses from a variety of projects provided by different AL companies. These projects range from the plasma processing and coating of carbon composites to plasma-liquid interactions and the use of neural networks in plasma applications, thereby providing hands-on experience to the selected students.

ISWC	2011	2012	2013	2014	2015	2016	2017	2018	2019	2021			2022			
	Partic.	Partic.	Partic.	Partic.	Partic.	Partic.	Partic.	Partic.	Partic.	Applic.	Partic.	Partic. Rate	Applic.	Appl. Incr/Decr	Partic.	Partic. Rate
African-American (non-Hispanic)	0	0	0	2	1	0	0	1	0	1	0	0%	2	100%	1	50%
Hispanic or Latino	0	0	0	0	0	0	0		0	0	0	N/A	0	N/A	0	N/A
Asian or Pacific Islander	4	2	4	1	3	2	5	1	2	2	2	100%	4	100%	4	100%
Native American/American Indian	0	0	0	0	1	0	0	1	0	0	0	N/A	0	N/A	0	N/A
Minority Participation	**4**	**2**	**4**	**3**	**5**	**2**	**5**	**3**	**2**	**3**	**2**	**67%**	**6**	**100%**	**5**	**83%**
White (non-Hispanic)	6	8	6	5	5	6	3	6	6	4	2	50%	1	-75%	1	100%
No Response (Ethnicity)	0	0	0	0	0	0	0	0	0	0	0	N/A	0	N/A	0	N/A
Total Number	**10**	**10**	**10**	**8**	**10**	**8**	**8**	**9**	**8**	**7**	**4**	**57%**	**7**	**0%**	**6**	**86%**
Women	3	3	3	3	4	2	4	3	3	4	2	50%	2	-50%	2	100%
Men	7	7	7	5	6	6	4	6	5	3	2	67%	5	67%	4	80%
No Response (Gender)										0	0	N/A	0	N/A	0	N/A
Total Number	**10**	**10**	**10**	**8**	**10**	**8**	**8**	**9**	**8**	**7**	**4**	**57%**	**7**	**0%**	**6**	**86%**
Freshman	0	0	0	0	0	0	0	0	0	0	0		0		0	
Sophomore	0	0	0	0	0	0	0	0	0	1	1		0		0	
Junior	0	0	0	0	0	0	0	0	0	4	1		1		0	
Senior	5	7	4	6	7	3	4	4	3	0	0		0		0	
Graduate Student	5	3	6	2	3	5	4	5	5	2	2		6		6	
Research Institutions										6	4		6		6	
Non-research Institutions										1	0		1		0	
Research Institution Not Collected	10	10	10	8	10	8	8	9	8	0	0		0		0	
Incomplete Applications										0	0	N/A	0	N/A	0	N/A

FIGURE 7
Demographic data presented in the same format as Figure 4 for the ISWC for the period 2011–2022. Data collection prior to 2020 was not as detailed as it is currently but basic demographic and gender was collected.

2.4.2 Programmatic goals

The goals of CIPPTA are twofold. One is to provide students the opportunity to establish connections with PSE-related industry and university professionals. It is open to undergraduate and graduate students in a broad spectrum of STEM disciplines. The program focus is to engage a diverse, educated, and skilled pool of scientists and engineers to promote long-term relationships between students, academia, and industry to enhance the Alabama workforce. In so doing, we hope to improve the industry-academia connection in plasma physics, which, at least for AL, is not well established. This is the second important goal of the program. While focused more generally on plasma physics applications, the internship program is a clear pipeline into the strong AL (and certainly the Huntsville and Mobile) space and aerospace industrial and commercial sector. Under FTPP, we anticipate expanding CIPPTA further.

2.4.3 Outcomes

CIPPTA is a program that was quite heavily oversubscribed in the pre-COVID years. This is illustrated in Figure 6 in which CIPPTA had 44 applications and we were able to provide only 7 internships. During this year, we were markedly successful in our minority participation with 2 African-American and 2 Asian or Pacific Islander participants out of a total of 7 internships, of which only one was a woman student. The 2021 post-COVID year was partially hybrid and yielded a dramatically smaller number of applications. This led to only 5 internships being awarded, and a slight decrease in overall diversity but a modest increase in woman interns. As with the other programs, the URM and female participation breakdowns are consistent with the targets presented in Section 1. The 2022 year was also significantly impacted although the number of applicants increased from the year before but only three internships were available as the companies struggled to adapt from the COVID pandemic and lockdown.

The post-COVID data is difficult to understand, both because of the impact on the students themselves and also because of the impact on the companies providing the internship projects. If the prior-COVID data can be regarded as reasonably reliable, our recruitment of minority students into a hands-on industry-academic internship plasma program was effective in drawing a large number of applications that well reflected the diversity of the State.

2.5 ISWC program

2.5.1 Organization

The International Space Weather Camp or ISWC provides AL students an opportunity to learn about space physics in the context of meeting a very practical need–to understand the influence of the Sun on the space and upper atmosphere of the Earth and to explore its related impact on the technological systems and needs of modern society. This of course is the new, exciting, and emerging discipline of Space Weather. Its societal importance can be judged from the attention paid it by the White House and senior leaders in government, i.e., a recognition of the importance of ensuring that our technology investments are properly protected against severe Space Weather.

The ISWC is now supported in part by the NSF EPSCoR CPU2AL/FTPP consortium as well as the UAH through the Vice President of Research's Office and CSPAR. The current manifestation of the ISWC derives from the Camp that was run annually since about 2011. Initially, the ISWC resulted from a partnership between UAH and the DLR and the University of Rostock as part of a Memorandum of Understanding (MOU) between the three institutions in 2010/2011. The MOU was a reflection of the considerable historical ties that exist between Huntsville and the state of Mecklenburg Vorpommern (Germany) in the development of rockets, missiles, and eventually manned space flight. The primary initiators of the ISWC were the Director of CSPAR, Gary Zank, and the former Vice President of Research, John Horack, working together with their colleagues at the DLR in Neustrelitz, Wolfgang Mett, Holger Wandsleb, and the University of Rostock's Wolfgang Schareck (Rektor of the University of Rostock).

After the first 4 years of the ISWC, the program was expanded to include a South African component. The South African National Space Agency SANSA asked to join the program, at which point the program was expanded to create a three-legged program in which 2 weeks of the camp would be spent at two of the three participating institutions on an annual rotating basis. Thus, in 1 year all the students would spend 2 weeks in Huntsville followed by 2 weeks in Neustrelitz, and the following year it might be Huntsville and Hermanus in South Africa, etc. To avoid the complications of funding international partners, each of the partners covers the costs for all the students at their home institution and each partner is responsible for their own travel costs.

The ISWC was further expanded when CPU2AL (and now FTPP) took over the program by incorporating all the AL universities in the CPU2AL/FTPP consortium. The program is now no longer restricted to UAH students but instead incorporates all of Alabama and from this year, the US Southeast region. The purpose behind this expansion was to diversify the ISWC further and to provide opportunities to communities not traditionally engaged in space physics activities.

2.5.2 Programmatic goals

Prior to the pandemic, approximately 10 students from each of the three partners participated, i.e., about thirty students from Alabama, Germany, and South Africa participated in a multiple week series of lectures, hands-on projects and experiments and excursions. The goals of the project are threefold: the first and second are to learn both the theoretical underpinnings and practical applications of Space Weather and solar and space physics. Space weather is assuming an ever larger role in space physics, motivating the need to understand the academic component of space physics better as well as its economic impact on a technological society. The third goal is less tangible but perhaps as important, which is that ISWC was created to forge ties and develop communication between two regions that have had an enormous impact on the 20th century.

2.5.3 Outcomes

Figure 7 provides 11 years of demographic information from 2011–2022. The data from 2011–2020 is not as detailed as the records kept for 2021–22, but the basic demographic information was recorded. The table provides a detailed breakdown, when available, of ethnicity, gender, and educational levels, and whether from a research or non-research institution. The panels below the table of **Figure 7** are a simple graphical representation of the yearly breakdown of minority (orange—blue annuli) and gender (blue—pink annuli) ISWC participants. This extended period ensures that the perspective is not skewed excessively by the pandemic period. The columns corresponding to the COVID period also contain the application numbers broken down demographically.

In only four of the years did we have African-American participation but detailed application records were retained only in the last 2 years. A factor that we believe influences these numbers is that the ISWC became more focused on new graduate students after about 2014/15 as we recognized that undergraduates needed exceptional levels of preparation to manage the camp. An additional reason for the graduate student focus is that the German and South African cohorts were exclusively comprised of graduate students and undergraduate students clearly struggled with the program in these countries. Because of the focus on graduate students, this has made recruitment of African-American students into the ISWC exceptionally challenging. Nonetheless, we have been modestly successful and the 2022 African-American ISWC participant switched universities to enroll in a graduate space physics program rather than the graduate physics program he was enrolled in. In terms of diversity measured by the Asian or Pacific Islander category, the ISWC has been very successful in attracting significant levels of participation, well illustrated by the blue-colored annuli of **Figure 7**, which, despite yearly variability, has a large fraction colored in blue. After the first 3 years, the pink-colored annuli of **Figure 7** show good progress in increasing the representation of women attending the ISWC, and despite the downturn in gender diversity in 2022 (which we attribute to the virtual camp), we anticipate rapidly returning to a roughly balanced gender distribution in 2023. We can conclude that the ISWC URM and female participation meets our target goals presented in **Section 1**.

3 Individual success stories

As much as statistics can tell the story of the success or otherwise of the summer programs and internships discussed above, much greater resonance is frequently achieved through concrete stories and perceptions from individual students. Here, we attempt to summarize the numerous qualitative statements from

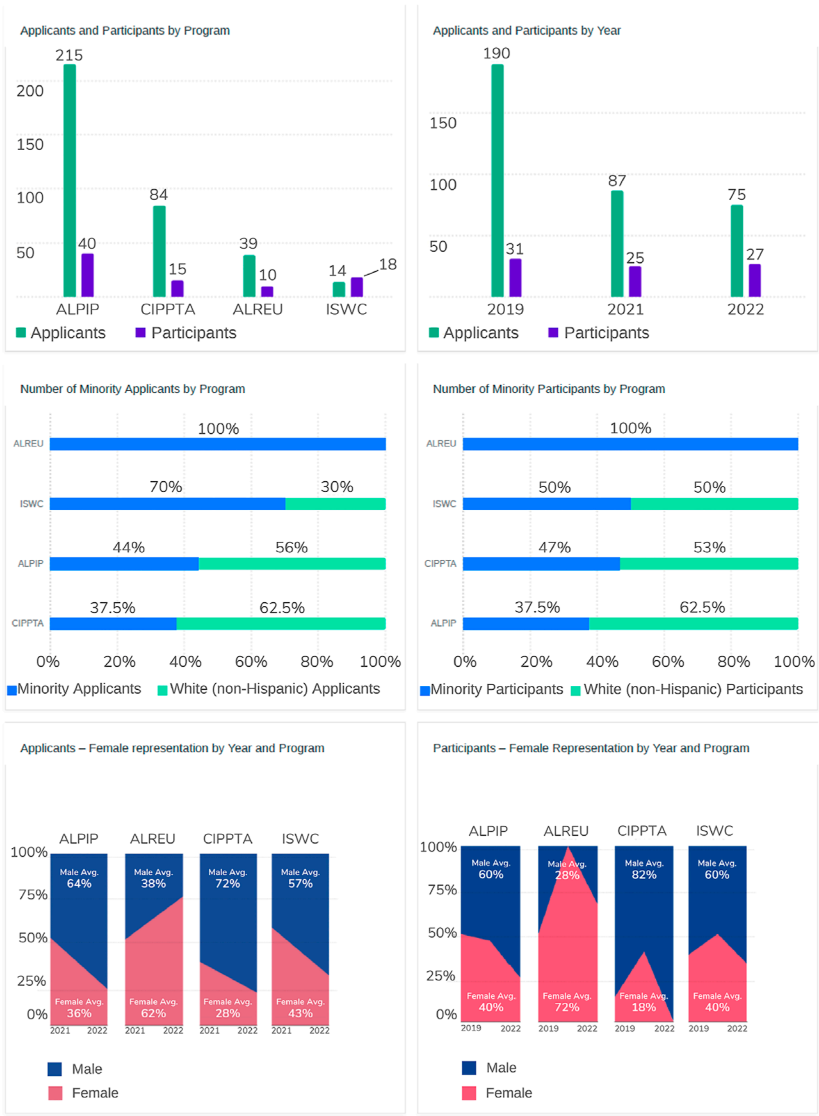

FIGURE 8
Summary of demographic data for the four CPU2AL summer programs over 3 years 2019, 2021, and 2022. No summer programs were held in 2020. Top left: Total number of applicants and participants per program for the three-year period. Top right: Total number of applicants and participants per year. Middle left: Total number of minority applicants by program. Middle right: Total number of minority participants by program. Bottom left: Total number of female applicants by year and program. Bottom right: Total number of female participants by year and program.

past interns that illustrate their success in the programs, the role played by our summer programs in students' subsequent career choices, and the impact on students who are not traditionally or typically exposed to an intensive research environment. In Supplementary Appendix S1, we provide a deeper presentation of the feedback we received from our students, together with some commentary about the broader implications of the student statements for our summer programs, for STEM in general, and for the Alabama and US workforce.

3.1 NSF REU program

Our NSF REU program has been organized uninterrupted since summer 2012 with the exception of 2020 when it had to be canceled due to the COVID pandemic. We therefore have a significant pool of REU alumni gathered over the past 10 years. We perform longitudinal tracking to follow the career paths and current jobs of our alumni. The institutional and sometimes demographic diversity of our REU cohorts is frequently reflected in the chosen career paths. Some chose to pursue graduate education in STEM fields, followed by careers in academia or industry; some went directly to industry after completing an undergraduate degree, and some chose a career path unrelated to the undergraduate majors they were pursuing at the time they participated in our REU program. Regardless of the career paths chosen, the responses to our surveys demonstrated that our REU program affected the career decisions of many of our past REU students. This was also reflected in email exchanges between REU students and their mentors as well as members of the REU

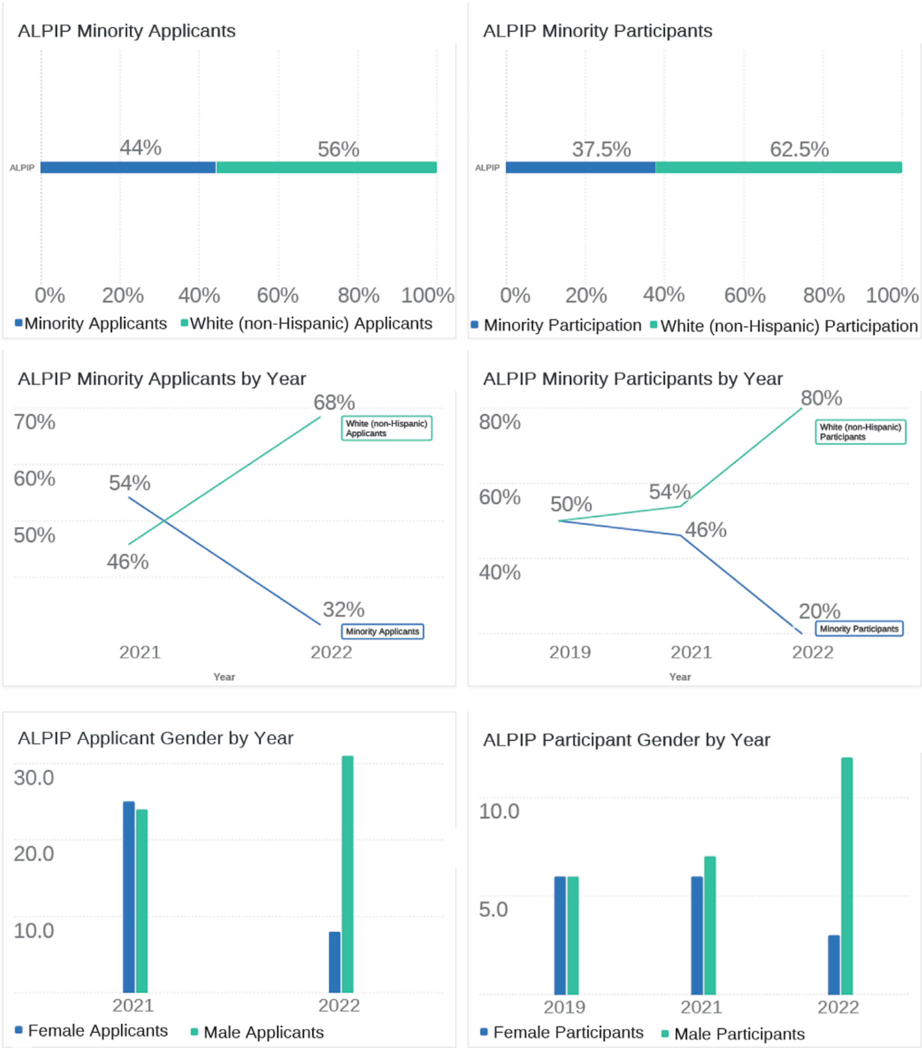

FIGURE 9
Summary of demographic data for the CPU2AL ALPIP summer program over 3 years 2019, 2021, and 2022. Top left: Total number of applicants. Top right: Total number of minority participants. Middle left: Total number of minority applicants by year. Middle right: Total number of minority participants by year. Bottom left: Total number of female applicants by year. Bottom right: Total number of female participants by year.

Management Team. Although not at all quantitative, it is nonetheless extremely illuminating to present a few individual ‘success’ stories from our NSF REU program alumni who are currently at different stages of their careers.

Besides having recruitment criteria that aim to increase diversity in race, gender, year of study, and attendance in a non-research institution, we have an additional recruitment criterion that encourages admission on a “need” basis. In scoring an applicant’s need, we consider whether the applicant has had research opportunities before and/or attends a research university (i.e., a university that offers a graduate program in the field of study of the applicant). We generally judge an applicant’s need by a combination of their essay, including their interest in our program, letters of recommendation and transcripts indicating their academic preparation, and their knowledge about the program. An application is assigned a point value for each of these categories. In this way, an applicant who is extremely interested and well-prepared, and has previously completed an REU is on equal footing with an applicant who is also extremely interested, but has no research experience and hence has a high “need”. Occasionally, we have applied this “need” criterion to applicants who are extremely interested in our program and attending research universities but are not well prepared academically for various reasons indicated in their applications. We assess such students as having potential that is not easily demonstrated, and this makes it difficult for them to be accepted to any research program given the highly-competitive nature of REU programs today. We have had two such students, one from summer 2012 and another from summer 2019, whom we accepted based on the ‘need’ criterion.

The first student was a rising-senior from a well-known research university in Florida majoring in Astronomy/Astrophysics. He wrote an exceptional essay explaining his interest in our REU program

 10.3389/fspas.2023.1155972

FIGURE 10
Summary of demographic data for the CPU2AL ALREU summer program over 3 years 2019, 2021, and 2022 in the same format as Figure 9.

and had good letters of recommendation. However, his GPA was not competitive nor did he have any prior research experience. Both of these factors almost certainly prevented his being accepted into an REU program elsewhere. However, his “need” score was high, which allowed us to accept him into our REU program, where he worked with one of our NASA MSFC mentors. His performance in our program was exceptional and led to his pursuing a graduate degree in Optical Science and Engineering at UAH, from which he was hired by NASA MSFC as an Optical Physicist.

Another anecdotal example of a student with high “need” was a 2019 applicant who was a rising-senior at a well-known research university in California majoring in Astrophysics. She was part of an underrepresented community in STEM fields with a relatively low GPA. However, her letters of recommendation were excellent. Despite having some research experience at her university, she had a difficulty obtaining student research positions elsewhere. Her potential as measured by our need criteria was high and so she was admitted to our REU program. She proved to be an outstanding young researcher and gave an excellent final presentation. Thanks to the positive impact of our program, her senior academic year proved very successful. After graduation, she was determined to pursue a graduate education in Physics and applied for a number of programs in research universities of different rankings in the US but was unsuccessful. Consequently, she began to work in industry but her priority remained to enter graduate school. She applied for a second time to various schools and was recently admitted to the graduate program in Physics at a well-known research university in Georgia. For both her application attempts, we provided her with very strong letters of recommendation.

Our 2021 cohort included a female applicant who was a rising-junior attending a non-research university in South Carolina majoring in Mathematics. She had neither prior knowledge of Solar and Heliospheric Physics nor any research experience. She had also made a decision about pursuing graduate studies. She completed our REU program, finding it a life-changing experience. She is currently in her senior year and planning to apply for graduate programs, especially in the area of Astrophysics.

Finally, we point out an interesting outcome from the REU Poster Competition that we have organized since summer 2021. The top three poster presenters receive various prizes (including a first prize winner having the opportunity to attend an international conference outside the US). In 2021, the second place student came

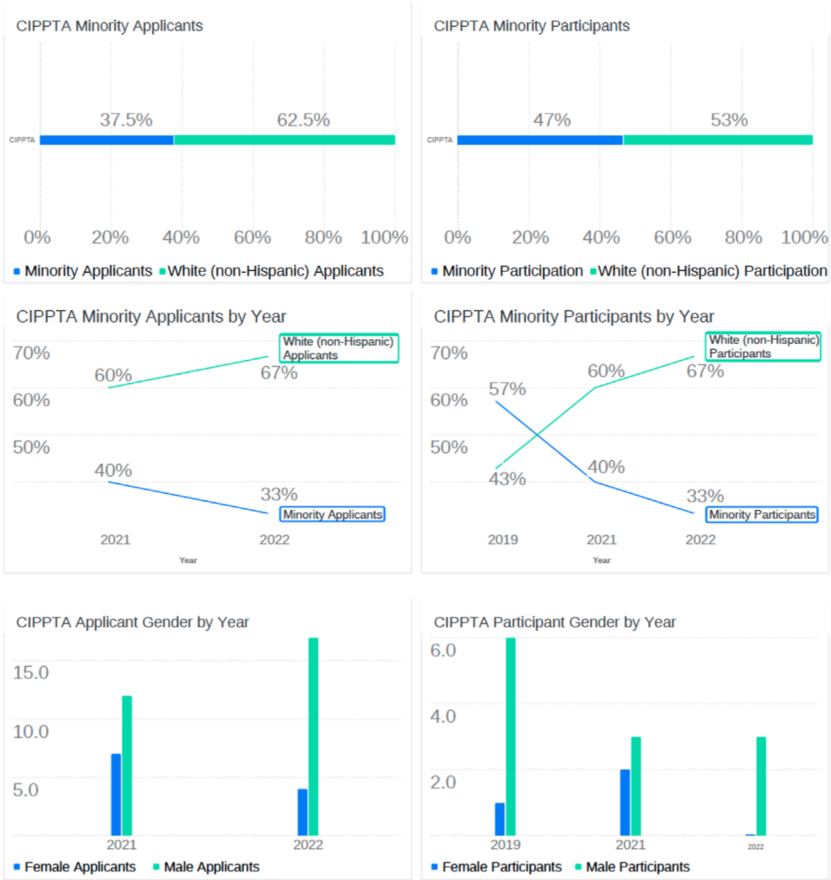

FIGURE 11
Summary of demographic data for the CPU2AL CIPPTA summer program over 3 years 2019, 2021, and 2022 in the same format as Figure 9.

from a Californian community college. In summer 2022, the first and third place winners came from a non-research university in Iowa and a community college in North Carolina, respectively. None of these students had any prior knowledge of Solar and Heliospheric Physics! Besides reflecting good mentorship with our program, it illustrates very clearly that the opportunity to engage in cutting-edge space physics research projects, appropriately tailored, is highly engaging and stimulating to all of our students, even those with relatively little experience or who are "not-so-strong on paper." Given the opportunity, our REU students have uniformly been very eager to learn about Space Physics and their enthusiasm supports and encourages everyone in the cohort.

3.2 ALPIP program

We request feedback from our students at the end of their ALPIP internship using an exit program survey. Of the various questions asked in the survey, two provide particular insight into the success of our program: *"Overall, how would you rate your internship experience?"* and *"Did your mentor have a positive effect on your experience?*". The breakdown of responses to the first question was, with respect to the year of the program, as follows: 2019—58% "Excellent", 25% "Good", and 17% "Fair" from a cohort of 12 students; 2021 was a virtual program—54% "Excellent", 38% "Good", and 8% "Poor" from a cohort of 13 students; 2022—67% "Excellent", 27% "Good", and 6% 'Fair' from a cohort of 15 students. The breakdown of responses to the second question was: 2019—92% "Yes", and 8% "No"; 2021—92% "Yes", and 8% "No"; 2022—93% "Yes", and 7% "No".

The student feedback also includes comments about their internship experience. Some examples are *"After this internship, I'm more than confident in my career goals now! I hope to enter into a materials science Ph.D. program to study plasma!"*; *"It was great. I was really scared at first and felt welcomed and comfortable very quickly. It felt like everyone really wanted to make sure we all had the best experience that we could. I learned a ton. I would definitely do it again if I was given the chance."*; *"I enjoyed the experience a lot. I felt the experience helped me get a clearer idea of what I wanted to pursue in my career. This experience I think has been an important step in professional development."*

What is brought out by these comments is the evident impact on 1) encouraging and developing career and professional goals; 2) instilling confidence that career and academic aspirations can be realized, and 3) drawing strength, inspiration, and confidence from their peers and mentors. These factors are strong drivers for students electing to continue their studies in STEM and as a result, develop the technical skills for the future Alabama and national workforce.

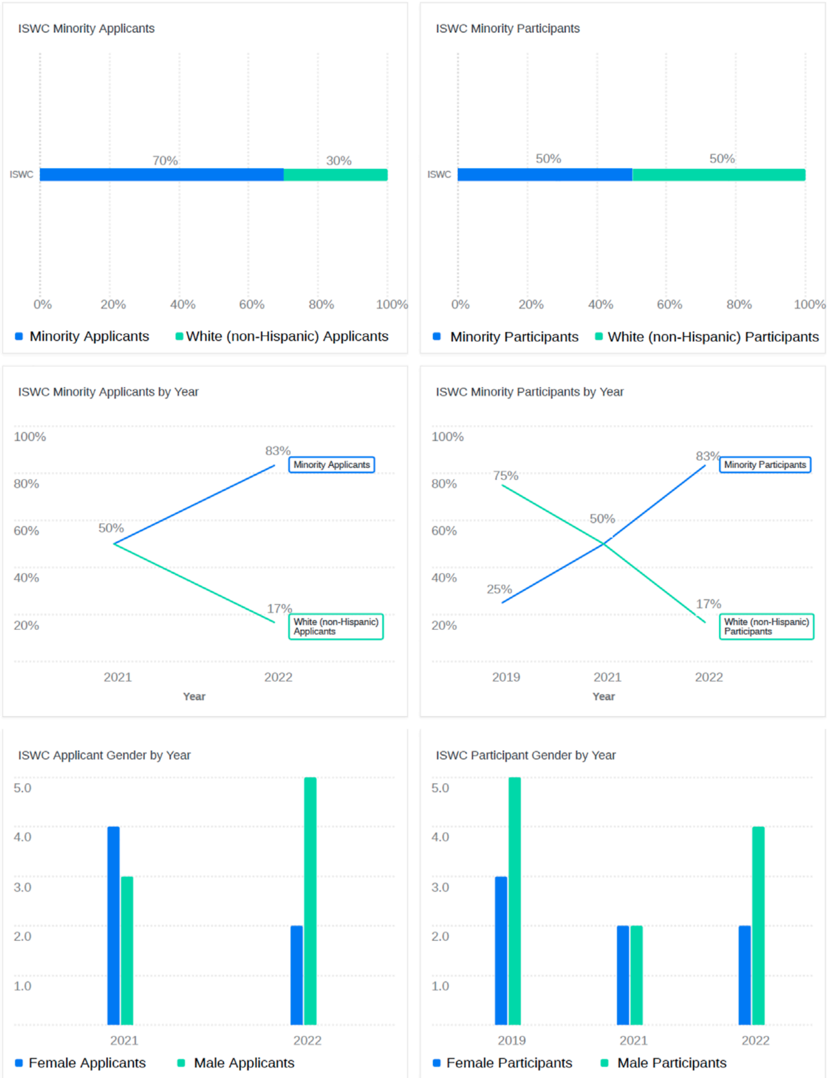

FIGURE 12
Summary of demographic data for the CPU2AL ISWC summer program: Applicant and participant data over the 2 years 2021, and 2022 for which we have complete data. We also present participant data for 2019. The format is the same as Figure 9.

3.3 ALREU program

As above, we ask the same two questions of our ALREU students, obtaining the following responses to the first question: 2019—75% "Excellent", and 25% "Good" from a cohort of 4 students; 2021 was a virtual program—67% "Excellent", and 33% "Good" from a cohort of 3 students; 2022—100% "Excellent" from 3 of 4 students. For the second question, our ALREU students answered "Yes".

Some of the ALREU student feedback about the internship experience is as follows: *"It was a great internship! It was really nice to learn about plasma and it is future in agriculture. There was so much challenge as the chemistry of the plasma activate water was complex. But I learned that researches can be difficult at a times and the more you read the more information you will get and also you might not get all the experience but I learned to react to challenges and learn from mistakes and working with teams and asking for advice and reach to a goal. Overall, it was really eye opening project and I will take my experience to graduate school and continue my research journey."*; *"I enjoyed this internship experience and will definitely suggest to fellow undergraduates"*; *"I gained new skill set and knowledge base which would not have been possible without my mentor's approach to mentorship"*.

The impact of the ALREU program mirrors the statements above.

3.4 CIPPTA program

As discussed, the CIPPTA program is unlike the more traditional summer programs that we run in that it is a bridge between academia and industry. This program is motivated strongly by the CPU2AL and FTPP goal of developing the Alabama workforce. Like our other internships, it has been very successful and until the pandemic, the program was enormously oversubscribed. Response to the first question asked above were: 2019—43% "Excellent", and 57% "Good" from a cohort of 7 students; 2021 was a virtual program—80% "Excellent", and 20% "Good" from a cohort of 5 students; 2022—33% "Excellent", 33% "Good", and 33% "Poor" from a cohort of 3 students. For the second question, 93% of our entire CIPPTA cohorts replied "Yes", and only 7% replied "No".

Comments from our CIPPTA interns about their internship experience include: *"This internship was a great opportunity to experience the industrial working environment and fill the gap between academic research and industrial R&D" "As a computer engineering student, I believe that working on problems related to plasma physics is a great way to apply knowledge in technology and computer engineering. I was fortunate to have the opportunity this summer to apply a lot of things I've learned"*.

These are just a few of the many "success" stories we have experienced with our students. Witnessing the achievements and enthusiasm of the students is highly motivating to our mentors, who because of this, are willing to spend time, summer after summer, working with a highly diverse group of students.

4 Conclusion

The field of Space Physics is certainly of significant interest to society, but it also offers a unique opportunity to draw young people into STEM education fields. Space science, whether exploring the Sun, interplanetary space, Solar System planets and bodies, exoplanets, stars and interstellar space, has the capacity to excite the imagination and interest of almost everyone regardless of age, gender, or demographic group. We have been looking into the skies for the entire history of humanity drawing inspiration, knowledge, cultural mores, and wonder that translates into a compelling interest in space science generally. Entering STEM via space science is a key to open the breadth of STEM to our children and students. The summer programs that we offer at the state, national, and international levels give a diverse population of undergraduate and graduate students the opportunity to learn about Space Physics and engage in cutting-edge hands-on projects. With the increasing number of success stories about recruitment in the field every year, our summer programs are a good example of how to address the question of increasing diversity in the field of space physics and thence STEM in general. As described above, we have attempted to provide a reasonable quantification of the successes of our summer programs, and we summarize the current status here with a set of summary charts.

Figure 8 provides a useful summary of the four CPU2AL (and now FTPP) programs in terms of applications, participants, diversity, and gender. Focusing only on the 3 years 2019, 2021, and 2022 (the 2020 programs being suspended), our programs had 352 applicants and we were able to support 75 participants across all four "workforce development" programs. As discussed above at some length, and clearly illustrated in the top right plot of **Figure 8**, the number of applicants dropped significantly after the COVID-19 pandemic. Even by 2022, the application numbers had not improved. The average acceptance rate was 21% and it rose from 12% in 2019 to 36% in 2021 because of the much smaller number of applications. The summer programs recruited women and minorities obtaining overall numbers of 33% minority applicants and 38% female applicants, averaged over a 2 year period (2021–2022 since no data was available for 2019). This translated into 39% of the participants being women and over half, 52%, were minority students, averaged over a 3 year period (2019–2022).

Figure 9 is a cumulative summary of the CPU2AL ALPIP program. Almost half of ALPIP applications are minority students, i.e., 44% on average over a 2 year period (2021–2022). This translated into 38% minority participation but there was a 30% decrease in minority participants on average over a 3 year period (2019–2022). The COVID pandemic appeared to have a larger impact on our minority students than our white (non-Hispanic) participants. A similar decrease was seen for female applicants and participants as we were slowly emerging from the pandemic, with 30% of applicants from 2021 to 2022 being female. The number of female applicants decreased by 68% between 2021–2022. The average female participation numbers reflected the application numbers with 37% female participation from 2019–2022, and similarly female participation decreased by 50% between 2021 and 2022.

A summary of the ALREU program is given in **Figure 10**. The ALREU program leverages the NSF REU programs that operate currently throughout the State of Alabama with CPU2AL recruiting exclusively minority students, especially from the HBCUs in AL. Therefore, all applicants and participants are minorities. However, over half of ALREU applicants are female, with 60% female applicants average over a 2 year period (2021–2022). The bottom right panel shows that the ALREU program increased or maintained female participation with 63% female participants on average over a 3 year period (2019–2022).

The cumulative demographics of the CIPPTA program are shown in **Figure 11**. Over one-third of CIPPTA applicants were minorities (38%) on average over the 3 year period. Overall, nearly half (47%) of CIPPTA participants were minorities although the number of minority CIPPTA participants decreased by 24% over 3 years, possibly reflecting again the outsize impact of the pandemic on minority communities. Of concern is the bottom panel of **Figure 11** which shows that 19% of the CIPPTA applicants in 2022 were female. CIPPTA has the lowest number of female applicants of all our summer programs despite having a reasonable number of minority applicants. As a consequence, the CIPPTA program has had fewer female participants than male participants each year, with none in 2022.

We conclude with a summary of the last 2 years (2021–22) of the CPU2AL-supported ISWC in **Figure 12** since we have complete data for these 2 years. Over this period, the ISWC had 70% minority applicants and participants, specifically 70% average minority applicants and participants (2021–2022) and 83% minority applicants and participants in 2022. Some 43% of the ISWC applicants were female and they made up 40% of the participants during this period. We draw attention again to the data presented in **Section 1** on which we based our target numbers for URM and women participants. **Figure 8** shows the cumulative breakdown of the diversity distribution of the PSE-affiliated summer program students. In view of the PSE statistics quoted in **Section 1**, as measured by both applications and participation, the summer program DEI numbers far exceed the participation levels of women and underrepresented groups for physics as a whole and PSE in particular. The URM and female breakdowns also exceed our nominal targets that were based on growing our student numbers by ~10% in all categories.

The success of our students, often best gathered anecdotally rather than in dry statistical charts, in our various summer programs motivates many of us to provide a high-quality research experience to students from diverse backgrounds. Not only is this of immense value to the students themselves with many either continuing their STEM education path as undergraduates or other continuing on to graduate studies in STEM fields but also it contributes to a vital state and national need in creating a highly-qualified US workforce.

Author contributions

MY is the Program Coordinator of the REU Program and the Co-Investigator of the REU grant. He contributed to the writing of the paper. GZ is the Principal Investigator of the NSF EPSCoR projects CPU2AL and FTPP, and the REU grant and contributed to the writing of the paper. LP is the Education, Outreach and Diversity Coordinator of CPU2AL and FTPP. She created the figures, compiled the success stories for the EPSCoR internship programs, and contributed to the writing. DS and KH contributed to the analysis of the data from the EPSCoR internship programs. All authors contributed to the article and approved the submitted version.

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Conflict of interest

Authors DS and KH were employed by the company Edu Inc.

The remaining 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.

Publisher's note

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Raising awareness on mental health in the heliophysics community

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To foster greater diversity, equity, and inclusion within the field of space sciences, it is crucial that we recognize and proactively address the mental health challenges experienced by our community. The purpose of this article is to raise awareness about mental health, assess the current state of our community in this regard, and explore ways to better safeguard and support our community members. We present a compelling argument for conducting surveys to evaluate the mental health and overall wellbeing of our community. Additionally, we offer several recommendations aimed to improve the mental health within our research community such as promoting honest conversations and programs on stress management and resilience building, training to notice and respond, and rethinking sick days. We recommend reevaluating our definition of success and reconsidering the existing strategies aimed at addressing the issues related to power imbalances. By promoting mental health awareness, fostering an open and supportive culture, and implementing policies that prioritize the wellbeing of all individuals, we can create an environment that is more inclusive and conducive to the thriving of every member.

KEYWORDS

mental health, heliophysics community, burnout, harassment, psychological safety, work-life balance, stress management, culture change

1 Introduction

Our community spans various institutional types, from academia to government agencies to industry, covering a wide range of constituents, including graduate students, postdocs, tenure track or tenured faculty, research faculty, and scientists and engineers at different career stages. Many researchers in our community, whose careers depend on winning research grants, experience great distress about the prospects of their careers, workload and workplace culture, among other issues.

While a career in research and academia can be enriching, the associated challenges can negatively impact the mental health of anyone, regardless of their career stage. Recently, more than ever, there has been a surge of mental health issues related to increasing pressure, anxiety, and burnout. A recent study by the National Academies of Sciences and Medicine [1] on mental health for students in higher education found a deteriorating landscape in all areas of mental health among college students, even before accounting for recent strong stressors such as the COVID-19 pandemic.

To foster greater diversity, equity, and inclusion within the field of space sciences, it is crucial that we recognize and proactively address the mental health challenges experienced by our community. By developing comprehensive strategies, we can effectively tackle these issues and create a supportive environment for all individuals involved. In Sections 2, 3 and 4, we highlight the importance of addressing the stigma surrounding mental health and provide a brief overview of various challenges that can negatively affect mental wellbeing, including burnout, job insecurity, and harassment, which can be exacerbated by our work environment. In Section 5, we present a compelling argument for conducting surveys to evaluate the mental health and overall wellbeing of our community. Additionally, we offer several recommendations aimed at enhancing the mental health of our research community. We provide suggestions to revisit our measure of success and devise ways to address challenges associated with power imbalances. These suggestions can serve as practical measures to foster a supportive and thriving environment for all individuals involved. It is crucial that we strive for a research community in which researchers can freely express their concerns without fear of reprisals, prejudice, and/or fear of judgment or discrimination from their peers, supervisors, or colleagues. In such a community, there should be zero tolerance for bullying, abuse, harassment, and discrimination.

We note that this article does not aim to provide an exhaustive review of all mental health issues that we face in our science community. Rather it serves as an initial step to raise awareness about mental health. We provide a few general practices that can help alleviate these issues. However, we recognize that delving into specific practices and implementation approaches is beyond the scope of this current work and will be the subject of future endeavors.

2 Where are we on mental health now?

There have been a few studies, mainly for graduate students and postdocs in university settings (not specific to Heliophysics), to evaluate mental health status, the prevalence of mental health issues, and interventions and their respective effectiveness (e.g., [2–6]). Some of these studies were conducted within specific institutions. For example, a 2015 University of Arizona report found that the majority of doctoral students' experience "more than average" or "tremendous" stress and recognized school and education-related issues as the largest contributors to their stress [3]. Data from the 2018–2019 Healthy Minds Study of more than 300,000 students at ~ 300 colleges and universities, which was conducted before the COVID-19 pandemic, highlighted that 40% of students reported significant mental health challenges, while 60% of undergraduates reported increasingly difficult challenges in accessing mental health support [6]. A survey of 2,279 individuals (90% Ph.D. students and 10% Master's students) from 26 countries and 234 institutions demonstrated that anxiety and depression have a considerable prevalence within the graduate student community [5].

Unfortunately, these impacts do not stop at universities, they go well beyond education and into the workforce. The COVID-19 pandemic exacerbated the general public's mental health through illness, grief for loved ones, unsustainable workload, isolation, absence of supportive community, inability to access mental health resources, etc. (etc. [7–9]). A 2020 survey of 5,247 graduate students in STEM showed the number of students with depression doubled, and the prevalence of anxiety rose by 50% [10].

3 Stigma around mental health

Several studies have shown that one in five people experience a mental health issue in their lifetime [7]. Those suffering from clinical or minor conditions often hide it. At work specifically, they fear that they may face discrimination from peers and supervisors or be viewed as incompetent and incapable of performing their work or completing their studies [11].

Recognizing and addressing our own mental health-related concerns fosters a deeper sense of self-awareness. This heightened self-awareness within our community can have a positive ripple effect, contributing to increased authenticity and enabling individuals to grow as better human beings, employees, and leaders [12]. Studies have shown that feeling authentic and open at work leads to better performance, engagement, retention, and overall wellbeing [13]. Employees can significantly boost their performance and professional relationships if they can openly express their struggles and concerns to their managers/supervisors. Neglecting to acknowledge the mental health challenges experienced by members of our scientific community will inevitably lead to a decline in productivity [14].

4 Burnout, isolation, poor work-life balance, and negative consequences of power imbalances

Burnout was included in the international classification of diseases of the World Health Organization in 2019 and is defined as "a syndrome conceptualized as resulting from chronic workplace stress that has not been successfully managed" [15]. This definition acknowledges that burnout is more than just an employee problem; it is an organizational problem that requires an organizational solution [16]. The COVID-19 pandemic has further intensified the experience of burnout for numerous individuals, including those in the research community. The blurring of boundaries between work and home has contributed to this heightened sense of burnout. Within our scientific community, there is often a culture that celebrates working overtime. However, studies have consistently shown that the risk of occupational burnout significantly rises when employees consistently work more than 50 h per week, and this risk further escalates at the 60-h mark. It is important to note that working longer hours does not necessarily lead to increased productivity, highlighting the need to reevaluate our approach to work-life balance (e.g., [17,18]).

The workaholism and poor work-life balance that exists in our community has been worsened by the challenges of the pandemic leading to increased burnout. Several studies have shown that more junior and historically underrepresented (including LGBTQ+, Black and Latinx) employees struggled more severely partly due to less autonomy at work, lower level of seniority, and feelings of loneliness and isolation (e.g., [16,19,20]). Parents with young or school-aged children faced unique challenges during the pandemic. With limited child care options available, they were compelled to juggle the responsibilities of homeschooling their children while simultaneously working from home. Additionally, the increased household chores stemming from having everyone under the same roof 24/7 added further pressure on these parents.

Most, if not all, of the career-related mental health issues addressed here are ultimately caused by financial stress (e.g., [10]) and the uncertainty caused by the soft-money funding scheme. For many, the sole-reliance on "soft money" exerts tremendous pressure and anxiety to secure grants, publish papers, and to maintain their reputation in the research community (e.g., [21]). To fully fund one's self often requires submission of at least three plus proposals per year to increase the likelihood of being fully funded in a given year (considering the typical proposal winning rate of ~20%). This means more time is consumed by proposal writing and less time on actual science and publications, which is even more damaging to our careers. Working longer hours in a culture in which stress and anxiety are normalized will jeopardizes our health at every level (mentally and physically).

Sexual harassment is yet another big factors that disproportionally affects women in science. In a survey of 474 astronomers and planetary scientists, Clancy et al [22] found that 30% of women felt unsafe because of their gender (compared with 2% of men). Pervasive and damaging sexual harassment in science has been reported in by a special committee appointed to examine this issue by National Academies of Sciences, Engineering, and Medicine [23].

5 What to do to improve mental health?

In this section, we present a set of simple yet impactful recommendations aimed at bolstering support for our community members, addressing their needs on both an individual and institutional level. These suggestions offer practical steps to foster a more supportive and inclusive environment for everyone involved.

5.1 Comprehensive surveys of the heliophysics community

The first step towards a positive change and improve mental health is to better understand the current state of affairs. For this, we must better analyze and assess the state of wellbeing in our specific scientific community. We need mental health studies and surveys among researchers and scientists at all career stages across the Heliophysics field. These surveys should be conducted over all types of constituents (students, postdocs, tenure-track and research faculty, and research scientists in academia, research institutions, and industry). These surveys should be thorough and conducted under the guidance of mental health professionals. They should cover a wide array of topics, including mental health, stigma, job security, workplace culture, work arrangements and locations, pandemic-related challenges, racial injustices, bullying, harassment, and more [24]. Moreover, it would be valuable to conduct additional surveys to identify existing interventions supporting researchers, assess their effectiveness, explore areas for improvement, and propose additional provisions that can be implemented.

The results of such surveys should prompt academic institutions, organizations, and policymakers to consider intervention strategies and evaluate the effectiveness of those strategies. This is an essential requirement to ensure a healthy workplace and the accessibility to mental health resources for all researchers.

5.2 Need for a culture change: Honest conversations and a psychologically safe environment

Our scientific community members should feel safe while discussing and/or expressing their challenges without the fear of being judged, excluded, or passed up for the next opportunity or for a promotion. To help set a culture of openness, mental health needs to become a mainstream topic and conversation (e.g., [20]) and to achieve that we need to have open and honest conversations about it within the community. A practice that has already been implemented and we encourage to continue is to hold sessions on mental health and diversity, equity, and inclusion (DEI) at major scientific events such as CEDAR, GEM, SHINE, and AGU. These sessions can include panel or general discussions from mental health experts as well as heliophysics community leaders and members.

When individuals engage in open discussions about their mental health challenges, several positive outcomes arise. Firstly, it normalizes conversations surrounding mental health, creating an environment where those struggling find it easier to speak up and seek assistance. Secondly, it signifies an acknowledgment that careers in science and engineering come with unique stressors, while demonstrating our commitment to addressing these issues and striving for improvements.

In addition, open conversations enable us to recognize the areas where our community falls short, paving the way for implementing positive changes that continuously enhance the wellbeing of everyone involved. To have meaningful impact, these conversations can be greatly supported by data on the state of the profession and mental health, obtained through surveys. Such data allows us to address problems in the most meaningful and effective ways.

Cultivating a culture change requires a comprehensive approach that involves both top-down and bottom-up efforts, extending beyond the purview of Human Resources (HR) and involving everyone [25–32]. Leaders and supervisors play a crucial role as allies in fostering an open culture. They can actively contribute to creating an environment of psychological safety, where individuals feel comfortable expressing vulnerability. This entails demonstrating compassion, flexibility, and providing sustainable solutions or work practices [33]. In a psychologically safe environment, people are at ease being themselves and expressing their thoughts and emotions [34].

5.3 Programs and education on stress management and resilience building

Until recently, self-care has been prescribed as the cure for burnout. While some tools can be used for improving wellbeing (e.g., meditation or yoga), they are not effective when it comes to preventing burnout [16] or other mental health issues that may require professional therapy or medical treatment. Similar to a culture change, we need top-down as well as bottom-up approaches. To this end, we recommend that institutions examine the systematic causes of burnout and investigate ways to relieve it, offer and advertise the use of programs, resources, and education on stress management, building resilience, and address work-life imbalances apparent in their own organizations. Some practical programs include mental health resource pages, flexible hours and working arrangements, peer to peer outreach programs such as mental health employee resource groups, and direct check-ins on employees (e.g., [35,36]). Two additional approaches adapted from [11] are briefly described in 5.3.1 and 5.3.2.

5.3.1 Training to notice and respond

It is also important to train people, including management, to notice and recognize the signs of someone who might be struggling with a mental health challenge, to assess the risk of suicide or self-harm, identify when a colleague is suffering from panic attacks, for example, and connect them to support resources such as mental health first aid, workplace mental health training and strategic advising [37,38]. Mental health policies, practices, culturally competent benefits, and other resources must be put in place and (over) communicated.

5.3.2 Rethinking sick and personal days

Arguably, the most effective approach to addressing burnout is for individuals experiencing it to take a break from work and reconnect with their personal lives. The prevailing work culture in the US often emphasizes over-achievement, which is frequently linked to overworking. To combat this, it is essential that we become more comfortable with the notion of taking time off to prioritize and improve both mental and physical health.

Unfortunately, not all institutions offer adequate paid sick leave or personal days to their employees. To support this necessary shift, funding agencies can play a role by incorporating explicit language in grants and contracts, emphasizing the importance of work-life balance and mental wellbeing. Such measures can help create an environment where individuals have the necessary support and resources to prioritize their mental health alongside their professional responsibilities.

5.4 Revisit measures of success/ performance

Many of the challenges faced by our community are interconnected and cannot be effectively addressed in isolation. One common thread among these challenges is how success is defined and perceived in our field. Given the intensely competitive nature of our profession, researchers at all stages of their careers often experience immense pressure to excel in multiple areas at the expense of their personal wellbeing.

It is essential for us to recognize and address these pressures within our community, working collectively to redefine success and foster a healthier work environment that allows individuals to prioritize their wellbeing without compromising their career prospects. To accomplish this, it is imperative that we acknowledge the diverse roles our members play in advancing our field. Metrics such as principal investigator (PI)-ship or h-index heavily influence our careers, impacting promotions, committee assignments, grant success, and job opportunities. It is important to acknowledge that not all roles or positions yield the same number of publications or grant successes in the PI role. Individuals who dedicate substantial time and effort to developing instruments or scientific models should receive due credit, similar to those who utilize these tools to publish new insights and discoveries. Leadership in projects should not be the sole determinant of success. Furthermore, as careers progress, individuals may find their passion lies in public outreach and communication rather than leading missions or large research projects.

Organizations should strive to move beyond simplistic metrics like h-index or the number of funded PI proposals and instead focus on assessing contributions to projects as collaborators, co-investigators, or other indicators of community involvement, service, and broader scientific impact. By broadening our evaluation criteria, we can foster a more inclusive and supportive environment that recognizes the diverse ways in which individuals contribute to the advancement of our field.

We must also acknowledge and respect that each individual's journey to success is unique. Foreign students and employees attending universities or institutions in the US often encounter additional challenges, such as language and cultural barriers, as well as the difficulties of being separated from their families and loved ones. Additionally, students from lower-income families, both international and domestic, may face financial hardships. These factors can significantly impact their experiences and trajectories in the field. Furthermore, it is important to acknowledge that some individuals may take a "break" from their careers and re-enter the field later, which can result in the loss of valuable "early-career" years. We must be mindful of the diverse circumstances and choices individuals face, understanding that their path to success may deviate from conventional timelines.

5.5 Policies to address power imbalances in the community

Regrettably, it is not uncommon for researchers in leadership positions to engage in unethical and abusive practices, including harassment, bullying, and making decisions that can adversely impact team dynamics. Such behaviors can stem from individual personality traits or a lack of training on effective leadership practices.

While institutions and conferences are strengthening their value statements, codes of conduct, and rules of the road, more efforts are required to address these issues. Funding agencies should take a proactive role by implementing direct supervision and providing specific guidelines on how PIs, project scientists, and leadership should treat individuals working on projects. Additionally, it is essential to offer leadership training to PIs at every stage of their career to equip them with the necessary skills to create inclusive and supportive work environments.

6 Conclusion

To improve the mental health of our science community, we, strongly advocate for a culture change that actively reduces the stigma surrounding mental health and fosters an open and accepting environment. Furthermore, we address several common mental health issues that are highly prevalent in our community, such as burnout, isolation, and poor work-life balance. We recognize the need to reevaluate policies and practices to alleviate these issues and improve overall wellbeing. Our recommendations, in broad, toward achieving this goal include: more open discussions on mental health both at work and scientific conferences, building a culture of connection through frequent check-ins, training to respond, rethinking sick days, offering more work flexibility, reevaluating the measure of success, and reconsidering policies to address power imbalances at work places. Specific implementation strategies and the best practices for each of these topics can be accomplished through collective efforts from scientists, managers, mental health experts, and human resource professionals. Through these collective actions, we can continue to make strides towards a research community that upholds principles of diversity, equity, and inclusion, while also prioritizing the mental health and wellbeing of its members.

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

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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The importance of recruitment and retention in Heliophysics: it's not just a pipeline problem

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A major obstacle in cultivating a robust Heliophysics (and broader scientific) community is the lack of diversity throughout science, technology, engineering, and mathematics (STEM) fields. For many years, this has been understood as a "leaky pipeline" analogy, in which predominately minority students initially interested in STEM gradually fall (or are pushed) out of the field on their way to a scientific research position. However, this ignores critical structural and policy issues which drive even later career Ph.D.s out of a career in Heliophysics. We identify here several systemic problems that inhibit many from participating fully in the Heliophysics community, including soft money pressure, lack of accessibility and equity, power imbalances, lack of accountability, friction in collaboration, and difficulties in forming mentorship bonds. We present several recommendations to empower research-supporting organizations to help create a culture of inclusion, openness, and innovative science.

KEYWORDS

workforce, science policy, informal education, diversity, mentoring, evaluation and assessment frontiers

1 Introduction

The Heliophysics field faces significant challenges in maintaining a diverse and inclusive community (Clancy et al., 2017; American Geophysical Union, 2021; Batchelor et al., 2021). It is often referred to as the leaky pipeline phenomenon, whereby underrepresented and minority populations leave the field at higher rates. The leaky pipeline indicates that the current culture is not conducive to their growth and retention (American Geophysical Union, 2021). This paper follows the discussion initiated by Katherine Garcia-Sage and Alexa Halford during the Helio2050 workshop and the recent publication Halford et al. (2023), highlighting the importance of investing in Heliophysics's culture and community. By examining the need for inclusivity, addressing unconscious biases, and recognizing the impact of power imbalances and microaggressions, we aim to provide insights and recommendations to create a culture that fosters and supports the success of all individuals within the field (e.g., Blue et al., 2018). Through collective efforts, we can create a vibrant and diverse Heliophysics community that benefits from the inclusion of different perspectives and ensures that the field attracts and retains talented individuals from all backgrounds (e.g., Liemohn et al., 2023).

However, not everyone within the Heliophysics community is convinced that having a culture where all are respected, accepted, and welcomed will benefit science. Likewise, not everyone is yet convinced that these issues affect them, are something they should worry about, or are something that they have control over. Therefore, it is important to emphasize the following (e.g., Page, 2008; Medin et al., 2014; Gibbs et al., 2019):

- Equity and inclusion benefit everyone.
- Both intentional and unintentional actions by peers and organizations have a major impact.
- Everyone has unconscious biases. The key is understanding them and implementing a conscious ethic of identification/detection and mitigation.
- Antiracism is an important principle to understand. It focuses on what we are doing to address racism at all levels and encourages all to help eliminate individual and institutional racism.
- Power imbalances, particularly indirect power imbalances, do impact careers.
- People tend to interact socially (both at work and after work) with people they feel most comfortable with. This can result in exclusion from important connections, access to networking opportunities, and in severe cases, the social climate phenomenon of "invisibility."
- Microaggressions are commonplace, often unintentional, actions contributing to a climate of exclusion or hostility. Studies show that many identify microaggressions integrated over time as more harmful and damaging than explicit racism or sexism.

Parts of our culture and policies systematically push portions of our community out of Heliophysics. A clear example of how our culture can unfairly burden certain groups is by relying on metrics like the number of scientific publications as a basis for promotions and awards. However, women, non-binary, and people of color typically have disproportionate Diversity, Equity, Inclusion, Accessibility, Justice (DEIAJ), and other service responsibilities, pulling them away from their research and writing papers (e.g., Guarino and Borden, 2017; Jimenez et al., 2019; Gewin, 2020; Simien and Wallace, 2022). Acknowledging and appreciating the contributions of the subgroup responsible for growing, supporting, and maintaining an inclusive community is absolutely essential in a professional capacity. Neglecting to do so would not only undermine their efforts but also go against the core values of inclusivity and fairness. If a particular subgroup is experiencing a higher degree of implicit and explicit biases, then we will see a pattern where people from underrepresented and minority groups are leaving our field at a disproportionate rate. This is why it is crucial for our institutions to take measures to change our culture, policies, and spaces so that everyone is supported. Otherwise, our efforts to improve diversity and the overall health of our community will have the opposite effect, pushing these groups out of the field even more disproportionately.

For decades, a leaky pipeline analogy has been used when discussing diversity issues in science, technology, engineering, and mathematics (STEM) fields. However, this imagery is overly simplistic and does not capture critical issues contributing to people leaving the field. It puts distance between structural issues, our actions, and why people leave. A leaky pipeline is passive: it lets the water flow out. What we have within STEM and the Heliophysics community is something more active. Our systems and infrastructure, at times, actively push people out of our field. When we view our research structure as something more intentional, we can start taking ownership and frame more impactful solutions instead of misidentifying important issues and providing ineffective short-term solutions.

An inclusive workplace culture must be actively developed and continuously maintained. Many of the issues discussed in Halford et al. (2023) regarding inclusivity in the heliophysics community have counterparts within our policies and institutions. To fully address and mitigate the current problems within our field, we have identified a need to cultivate a positive, safe, inclusive, and effective environment. However, we need both cultural and programmatic changes. In this current paper, we have considered the obstacles that hinder complete participation and provided practical solutions. Furthermore, we have emphasized the industries and communities that have effectively employed optimal strategies to foster innovative environments.

2 The scientific process

Science occurs through collaborations, but we have not always acknowledged this (e.g., Nobel Prize Outreach, 2019). Discoveries require scientists to cooperate, evidenced by the increasing size of successful scientific collaborations (e.g., Cooke and Hilton, 2015; Stanchak, 2016; McGranaghan et al., 2020). How we do science and collaborate directly impacts the results we achieve. How we build collaborative teams, mission teams, proposal teams, and even the selection of conference coordinators, chairs, and speakers impacts who can participate in science. Perhaps even more importantly, this also determines who drives the conversation about how our science questions should evolve (Cooke and Hilton, 2015; Garcia-Sage et al., 2020).

2.1 Open science

Open Science has many schools of thought, but it is based on a few key ideas: open data, open code, and open access to reading journals, all of which help improve diversity and inclusion within our community (e.g., Max Planck Society, 2003; Bloomstone et al., 2022; Roscoe, 2022; Xenopoulos et al., 2022). All of these lower barriers to entry to science and help with the reproducibility of scientific results. Some groups within our field are already adopting these best practices, and groups like the United States of America's National Aeronautics and Space Administration (NASA) Transform to Open Science (TOPS) team are working to make the field more accessible through a focus on open science, open software, and open data (NASA, 2022; Gentemann et al., 2023). The Python development community within Heliophysics is one such community. Best practices identified for open code are referenced in Burrell et al. (2018).

2.2 Best practices in team formation—a move away from collaboration cliques

Science is a team endeavor. The formation of teams impacts who participates and how science is conducted. Science of Team Science is a field of research that looks at how scientists work best within teams and collaborative environments (e.g., Bang and Frith, 2017; Maestre, 2019). The National Academies has reviewed the Science of Team Science and best practices for different types of groups (geographically dispersed, culturally diverse, different types of leadership, etc.) (Cooke and Hilton, 2015). The field of Team Science will allow us to more easily link the sciences to other disciplines, such as industry or the humanities, which is vital to our goal of achieving a more diverse, inclusive, and safe research environment (e.g., Skorton and Bear, 2018; McGranaghan et al., 2020, and references therein).

For instance, it matters who is invited to a team's first few meetings. Inviting only those we think of first, typically those who look like us and have similar backgrounds to ourselves, when forming a collaboration or a proposal team is exclusionary. It limits knowledge transfer between groups and a team's ability to identify missing links and deficiencies. If diverse people are added later in the process, they may have missed the opportunity to become essential. Individuals added later must expend extra time and effort to catch up to the rest of the team. This may include learning the team's jargon, tools and codes, and the background of the work. This inhibits an individual's ability to be a fully functioning member, and some infer an inability of new team members to be constructive contributors. Thus, new members need support and resources to come up to speed and feel that they can be full members of the team. Subsequently, when minority and underrepresented groups within our community are continually added after initial meetings, they will continue to feel looked over, secondary, and not fully valued.

2.3 Interdisciplinary scientists and projects require a home

Interdisciplinary expertise is required to understand the interconnectedness of the heliosphere. Therefore, making it easy to participate in multidisciplinary work is necessary for Heliophysics to flourish beyond the advancements made in the past decades (Garcia-Sage et al., 2020). The high-level best practices in the Science of Team Science lead to effective teams, improved creativity, and innovative scientific results. Often, we see that individuals who do interdisciplinary work are not considered to belong to any sub-field and find themselves at times out of these close networks. Scholars in minoritized groups, such as women and people of color, are often more likely to work in subfields beyond the core of a discipline (Gonzales, 2018; Settles et al., 2021; Stevens et al., 2021).

Furthermore, journals focused on interdisciplinary science often are valued lower than the (traditional) disciplinary publication forums. Unless we want to lose multidisciplinary expertise from the field, we need to make sure that there are jobs for these individuals (e.g., Settles et al., 2021, and references therein). Thus, it is crucial to make decisions for hiring and committee appointments for relevant positions where interdisciplinary expertise is considered a strength.

Similarly, genuinely interdisciplinary projects often struggle to find a funding source, as funding agency divisions may not consider interdisciplinary proposals core to their objectives (Hoppe et al., 2019). Likewise, interdisciplinary science questions are often not seen as compelling by review panels, who are often looking at very focused science topics with clear outcomes. A possible way to mitigate this is to build funding sources and academic departments within the field, whose core objectives are to foster interdisciplinary projects. An example could be the formation of a trans- or interdisciplinary division within NASA and other funding bodies, recognizing the potential for scientific discoveries in our field in the vast unknowns between disciplines.

3 Soft money science

Most of us will be or have been on soft money for at least a portion of our career (DeJong et al., 2020, and references therein). The Heliophysics community often regards soft-money positions as temporary, being filled by graduate students or early career researchers. However, many members of the Heliophysics workforce are supported by soft money throughout their careers, and the success of groups building space experiments or comprehensive databases, models, or simulations often critically depends on the contributions of these researchers (e.g., Herschberg et al., 2018, and references therein). Soft money positions can have benefits, such as fewer or no teaching obligations and greater flexibility in work locations and hours, but there are also pitfalls (e.g., Barinaga, 2000; Kean, 2001; López et al., 2018). Some difficulties that soft-money employees encounter are directly related to HR and grant and contract policies of their employers and funding agencies. Heliophysics research can bring millions of dollars to universities and other institutions, but the departments and investigators who secured this funding often see little or no return on their overhead. For example, the facilities and administration (F&A) costs charged on grants and contracts that support soft-money employees go into the general fund accounts of these institutions. That is, the PI of the grant does not directly control them. This can make it difficult for individual PIs or their departments to provide adequate computing resources, laboratory access, office space, and furniture to soft money employees, as these "general-use" spaces and equipment often cannot be directly paid for by grants and contracts. A further example is that the department may deem that a software tool like MatLab is necessary and vote to spend those funds for MatLab licenses while one or more of the researchers who contribute to those funds do not use MatLab and instead need IDL.

Additionally, many institutions include a separate line item in grant/contract budgets for fringe benefits (e.g., healthcare, worker's compensation, tuition assistance, retirement benefits). When their institutions classify soft-money employees as full-time, regular employees, they often receive these benefits. However, soft-money employees classified as temporary or independent contractors may not have access to these benefits, providing little incentive for these individuals to continue working in Heliophysics. Policies that encourage hiring full-time employees over temporary workers would contribute to a more stable, experienced Heliophysics workforce while improving the productivity of the groups.

The issue of increasing term and soft money positions leading to toxic impacts within a research field is not new or limited to the Heliophysics field (Cardelli, 1994; Cameron, 2014; Bourne, 2018). The short time frames and budgets of grants and contracts drive the need for soft money researchers and employees working at full-cost accounting institutions to write new proposals constantly. Anxiety over job security can motivate researchers to leave academia and the field. For example, researchers supported through soft money are often regarded as less capable than those holding tenure-track faculty positions, even if their scientific contributions are of equal quality. Many soft-money researchers mentor students and post-docs, manage projects, and serve on service committees. In effect, soft-money researchers carry out many of the same duties as faculty (e.g., Haviland et al., 2017; Flaherty, 2018). Still, they are often ineligible for many opportunities that support professional development, mentoring, and large-scale or long-term projects (e.g., the United States of America's National Science Foundation [NSF] CAREER awards, Major Research Infrastructure). Including soft-money researchers in these policies and proposal calls would help ease the anxiety and improve the Heliophysics workforce morale. For example, the overhead allocation to support bridge funds could support all employees between grants for a month or two. Another idea would be to return a fixed portion of each grant's overhead (2%, 5%) directly to each researcher on the grant and pooled into discretionary 'rainy-day funds that do not expire. Every step to improve financial and funding security helps keep people in Heliophysics.

4 Accessibility and equity across different sections of our community

Many subfields and social communities within Heliophysics have different needs to participate fully in day-to-day science activities. For example, physics buildings at US research institutions are often old and "grandfathered" into not meeting Americans with Disabilities Act (ADA) requirements. Due to the lack of funding at many institutions, these challenges are not adequately addressed, and the burden falls on the disabled individual to navigate campus support. While renovating an entire building may be impossible under budget constraints, minor improvements, such as retrofitting automatic doors on restrooms or wheelchair lifts, are within possibilities and should be pursued more actively. Additionally, participating in conferences is physically demanding and presents restrictions to many. Catching a specific talk may require moving quickly from a poster hall to another room. Scientists with physical limitations may be forced to stay in one area and miss out on other opportunities. Individuals not able to stand for several hours in a poster session can request chairs, but this can also cause issues, as sitting in a chair makes it difficult to support a crowd of people visiting the poster. The standards for ADA accommodations at conferences need to change from special requests which burden the disabled individual to standards that present minimal barriers to networking.

There are many more elements than conferences and building layouts that can be adapted to make community members feel welcome. While we are not able to list them all in this paper, we have tried to highlight some key areas where more work is needed surrounding accessibility and equity across different sections of our community:

- Consideration of the needs of those with visible and invisible disabilities in the initial phases of policy making and planning.
- Accommodation for scientists with disabilities (e.g., teleworking, virtual conference participation, live captioning).
- Reasonable deadlines that fit into the months-long clearance processes that many within our community are tied to.
- Family care inclusivity and equity.
- Child/family care grants, including care at conferences and support at home;
- Ability to work half-time for extended periods;
- Continued support for family leave.
- Reduced costs of participation, e.g., cost of conferences, laptop computers, software, and publishing in and reading scientific journals.
- Hybrid or fully online options for conferences and workshops mitigates issues with travel. Many smaller workshops found that more people attended from a broader geographical representation of home institutions during the pandemic as the barrier of travel costs was removed.
- Encouraging open science practices such as using freely available coding languages (e.g., Python, Julia), publishing in open access journals (e.g., providing NASA/NSF funding for gold open access like other agencies do, such as National Environmental Research Council [NERC]), and making our research open will enable more people to participate as well as enhance the reproducibility of scientific results.

5 Promoting hybrid meetings

With the increasing pace of technology and online connections tools, we have greater flexibility than ever in how we collaborate. We are no longer limited to being in the same physical space for meaningful discussions. There are benefits and challenges unique to in-person or virtual collaboration (e.g., Sarabipour, 2020; Ostler et al., 2021; Tao et al., 2021; Ellis et al., 2022). Hybrid meetings allow for the best of both worlds: more accessible in-person discussions and networking for those who can come on-site and the ability to contribute viewpoints and scientific debate for those unable to travel. However, we must be careful that this physical separation between on-site and online colleagues does not also produce a "participatory" bias. Care must be taken in establishing the culture/norms of these hybrid meetings, ensuring online and in-person voices are equally heard. Some possible suggestions include:

- Having someone on-site with the specific responsibility for raising the voices of those not physically present (e.g., reading out questions, raising a hand on behalf of a virtual participant).

- Having laptops/phones/etc. Out for engaging with the remote team members via chat.
- Dual online/in-person poster sessions; webcams and screens for live chat with online participants.
- Asynchronous collaboration, including recorded talks, continuously available poster access, or question and answer in a message board format.

6 Common, collaborative, affordable tools

Science is a collaborative endeavor and is often best done when we collaborate across institutions. We have many different tools for virtual collaboration available to us. Today, we can communicate and collaborate via options as diverse as Email, Google Meet (Google, 2023 Accesssed: 2023-7-07), Stack Overflow (Stack Overflow, 2023 Accesssed: 2023-7-07), Overleaf (Overleaf, 2023, which was used in the collaboration of this project), Github (github, 2023), and Jupyter Notebook (Kluyver et al., 2016). However, many institutions, especially within the government and industry sectors, limit employees' access to collaborative tools. This impacts the ease and effectiveness of collaborations across institutions. Our collaboration tools and relationship with them can greatly impact how welcome we feel within the community, especially if we do not have access to them. However, this also means that there are a large number of spaces we have to monitor. Although internet-based collaboration tools may always be "on", we must develop a culture that does not necessarily expect us always to be on and interacting with those tools. A healthy balance between synchronous and asynchronous collaboration will maintain connection and productivity.

7 Need to address power imbalances

In the current academic infrastructure, there is inherent unbalanced power at all career levels. Whether it is a graduate student at the mercy of their Ph.D. advisor, a postdoc who is unsupported by their supervisor, or a senior scientist who experiences unhealthy dynamics with their mission PI, individuals deserve a structural system that allows them to report abuse and harassment safely (Turner, 2018; Gómez-González et al., 2022). Our current structure is insufficient, and we can work to build better support systems. For example, students and early career researchers often have only one mentor. By having two mentors or co-mentors/co-advisors, individuals may have an ally who can help before things escalate. Other solutions, such as the Faculty Allies at the University of Michigan, can also help (The Regents of the University of Michigan, 2023). Everyone deserves to exist in a safe environment to perform their research, see abusers held accountable, and help ensure our field is safe for those who come next. In short, they deserve a chance for justice (Milazzo et al., 2021). We must build institutional systems that check power imbalance. One example of such a process is the dual anonymous peer review, which has been demonstrated to increase the diversity of researchers who win proposal calls (Witze, 2019; Radebaugh et al., 2021).

8 Accountability for bad behavior

Accountability is a necessary but complex topic. We want to acknowledge that people can grow and change. However, we need precise mechanisms for reporting and accountability for bad actors and continual harassers. There is a quantifiable risk to the careers and the reputations of people who bring forward complaints (See "Picture a Scientist", the 2017 documentary (Witze, 2020) and Turner (2018)). This can include further implicit bias when the harasser or their supporters review papers and proposals. While the risk may never be zero, some mechanisms can help mitigate this risk and address other issues of bias. We need precise tools for reporting and accountability for bad actors and continual harassers.

Further, we know that harassment disproportionately impacts women of color. A recent study by Clancy et al. (2017) found that of astronomers, 40% of women of color felt unsafe due to their gender or sex and 28% due to their race. The authors also found that 18% of women of color and 12% of white women skipped professional events due to these concerns, leading to fewer opportunities for networking and furthering their careers.

The current institutional and agency mechanisms for accountability for unethical behavior, such as Title IX in the United States of America, are fundamentally flawed (Walters and McNeely, 2010; of Education, 2023; Civil Rights Division, 2023; Das, 2003; Hartman, 2020; Swan, 2020). As an example, Title IX forbids discrimination on the basis of sex in any US Federally-funded activity. However, it does not provide a national resource for addressing harassment (Walters and McNeely, 2010; Civil Rights Division, 2023; of Education, 2023). The handling of individual cases is left to the institutions themselves, and the effectiveness of their responses can vary. Additionally, non-retaliation policies only apply within an institution—but our careers require us to transcend communication across institutions and around the globe (Mattheis et al., 2022). There is currently no policy in place to prevent influential scientists from retaliating against their subordinates or victims. This retaliation can take the form of unfair reviews of their papers or proposals, negative references, and even depriving them of career advancement opportunities or awards (Wadman, 2017a; Wadman, 2017b; Witze, 2020; CULOTTA, 2018; Fortney and Morris, 2021; Liemohn, 2022). These actions are unethical and must be addressed. The Geoff Marcy case is just one example of how powerful scientists can maintain positions of power and continue to influence individual careers and the culture of a field (Ghorayshi, 2015). Additionally, imperfect implementation and enforcement require the person harmed to have significant resources, both financially as well as strong emotional and career support networks, thus putting the onus on the person harmed.

Consequently, individuals have an inherent career risk when reporting harassment and seeking justice for enduring harmful working conditions. This is unacceptable and must be addressed immediately. Therefore, we recommend that government institutions like the European Space Agency (ESA), NASA, and the NSF create trans-institutional Human Resource (HR) support for safe, anonymous reporting. As harassment can and does occur and impact individuals' careers at any stage, scientists from all career levels would benefit from such trans-institutional HR support.

ESA, NASA, and the NSF can help hold researchers accountable by creating an ombudsperson role for missions (which are virtual institutions within themselves) and non-mission-related projects (such as proposal calls) (McDonald et al., 2014). These ombudsperson roles could start as extensions of a Project Scientist role on a mission or equivalent point of contact on proposal calls and eventually be integrated into a newly created position to ensure maximum accountability for unethical behavior in all forms.

Scientific societies can also help play a role here. Societies often cross not just institutional boundaries in a single country but across the globe. They also often are associated with the primary journals of a field which can then more easily survey a much broader community (Ford et al., 2018; Langenberg, 2018; Hanson et al., 2020; American Geophysical Union, 2021; Roscoe, 2022). Having societies and journals help with cross-institutional enforcement would help protect those harmed within their specific research community. The American Geophysical Union (AGU) has rewritten its ethics code to define discrimination, harassment, and bullying as forms of scientific misconduct (Science suffers from harassment, 2018), and other professional organizations should follow this lead.

9 Mentorship

Mentoring can be incredibly valuable in supporting the careers of individuals (Bernstein et al., 2010; Mullen and Klimaitis, 2021). Many of us who have succeeded have benefited from supportive mentoring (e.g., Fuselier, 2022; Smith, 2022; Liemohn et al., 2023). This mentoring may have been informal or formal. For example, it may have been a principal investigator (PI) or Co-I engaging us in the development of a science traceability matrix, or it may have come in weekly coffees to discuss career goals and how to navigate through the community. Formal and informal mentoring is incredibly invaluable and a key component of retention and future success.

Mentoring can take many forms. It may be informal (e.g., Mummery et al., 2021, and references therein), it can be peer-to-peer (of Colorado, 2023), or it can be structured either through group mentoring (Whitebeck, 2001; Daniell, 2006) or one-on-one mentoring within organizations, (Hund et al., 2018; Stelter et al., 2020; Ålund et al., 2020). There is a strong need to convey the importance of mentor networks within our community (Adams et al., 2016; Womack et al., 2020). Researchers need counsel on science, emotional support, next career steps, leadership, resilience, work-life balance, and more (Fuselier, 2022; Smith, 2022; Liemohn et al., 2023). One's advisor/supervisor cannot be all these things simultaneously. Thus we support the idea that people should have multiple mentors.

For example, the Significant Opportunities in Atmospheric Research and Science Program (the SOARS®) has used a multiple mentorship model with much success (Windham et al., 2004). SOARS is a multi-year undergraduate-to-graduate bridge program focusing on increasing the diversity of the atmospheric and related sciences and career pathways. Specifically, an excerpt from Haacker (2015) describes that mentoring the whole student is extremely important: "Beyond just a research experience, the (SOARS) program provides a multi-pronged approach to supporting students in their summer research and throughout their higher education and entry into the workforce. Students are paired with a research advisor and mentors covering other aspects of being a scientist, including writing, public speaking, and programming. Perhaps most importantly, each student works with a formal peer mentor and a life coach to handle stress and help with life choices. This gives the student a broad sense of support and multiple opportunities to make a meaningful personal connection. The formalized mentoring relationships are focused on the summer internship part of the program. At the same time, a strong peer cohort and support from staff run year-round and, to a lesser degree, over many years. The personalized, caring, and consistent support is one of the key elements of the program's success; since its inception 20 + years ago, 90% of SOARS participants have entered graduate school or STEM (science, technology, engineering, and mathematics) careers after graduation."

Concerning formal mentoring, some institutions have developed and used documented mentoring plans between early-career scientists and their mentors or supervisors (OConnell, 2015). When used properly, mentoring plans ensure both the mentor and mentee get the best out of the relationship and have clear communication and expectations (Klinge, 2015). But, more often than should be the case, these documents are not taken seriously (Eby et al., 2000; Murray, 2001, Murray, 2002).

Additionally, the power imbalance between mentor and mentee can have significant consequences. For example, a mentor who implicitly or explicitly acts in ways that harm a mentee's career, including sexual harassment, will often face minimal or no consequences (e.g., John et al., 2016; Johnson et al., 2018; Deloitte Access Economics, 2019; Ro, 2021; Marin-Spiotta et al., 2022). Establishing clear expectations with accountability should be the norm. This mentorship agreement could hold more weight if monitored by the institutions or agencies running the mentoring program and if mentees know and feel safe to report incidences to the relevant institution. Just as with other unethical behavior, the institutions should hold mentors and mentees found acting unethically, bullying, or harassing accountable.

Formal mentor-mentee roles and responsibilities must be communicated and agreed upon, informed by community norms across institutions, and use transparent mechanisms for accountability (Treasure et al., 2022). One commonly used tool for this is the Individual Development Plan (Brown University, 2022; Fuhrmann et al., 2023). Other mechanisms include mentoring agreements (Together Software, 2022). In all cases, oversight is needed to ensure mentors and mentees do not treat these accountability methods as a box-ticking exercise. It is important that we normalize and make transparent the using of mentorship agreements that have accountability for all involved.

Mentoring is a skill that is not taught in a standard STEM Ph.D. curriculum. However, it is a skill that can be learned (e.g., OConnell, 2015). Agencies can help play a role in teaching new skills, such as mentoring. The NSF requires graduate students who receive funding to take a science ethics class. However, all scientists would benefit from this type of knowledge and benefit from continued study of ethical practices. It is important that we support regular training on topics such as mentoring and ethics for all researchers funded by NSF, NASA, and other agencies and institutions.

Mentorship is not only crucial for students who are new to the field but also for researchers at all career levels (Daniell, 2006; Lozier and Clem, 2015; Morris, 2017; Curran et al., 2019). These mentors can include peer mentors, mentors ahead of them in the career stage, and mentors more recent to the field. Researchers need a web of mentors to reach out to at different times. Peer mentors can be within the same area and location, but there is also a need for peer mentors at various institutions and even different sub-fields to get a breadth of perspectives (OConnell, 2015; Casad et al., 2021). Mentors ahead of the mentee in their career stage are beneficial for "next steps" since they recently went through those transition stages and have the most relevant experience. Mentors even further along in their careers are excellent for networking, contacts, science, leadership, etc. Mentors who are more recent to the field than the mentee bring new ideas, techniques, and enthusiasm. Many of these conversations and mentoring webs are forming on platforms - such as Slack (Slack, 2023) and Discord spaces (Discord, 2023)—but need more motivation and encouragement (if not formality) from institutions and professional societies. More platforms that all people can easily access should also be provided for these mentoring discussions.

It is clear that there is a need within the Heliophysics community for multi-generational and multiple formal and informal mentoring types. Additionally, there is a need for more communication about where to find such activities and groups or how to form new groups [e.g., as described in the book "Every Other Thursday" (Daniell, 2006)]. Thus we see a need for the following:

- Mentor/supervisor training - Most scientists have not been trained to be mentors or supervisors. This skill set can be learned and should be continually cultivated. Mentoring and supervising is also an opportunity to learn and grow the mentor/supervisor's network, mentorship training (Lee et al., 2007; Fleming et al., 2013; University of Wisconsin Institute for Clinical and Transactional Research, 2022).
- Peer mentoring groups - Peer mentoring groups are a fantastic way to provide mentoring and build a network. It has been shown that pairing similar demographics helps with career success, such as women in STEM (Dennehy and Dasgupta, 2017) and lesbians (Gedro, 2006). Some groups adjacent to Heliophysics have peer mentoring groups [e.g., the Earth Science Women's Network (ESWN, 2022)].
- Many mentoring opportunities are available but are often difficult to find. There is a need to advertise these opportunities better and where to find them.

For all community members, especially new members and early career researchers, broad and equitable support systems are fundamental to ensure a safe and accessible work environment, professional growth, and career success. Each individual's needs vary, so support systems must be varied and applied equitably to different cases. The role of mentors and mentoring is a crucial pillar of these support systems.

Examples of the support that needs to be provided by mentoring include Inclusive Mentoring from the Sheridan Center (Brown University, 2022) as well as:

- Emotional and personal support and advice.
- Guidance with the science process (e.g., research project development, paper writing)
- Guidance through bureaucratic processes (e.g., proposals and grants, assessments)
- Sponsorship (e.g., Letters of recommendation, networking introductions, travel support)

Opportunities for mentor training and mentoring experience should be formally available and advertised, including inter-institution and inter-disciplinary opportunities. For example, AGU provides some programs to connect mentoring groups (American Geophysical Union, 2022). Peer-to-peer mentoring opportunities should also be available and encouraged in Heliophysics, with models to be learned from adjacent fields [e.g., ESWN—An international peer-mentoring network of women in the Earth Sciences (ESWN, 2022)].

Mentors should also have the support they need, especially those with underrepresented identities (Whitaker, 2017). Underrepresented mentors often do more of this type of service work without credit and to the detriment of their scientific output compared to those in the majority (e.g., Guarino and Borden, 2017; Jimenez et al., 2019; Gewin, 2020; Simien and Wallace, 2022). Mentorship should be evaluated, and good practices and outcomes in mentoring should be valued and rewarded, for example, in hiring or tenure decisions. This can be achieved by taking a holistic approach to the criteria applied for hiring or promotion, as discussed by Liemohn et al. (2023).

Critically, women, non-binary individuals, and people of color typically have disproportionate mentoring, outreach, and other DEIAJ responsibilities (Gedro, 2006; O'Meara et al., 2017a; O'Meara et al., 2017b). These activities are rarely valued in performance evaluations to the same degree as other job functions. If the burden of promoting a diverse, inclusive community falls disproportionately on a subgroup, it should be recognized and valued professionally. Otherwise, these actions aimed at improving DEIAJ have the opposite effect, disproportionately pushing members of under-represented groups out of the field.

10 Recommendations

Individuals need the support of organizations to help create a culture of inclusion, openness, and innovative science. Through building this culture of inclusion, openness, and innovation, we can improve retention and start building a more diverse community. The recommendations below help empower individuals and institutions to ensure our community is welcoming to all.

- Work more closely with experts in the Diversity, Equity, Inclusion, Accessibility, and Justice (DEIAJ) research community and adopt the best practices they have identified for creating a positive climate and culture for our field.
- Create a database of resources and models/frameworks for cultivating an open and inclusive climate.
- Create and maintain clear and easily accessible tools for reporting bad conduct and holding individuals and institutions accountable.
- Coordinate across agencies to bring awareness to reports of harassment. Create and maintain a list of convicted harassers shared within the field. This is one wayvadjust

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to address the challenge of the disconnect between institutions/societies/organizations/funding agencies when reporting harassment.

- Create effective and thorough protection regarding retaliation for reporting cases of harassment, especially in imbalanced power dynamics (faculty vs. graduate student, civil servant vs. contractor, and so on).
- Enable access to bystander/allyship and other types of training to encourage fundamental change by enabling people to speak up and act when they see something.
- Codify codes of conduct for the field, e.g., mentoring relationships, workshops, or committees.
- Address wage gaps. While not discussed here, this is an important issue regarding why some people leave the field.
- Agencies and institutions (e.g., government research centers, community societies such as AGU, and universities) need to work more closely with groups and people in the DEIAJ research community and adopt the best practices they find for creating a positive climate, culture, and mentorship for our field.
- Embed metrics and incentives into hiring, proportion, awards, and funding structures that value mentorship and other service activities.
- As an example for external awards, within the SPA fellows nomination committee mentoring was included as part of the broader impact one has on the field (Halford et al., 2022)
- As an example for external proposals, service activities need to be prioritized as a larger impact need than just mentioned in the bio sketch.
- As an example of internal promotion, proposal success rates and papers published are often the primary, if not the only, metrics used to evaluate researchers up for a promotion. Including mentorship activities as an essential part of annual evaluations and promotion, reviews would better incentivize these activities.
- As an example of internal performance evaluation at universities, we suggest the weighting of research, teaching, service be re-examined and balanced to account for the importance of service roles.
- Succession planning at agencies like NOAA and NASA, as well as at university institutions through mentorship, ensures that knowledge is not lost as people leave the field and provides new and more leadership opportunities and training.
- Opportunities for cross-generational leadership within the field across all areas (e.g., AGU, Universities, NASA).
- The Space Physics and Aeronomy Section of AGU, in cooperation with government agencies, industry partners, research institutes, and academia, should regularly sponsor a collaborative Heliophysics research space at the Fall AGU Meeting similar to the AGU Sharing Science SciComm space. This space would be used for scheduled meet and greets for research collaborations and job recruiting, interdisciplinary networking sessions for researchers looking for collaborators on future proposals, and tutorials on using data sets, models, and tools.

11 Nomenclature

Nomenclature is important—and perhaps even more so when discussing cultural issues. We created a glossary within our poster, which we hope individuals will find helpful (Halford et al., 2021).

Author contributions

AH lead the conception of the effort and the writing. All coauthors assisted in editing and revising. MJ wrote the information on the SOARS Program. NT assisted in editing and including information on harassment in the sciences and relevant policies. All authors contributed to the article and approved the submitted version.

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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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Supporting neurodivergent talent: ADHD, autism, and dyslexia in physics and space sciences

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Diversity, equity, inclusion, and belonging efforts must include disability and neurodivergence. While there is a long history of famous scientists being identified or speculatively indicated to be neurodivergent, identification on an individual basis has been limited until fairly recently. Definitions have changed and broadened, and people are being identified or are identifying themselves as neurodivergent and are learning about their paths and their brains in a way that was unavailable to people two decades ago. In the contemporary physics or space science classroom or workplace, we have both a responsibility to include and support our neurodivergent learners and scientists, as well as an opportunity to use insights from the neurodiversity movement to better support our teams and students. Herein we explain the language used to describe neurodivergent traits and offer strategies and ideas to support our neurodivergent community members. These strategies include ideas for supporting executive function as well as tips in the areas of physical comfort and sensory considerations.

KEYWORDS

neurodivergence, autism, ADHD, dyslexia, inclusion, disability, physics, space

1 Introduction: physics, space science, and neurodivergence

Diversity, equity, and inclusion efforts are important and have been making headway in physics and space sciences, (see, for example, the review [1]), and such efforts must include disability and neurodivergence.

Two famous archetypes in science and academia, the absent-minded professor and the socially awkward scientist, are evocative of some well-established neurodivergent traits and tropes (roughly speaking, ADHD and autism, respectively). A popular contemporary television show offered viewers an autistically-coded astrophysicist (though without ever acknowledging him as such). Physicists as a community seem at times to self-identify as having some social differences that would on the surface appear to have nothing to do with physics at all, selling buttons at an American Physical Society March Meeting that said, "Flirt harder, I'm a physicist." It is an old joke in the autistic community that some flirtatious cues can be missed.

Many famous physicists, astronomers, and inventors have exhibited traits suggestive of neurological differences such as ADHD, autism, dyslexia, or some combination of those. These include Marie Curie and Albert Einstein [2], Thomas Edison [3], Isaac Newton [4], Paul Dirac and Henry Cavendish [5], and many more. Freeman Dyson devoted a large part of his book review of a Dirac biography to discussing whether his colleague Paul Dirac was autistic, concluding that Dirac could have been, but only if autism could be understood as more of a neurological difference rather than a pathology [6]. In fact, some researchers have specifically shown that autism and autistic traits are more common in physicists' families than in most other occupations [7,8].

As these traits are more common in the broader physics-related community than other areas, physicists and space scientists could particularly benefit from making their workplaces more neurodivergent-friendly.

1.1 Neurodivergence and the neurodiversity movement

Neurodiversity is a vast umbrella term, including differences as wide-ranging as ADHD (which now includes what was once known as ADD), dyslexia, Tourette's, bipolar, autism, anxiety, and every possible combination of those and many others. Neurodivergent people approach tasks, problems, design, etc. in different, divergent, ways from neurotypical people. The term emphasizes brain, or neurologic, differences.

Concurrent with the evolution of this term is a neurodiversity movement. Emily Ladau [9] suggests that "for far too long, we've been led to believe that people have either "good" brains or "bad" brains, "normal" ones, or "abnormal" ones. Neurodiversity is a concept that rejects morality–and value-based judgements of the human mind, instead embracing the naturally occurring fact that no one's brain is exactly like anyone else's brain."

Herein we will address how to support neurodivergent talent and let people flourish as who they are. We will not attempt to break down strategies by neurotype, first because neurodivergent traits manifest so differently in each individual, but also because in practice we do not often know the neurotypes of the students and scientists we work with (nor do we need to). These are intended as broad strategies. In every case, these apply to some individuals but not all, and the key is letting people be who they are and doing what works for them.

Even if a PI or professor is themself neurodivergent, they may still need help in learning to accommodate their students or research team, because these traits can manifest very differently, and what works for one may not work for another. It is not necessary (nor usually appropriate) to ask about a person's neurotype. Instead, if someone has needs that are different than others, adjustments should be made to reflect this. It is useful to jettison deficit-based thinking, and instead support people while emphasizing their individual strengths and assets.

1.2 Spiky skill sets: unrelated skills are unrelated

One characteristic of note has been termed by the neurodivergent community as a "spiky" skill set. This refers to the observation that unrelated skills are unrelated, so struggles or strengths in one area do not necessarily imply anything about ability in another area. For example, the ability to do complex mathematics is unrelated to the ability to tie shoes, so the former does not imply skill in the latter (nor *vice versa*). There have been recent news articles about some non-speaking autistic people being valedictorians, but this should not be surprising, since speaking is an ability that is not directly related to thinking and completing schoolwork. Another important example is the ability to spell words correctly. While people who are brilliant scientists and can also spell well might not always realize it, these are actually unrelated skills, so a person who has difficulty spelling (as, for example, is the case with some dyslexic individuals) may be just as gifted a researcher as their spelling-bee-champion peers.

2 Neurodiversity-affirming (non-stigmatizing) language

While many senior scientists may be unfamiliar with the language of neurodiversity, recently people have grown up with a language to describe their identity and specific differences. One of the most straightforward ways to be supportive of neurodivergent students or colleagues is to avoid language that is stigmatizing or "othering." Table 1 has several examples of commonly used pathologizing language juxtaposed with more neurodiversity-affirming counterparts. While not an exhaustive list, it does cover several of the major known problematic words and phrases that are often used in both the medical literature and the mass media.

For example, the adult autistic community has been clear that they do not consider autism to be a disease or pathology that they "have," but rather a neurotype. A recent survey has shown [10] that 87% of autistic adults surveyed prefer to be called "autistic" rather than be described as "having" autism. In English, people are not said to "have" left-handedness or gayness, and they should similarly not be described as "having" some condition called autism.

Similarly, neurotypes should not be referred to as "disorders," and neurodivergent traits should not be presumed to be deficits. Medical texts often pathologize what they term "restricted interests" when they are referring to autistic people, where typical people are simply said to have passions. It is not necessary to pathologize the hyperfocus and deep dives common in autistic and ADHD neurotypes.

Functioning labels are often used in the medical community to describe autistic people as high- or low-functioning. These are problematic because they oversimplify and provide no information on any actual accommodation needs of either group. For more in-depth discussion on this language, see [11,12].

3 Organization and executive function

An expression sometimes heard in the online neurodivergent community is "*If you can't handle my executive dysfunction*, *you don't deserve my hyperfocus*." This reflects the frustration of people whose collection of traits include talents that their employers want to make use of, while those same employers disregard or even stigmatize any need for adjustment or accommodation.

Executive function is a term that refers to proficiency in areas of attention, self-regulation, and goal-directed problem solving. Fortunately this skill set is malleable and can be improved [13], and there is evidence for teaching practices that enhance attention, organization, time management, and motivation [14]. Some accommodations can support a variety of skills in executive function including, but certainly not limited to, the ability to "sustain attention, keep goals and information in mind, refrain

TABLE 1 Neurodiversity-affirming language, contrasted with some common and problematic versions currently in use. A few of these apply specifically to autism, since it is more commonly pathologized than some other neurotypes.

Language guide	
Use this (Neurodiversity-affirming Language)	**Avoid this (Pathologizing Language)**
Autistic Person	"Person with autism"
Autism	ASD (autism spectrum disorder)
Traits	Symptoms
Identification	Diagnosis
Neurotype	Disorder
Co-occurring	Comorbid
Passions or Interests	"Restricted interests"
Typical	Normal
Naming specific supports or accommodations	Functioning levels (e.g., high-functioning or low-functioning)

from responding immediately, resist distractions, tolerate frustration, consider the consequences of different behaviors, reflect on past experiences, and plan for the future" [13].

Some neurodivergent students and researchers may at times be able to hyperfocus on topics and do deep dives on them, which is helpful for research. As in any scenario dealing with real humans, their strengths are more evident when they are supported in ways that allow them to flourish, and some neurodivergent people can benefit from accommodations in executive functioning.

Executive function supports can include basic things like consistently using shared online calendars and making use of automated reminders.

Often a due date is helpful for time management purposes, but allowing a cushion after any artificial due dates can be useful. Also, letting students help select a due date (particularly for an extension) if needed has the benefit of the urgency of a deadline coupled with the knowledge they set it themselves, and often produces results.

Additionally, multiple means of communication can be useful. For example, while some do well with spoken descriptions and instructions, many do better with written communication. In class settings or labs with many members, using multiple forms of communication helps to keep everyone informed.

Finally, many individuals do best with clear, unambiguous language where they do not need to make inferences, and with step-by-step instructions to break down a large project into smaller pieces.

4 Physical comfort and sensory considerations

Another key consideration in an inclusive physics or space science workspace is physical comfort and sensory experience. Neurotypical people may experience their sensory environment differently than their neurodivergent peers. The way the brain filters and processes sensory information, such as noise, light, odors, movement, and physical positioning, varies from person to person. Being responsive to requests about the classroom or lab environment is paramount.

Due to differences in propioception, many neurodivergent people may prefer to sit in unconventional ways. Letting students stand or sit as they like, including cross-legged on chairs or on the floor (especially during exams) or letting them feel free to rock or move ("stim") to help focus can be important. Some will use fidget toys–the American Geophysical Union, for example, keeps large baskets of fidgets in some of their conference rooms at their headquarters–letting people move or fidget in this way can help people think or retain focus and should not be stigmatized. Some departments even have coloring pages at seminars to allow people to doodle or color stigma-free to help attendees focus on the talks.

Sound is an important consideration, and individuals may opt to wear noise-canceling headphones. Bright or overhead lighting can be uncomfortable or can even cause headaches or migraine attacks. If a person doesn't want overhead lights, they may prefer to make use of light from windows or lamps or use task lighting in the lab.

Another common difference involves eye contact. While many neurodivergent people enjoy eye contact, for some it can be distracting or uncomfortable. Due to the different ways people process and filter sensory information, for some people having the added visual stimulation from eye contact can be distracting or even overwhelming when also trying to focus on listening to what a person is saying. Some neurodivergent people intentionally look at the bridge of a nose or a forehead to give an illusion of eye contact, but it shouldn't be necessary to accommodate neurotypical people in this way. Realizing this and not pressuring neurodivergent people to accommodate neurotypical norms by performing eye contact can provide a more comfortable work environment.

Another key physical comfort piece is sleep: delayed sleep phase (a difference in circadian rhythm) can go along with neurodivergence, and can lead to awake times or productive times being very late or very early in the day compared to peers. These differences are not moral failings and should not be treated as such–scheduling meeting times when possible to match an individual's circadian rhythm is a simple accommodation.

5 Discussion

A key point of neurodiversity is to not moralize around neurological differences. A missed email, an untidy desk, or a different circadian rhythm are not moral failures. A preference for less eye contact, use of fidget tools, or doodling during colloquium do not indicate a problem. Letting people be who they are without stigmatizing allows them to flourish.

The current model of accommodation in universities and some workplace settings is one of a student or employee needing an official medical diagnosis of a condition along with a list of specific accommodations required. This is cumbersome at a minimum, but can even be unattainable, as medical evaluations can be thousands of dollars, and women and people of color are less commonly diagnosed than their peers. Certainly any recommendations received this way should be followed, but this is really a minimum. Reasonable accommodations should be allowed even in the absence of a medical diagnosis. The overarching strategy should be to not let what someone can't do get in the way of what they can do.

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

NT originated and led the work, in collaboration with HS. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

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