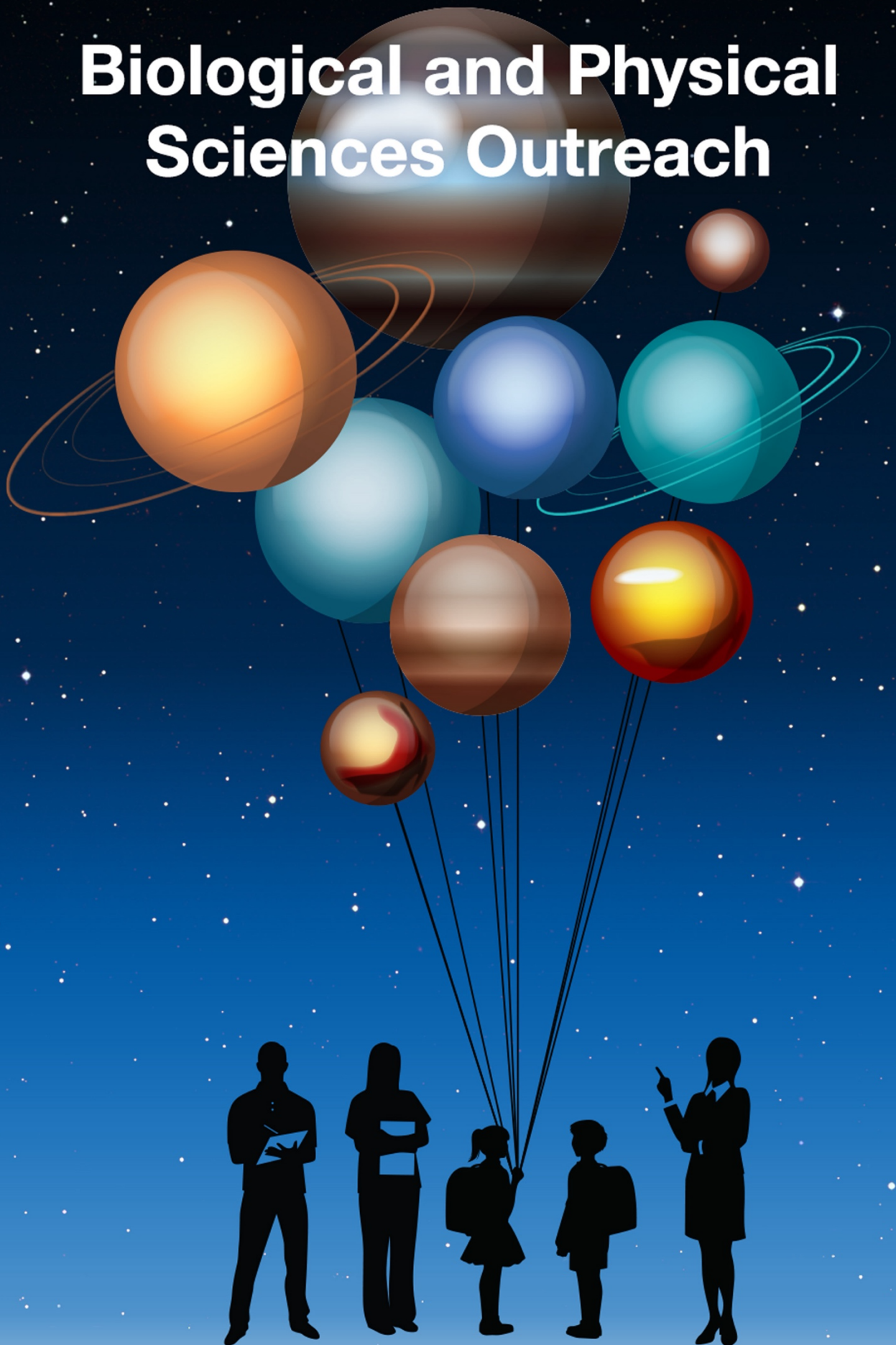
National Aeronautics and Space Administration

Biological and Physical Sciences Outreach



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Topical:

Biological and Physical Sciences Outreach

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I. Executive Summary.

Here we review the major achievements and identify the key gaps of NASA Biological and Physical Sciences (BPS) outreach and education programs. We provide recommendations for their improvement as well as directions and guidelines for future developments.

II. Rationale. *Outreach and Education as Key Focus Areas for NASA BPS Division.*

Unlike other federal agencies, NASA has assumed the responsibility not only to advance the scientific and technological developments related to space exploration, but also to disseminate the discoveries to the general public in an engaging manner, with the goal to inspire and educate the next generations of explorers. Programs for STEM education at NASA began as early NASA's authorizing legislation in 1958. In addition to the mission of educating the world and advancing scientific research, the focus on STEM, or as it may be expanded to include the fields of **a**rt and **d**esign, STEAMD, brings new ideas and encourages critical thinking. Ensuring diversity, equity and inclusion of the STEAMD scholars directly benefits NASA's economic potential and workforce development and supports the expansion of research goals.

NASA needs to be able to adequately respond to the developments of the last decade that include multi and inter-disciplinary efforts of human space exploration, grounded in industry-academic-government collaborations instead of government mandates, and interactions among space and terrestrial research and development. Even if STEAMD scholars did not directly contribute towards NASA's mission, they would nonetheless be able to advance technologies with potential applications both in space and on Earth and inspire future scientists.

> *"...when I stand in front of eighth graders I don't have to have to say to them, "Become an aerospace engineer so that you can build an airplane that's 20 percent more fuel efficient than the ones your parents flew on." That won't get them excited. What I need to say is, <...> "Become a biologist because we need people to look for life, not only on Mars but on Europa and elsewhere in the galaxy." <...> You put that vision out there, and my job becomes easy, because I just have to point them to it and the ambition rises up within them. The flame gets lit, and they're guided on the path." - Neil deGrasse Tyson*

Raising the next STEAMD generation is a far-reaching goal, but not beyond the capabilities of NASA BPS. On the contrary, the visibility and trustworthiness provides NASA with a particularly wide reach around the world. NASA has a unique capability to provide hands-on opportunities in space biological and physical sciences and draw on a wealth of historical data to provide context and assess the success of outreach programs. Therefore, in this white paper we **propose guidelines for BPS STEAMD engagement for 2023-2032** with the following broad-spectrum goals:

- Increasing motivation, awareness of and preparation for STEAMD careers.
- Providing skills to attain success in STEAMD careers.
- Broadening participation in BPS STEAMD activities, with a focus on under-resourced communities based on race, origin, income and other factors.
- Developing partnerships with professional science and engineering societies, other outreach programs, and global scientist and learner communities.

We do not advocate replacing or challenging the NASEM-led evaluations of educational activities at NASA. Instead, our goal is to **provide an additional perspective from NASA scientists and educators who are involved in outreach activities on a daily basis.**

III. The State of Outreach at NASA BPS. *Part A. Best Practices.*

NASA BPS currently oversees multiple STEAMD education and outreach programs, which provide an excellent starting point to expand them to include broader audiences and ensure higher learner engagement. The umbrella of programs includes, but is not limited to:

- Office of STEM Engagement.
- Programs supporting research funding with a focus on under-represented populations: Minority University Research and Education Project (MUREP), Established Program to Stimulate Competitive Research (EPSCoR), Space Grant Project.
- Agency-wide internships and educational programs including the Pathways program, the NASA Postdoctoral Program and the NASA Spaceflight Technology, Applications and Research (STAR) program.
- Agency-wide public outreach programs, such as the Space Apps Challenge.
- Directorate-wide science activation and citizen science programs.
- Contractor-led programs, such as the Blue Marble Space Institute of Science Young Scientist Program.
- Ad-hoc presentations and invited speaker events by NASA personnel in local community centers including museums, science centers, libraries, schools and universities.
- Opportunities at individual NASA centers, such as Gene Lab for High Schools and Space Life Sciences Training Program at Ames Research Center or Drop Tower Challenge at Glenn Research Center.

Some of the best practices that have been developed in individual programs described above and are adaptable for wider use include:

- Combining publishable scientific research (for example: 'omics data analysis to generate novel results) and learning (for example: fundamental space biology and bioinformatics).
- Directly involving and training teachers to encourage them to share their knowledge with the students.
- Fully funding programs – providing all resources required for participation in the programs.
- Developing credible citizen science engagement programs that incorporate the scientific method.
- Creating free, publicly accessible curriculum models, training plans and data sets for national and international use.
- Incorporating NASA content in accredited educational curricula.

IV. The State of Outreach at NASA BPS. *Part B. Major Gaps.*

For the numerous successful outreach programs described in the previous section, the only suggestions would be to continue and expand them. In addition we have identified gaps and issues to target in the next decade.

- ***Perception.*** In public opinion, NASA remains an agency for engineers and physicists. Students who are interested in space may not consider studying biology, and biological scientists lack awareness about opportunities and jobs at or associated with NASA.
- ***Retention.*** We lack clearly defined pathways for retaining budding space biologists and physicists, whether within NASA or among academic or industry collaborators. This issue is associated with gaps in ***knowledge transfer***, which causes multi-year research projects to suffer from loss of personnel with first-hand knowledge of the project. Additionally,

continuity is a challenge because participants in programs do not have an easy ability to stay involved with BPS science after the program ends. (This issue is discussed in detail in a White Paper by Amber M. Paul et al. **"Enhancement and Retention of Space Bioscientists and Students"**).

- ***Barriers to entry.*** We consider the chief barriers to entry to include the following: limited availability of NASA programs for international learners and non-English speakers; low involvement of learners from under-resourced communities; lack of programs focused specifically on graduate students; lack of BPS programs available for pre-K to middle school students; and limited funding opportunities; and limited number of participants in currently funded programs (see Figure 1 as an example whereby over 200 students completed applications for GL4HS for 15 available positions).
- ***Lack of subject matter experts to serve as mentors or to perform public outreach activities.*** Practicing BPS scientists and engineers do not always have skills and experience to communicate effectively with the general public. Furthermore, they may lack time for public engagement if it is not one of their assigned tasks upon which their performance is evaluated. In addition, new BPS investigators often have to focus on acquiring funding for their research; the availability of fullyfunded trainees at all levels to help young scientists generate preliminary data for competitive proposals would ease this burden.
- ***Lack of a centralized platform.*** Although decentralization of outreach programs has a successful history, NASA would benefit from a centralized feedback loop to ensure that outreach efforts would neither be duplicated nor miss a key group of learners, and both subject matter experts and learners would find it easy to identify outreach opportunities.

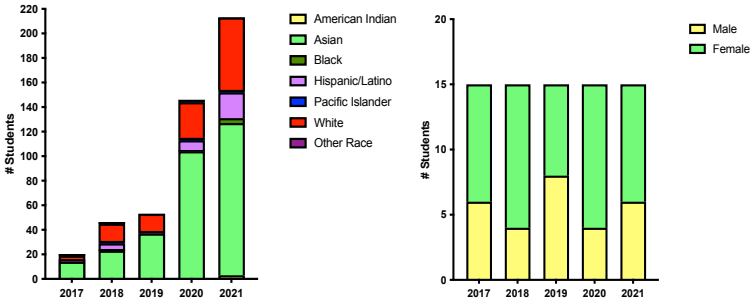

Figure 1. GL4HS demographics including racial demographics from total applicant pool and male to female ratios of accepted students.

V. Recommendations.

Our overarching recommendation for NASA BPS outreach efforts is to attract and retain a wider range of learners. We suggest these primary focus areas:

- ***Audience*** (e.g. K-12 students, interns and trainees, academic researchers, general public).
- ***Aims*** (e.g. improving STEAMD education and training in the US, strengthening the future NASA workforce, improving diversity in STEAMD).
- ***Achievement metrics*** (e.g. number of interactions, number of STEAMD majors in higher education, demographics of NASA workforce, tracking learners).

We recommend using the NASA Science Activation program objectives as an example. Specifically, we suggest gradual engagement of diverse audiences with the overarching goals of **understanding the value of scientific research and developing critical thinking skills.**

NASA Science Activation Program Objectives:
- Enable STEM education
- Improve US scientific literacy
- Advance national education goals
- Leverage efforts through partnerships

To effectively target K-12 and university learners, it will be important to **include educators** in addition to students in a structured instead of ad-hoc manner. This could be achieved by:

- Collaborating with national teacher/mentor **networks and professional societies**.
- **Creating a subject matter expert network** as a resource.
- Developing **virtual platforms, workshops, publications, and competitions** to increase the accessibility and expand the scope of efforts.
- Specifically targeting learners and educators in **minority-serving institutions and under-resourced communities**.

Pilot studies should be considered to determine the best approaches for outreach and educational efforts before expanding them to incorporate more learners. To achieve this, the best practices of **Fairchild Garden** Growing Beyond Earth program could be applied to:

- Set clear goals;
- Define and maintain efficacy metrics;
- Identify gaps and areas of improvement;
- Analyze and publish outcomes and engage in a public discussion.

Notably, evaluation is a specialized task that requires a separate budget, which should be considered when soliciting and funding the programs.

Furthermore, we propose **expanding already existing programs** to incorporate BPS content and expand them to reach new learner communities, with the following specific suggestions.

- ***Adding BPS resources to educational NASA websites, such as SpacePlace.*** SpacePlace is one of NASA's most visited websites that provides educational content to K-middle school students.
- ***Increasing the availability of small satellite and other flight opportunities for outreach and educational programs.*** Such opportunities might be used to attract learners with different skills and interest, including engineering, biology, data transfer, design and project management, and might include orbital missions as well as suborbital missions including scientific ballooning, and even ground analog facilities.
- ***Adapting Physical Sciences Informatics (PSI) database for use by non-specialist learners.*** PSI is a massive collection of data generated by NASA physical sciences research in space. Despite interest, currently it is not involved with any outreach or educational activities. However, it may be adapted to citizen science-based analysis projects as well as teaching-focused programs, analogous to GeneLab Analysis Working Groups and GeneLab for High Schools.
- ***Collaborating with external partners.*** Specific suggestions include the European Space Agency Education program, the United Nations Office for Outer Space Affairs (UNOOSA) Access to Space for All program and the American Society for Gravitational and Space Research (ASGSR) Ken Souza Spaceflight Research program, as well as academic institutions and industry partners.

In the context of developing **new content**, we suggest the following key focus areas:

- ***Engaging new learners*****,** including developing hands-on toolkits; translations to multiple languages (spoken and sign); adaptation for visually impaired and other disabled users; and training learners to be educators by tasking them with creating content for other, less-advanced learners. This approach is successfully used by the Chabot Space and Science Center in California.
- ***Training undergraduates and graduate students*** by covering fundamental space biology and physical sciences curricula. A good example of a NASA space biology course for postdoctoral researchers and above is the NASA STAR program, while a model undergraduate academic course in space biology is currently held at Carthage College. In

addition, sponsoring NASA advisors for graduate students; creating an open access database of online courses, opportunities, curricula and manuals; and promoting involvement of students in NASA outreach and citizen science projects.

- ***Incorporating new topic areas:*** moving from STEM to STEAMD to include art and design and incorporating statistics and data sciences. We suggest adopting best practices from existing non-BPS programs: e.g. engineering from NASA HUNCH program, art from the National Space Society Space Settlement Contest. Activities should start to feature diverse teams of individuals with members fulfilling unique roles to engage in different ways, mimicking the way that NASA uses diverse teams to solve complex challenges.

VI. Practical Considerations for Implementation of Proposed Ideas.

In addition to the gaps and suggestions outlined above, expanding BPS outreach requires addressing practical considerations, primarily regarding funding and personnel.

Funding suggestions for inclusive outreach:

- Stipends for all participants, including students and/or teachers.
- Prioritization of financial support for students experiencing hardship and coming from under-represented backgrounds.
- Supplies for experiment-based programs and small competitive grants for hands-on projects.
- Funding for transportation and technology.
- Computational and IT support for citizen science data analysis activities as well as documentation and storage of all findings.

Suggestions for **personnel development:**

- Dedicated staff for creating novel content and managing programs.
- Global think-tank network of experts who could guide short projects.
- Publications using NASA communications platforms.
- Formal engagement of practicing scientists and engineers as one of NASA's objectives:
    - Guidelines for supervisors for expectations of time commitment;
    - Communication between Office of Communications, legal experts and subject matter experts to ensure the best public representation of NASA research;
    - Guidance on teaching and/or science communication to diverse learners.
- Retention of both subject matter experts and outreach partners.

VII. Conclusions.

At present, biological and physical sciences are underrepresented in NASA outreach and education activities. With the incorporation of BPS Division into Science Mission Directorate (SMD), there are more opportunities for NASA to raise awareness of the importance of biological and physical sciences in space through SMD's Science Activation and Citizen Science Programs. This can be achieved through the expansion of existing outreach activities to reach a wider community of learners of all ages, establish multi- and inter-disciplinary projects and bring in more diverse learners, especially those from traditionally under-represented and under-resourced demographics. Furthermore, existing outreach and educational activities would benefit from an agency-wide unifying structure. Finally, more resources should be devoted to helping practicing scientists and engineers become involved in outreach and education.