Research Campaign: Making a commitment to sustainability while improving equity, diversity, inclusion, and accessibility.

Authors:

Christina M. Johnson, Ph.D.
Research Fellow
NASA Postdoctoral Program
Kennedy Space Center, Florida
Christina.m.johnson@nasa.gov
(805) 300-0468

Jade d'Alpoim Guedes, Ph.D.
Associate Professor
Scripps Institution of Oceanography
University of California, San Diego
jguedes@ucsd.edu
(857) 600-6485

Anjali Gupta, Ph.D.
Business Development Lead
Axiom Space, Inc.
Houston, Texas
anjali@axiomspace.com
(858) 337-880

Anna Voelker, B.S.
Executive Director
SciAccess, Inc.
sciaccess.org
voelker.30@osu.edu
(412) 303-7317

Sheri Wells-Jensen, Ph.D.
Associate Professor
Linguistics and TESOL
438 East Hall
Bowling Green State University
Bowling Green, OH 43403
swellsj@bgsu.edu
(419) 372-8935

Endorsed by

Lucie Poulet, Ph.D.
Lucie.poulet@nasa.gov

George Pantalos, Ph.D.
george.pantalos@louisville.edu

Sibyl Rae Bucheli, Ph.D.
bucheli@shsu.edu

Josh Gray, Ph.D.
jgray@mailbox.sc.edu

Ashley Macner, Ph.D.
ashleymacner@gmail.com

Jacob Torres, M.S.
Jacob.j.torres@nasa.gov

Aswati Subramanian, Ph.D.
Aswati.subramanian@simpson.edu

Lori Waters, M.B.A.
lori.waters@und.edu

Tristan Lewis, M.S.
Tristan_Lewis@yahoo.com

Guinevere Moyle, B.F.A
SterlingSpiderStudio@gmail.com

Chitra Ajala, Ph.D.
chitraajala@gmail.com

Lindsay Jones, B.S.
lindsay.jones830@gmail.com

Haley Boles, B.S. student
Hob1998@gmail.com

Airman Christopher Bermudez
Chrisbermudez117@gmail.com

Joseph Taylor, B.S., Ph.D. student
jstaylo8@vt.edu

Gilbert Cauthorn, M.S., Ph.D. student
Gilbert.cauthorn@und.edu

Introduction

Sustainable development includes three main pillars: economic, environmental, and societal sustainability. When any one of these pillars is neglected, the impact on humanity can be catastrophic (Olubukola et al, 2021). Historically, unsustainable business practices have led to disability, disease, and death (Abtahi et al, 2021; Briggs, 2003; Koengkan et al, 2021; Lin et al, 2018); therefore we feel it essential to address sustainability alongside accessibility in this white paper. Sustainability is an ongoing concern for our world. With the worsening extreme weather events and waves of disease outbreaks associated with the Anthropocene era (Tajudeen, 2021), more people want to live a more sustainable lifestyle. Increasing criticism is voiced against space research because of a perceived lack of focus on sustainability (Durrieu & Nelson, 2013). The United Nations Office for Outer Space Affairs published their Guidelines for the Long-term Sustainability of Outer Space Activities in 2019 (Martinez, 2021), which focuses on reducing proliferation of space debris and preserving the outer space environment, but makes scant mention of human health. Many technologies that have been developed for spaceflight have directly benefited sustainability on Earth (Maiwald et al, 2021), and many more can be made if we list it among our top priorities. Below the authors provide an overview of sustainability and accessibility considerations that can be implemented on earth and in space, to the benefit and advancement of all humanity.

Sustainability of research platforms

The recent report from the Intergovernmental Panel on Climate Change (IPCC) makes it clear that we have reached an inflection point and the climate crisis is already affecting every inhabited area of the globe (Arias et al, 2021). We must embrace a sustainable model, both for Earth and for Spaceflight. The platforms that send our research to space are currently out of the control of individual researchers. By choosing as a research community to only launch our research on the platforms that best reflect our commitment to a fully sustainable future, including low environmental impact and equitable wages for workers, we would make a bold statement about our commitment to global sustainability goals.

Space industry companies, cooperatives, and other new startups who are building sustainable research platforms must be supported and encouraged. Axiom and Interstellar Lab are companies that are deeply committed to sustainability. Axiom is committed to building a sustainable space platform for discovery and research. One example of Axiom's efforts towards sustainability includes the development of a regenerative propulsion system that leverages the Sabatier system currently aboard the ISS (Tobias et al., 2011; Shaw et al, 2020) The Axiom system will convert respiratory by-products, such as carbon dioxide exhaled by the crew, into methane. While both are greenhouse gases, Axiom's regenerative propulsion system will convert one gas (CO_2) into another gas (CH_4) to repurpose waste into fuel. This technology will eventually contribute to sustainable deep-space crewed missions and have implications for terrestrial applications as well. Interstellar Lab engineers closed loop bioregenerative life support systems. Interstellar aims to improve sustainable agriculture in urban and extreme environments on Earth and beyond, through simulation-based designs of waste management and crop production. Their habitat designs are fully enclosed with zero emissions. (http://interstellarlab.earth)

Research enabling disability access to space

According to the US Census bureau, more than a quarter of the US population has a disability (Taylor, 2018). The current prohibition against disabled people in space effectively eliminates >20% of potentially qualified applicants from these careers. Working in space is inherently hazardous, and space-workplace injuries may be a reality for future astronauts. Work done now on accessible design improves odds of success for all missions, especially long missions where there would be no access to medical and rehabilitation resources back on Earth. We advocate for the use of universal design in future space systems and vehicles. Universal Design is the intentional design of tools and environments so that they are universally accessible, understood, and useful by people of all abilities (Cumming & Rose 2021; Story, 1998). This in turn has immense potential to enhance the safety of space environments for all future space explorers, regardless of ability (Wells-Jensen, 2018).

In 2017 the ICAres-1 analog mission, analog astronauts documented the dynamics of working with a disabled crew member (Heinicke et al, 2018). A follow-up study, ICAres-2, will be conducted in 2022. The results of the ICAres study fed into the European Space Agency's Parastronaut Feasibility Project. ESA solicited applications from astronauts who are technically and professionally qualified but have a physical disability (Heinicke et al, 2021). ESA received 200 applications for their parastronaut opportunity, compared with more than 22,000 applicants for their other astronaut opportunities.

On September 15, 2021, Hayley Arceneaux, PA, became the first person with an internal prosthesis in space. During her three days in space she experienced no problems with her prosthesis. After the flight Arceneaux reported that there were no adverse effects post-flight. Following Arcenaux's historic flight, AstroAccess continued this effort to investigate and advance the accessibility in microgravity environments. On October 17, 2021, 12 disabled individuals experienced microgravity on a parabolic flight through the Zero Gravity Corporation (ZERO-G). This initiative, titled Mission: AstroAccess, aims to pave the way for disabled space explorers by demonstrating the capabilities, expertise, and advantages of crew members with disabilities in microgravity environments, and explores practical questions of universal design for spaceflight.

Here we propose a multi-platform series of studies, looking at the efficacy of commonly used medical devices, such as pacemakers and internal joint replacements, in microgravity. We would test implicit dependence on gravity in the design and function of medical devices. These devices would be tested for efficacy *in vitro* first with parabolic flights, then suborbital flights. If these are successful tests, they would then move on to *in vitro* tests in low Earth orbit on a space station, such as ISS or Axiom. If it appears that these medical devices can operate without modification in each of these environments, testing them in a mammal *in situ* in suborbital flights would be next, followed by *in situ* human suborbital flights. Because implanted medical devices may be impacted by space radiation (Reyes et al. 2014), it would also be important to test such devices in cis-lunar orbit on a platform such as Gateway prior to allowing them to be used by astronauts in a Mars transit mission. If these are successful, then spaceflight operators could be more confident welcoming potential fliers who are reliant upon these devices.

Reducing travel distances and improving accessibility for conferences through research into alternative hybrid conference formats

One answer to reducing our individual environmental impact is to reduce the distances we travel for research-related pursuits, including scientific conferences. Research into how to hold a successful virtual and/ or hybrid scientific conference for our community of space life and physical science researchers – including active duty astronauts – would be prudent. Other NASA communities of researchers have successfully navigated the switch to hybrid meetings but this group has not. Choosing a hybrid approach to future meetings will be more inclusive of those who are unable to travel for many reasons, including disability, financial need, and family obligations. By requiring that all meetings in which NASA funded research is presented take place either online or in a hybrid fashion, more voices can be included in the dialogue, thus addressing issues of equity, inclusion, and accessibility.

We can learn from many examples of successful online conferences and expanded types of symposia, meetings, and seminars. These examples come from a variety of fields. The American Geophysical Union (AGU) and its sister organization, the European Geophysical Union, both held their 2020 conferences online; the latter attracted 26,000 participants, instead of the usual 16,000. Another example comes from the field of archaeology, where a webinar entitled "Archaeology in the Time of Black Lives Matter" drew an audience of over 2000 people in attendance (with over 3,500 who viewed its online recording). If this had been an in-person event it might have drawn approximately 150 attendees. These webinars also have a wider temporal impact as they are now recorded and are used as teaching material for training students (Flewellen et al, 2021; Franklin et al, 2020). The International Forum on Advanced Environmental Sciences and Technology (iFAST) seminar series, featuring well-known senior global change scientists, has attracted more than 1,000 attendees on average, with similar numbers viewing seminars on-line afterwards. The international PUGSLEY global change symposium has >600 subscribers from >50 institutions and a total of >2,000 participants over 25 sessions. These examples clearly demonstrate that online options can be effective, possibly even more so than their in-person counterparts.

Traveling to and from conferences is detrimental to environment. But how bad is it? A short-haul return flight from San Francisco to Los Angeles contributes more CO_2 than the mean annual carbon emissions of a person in Uganda or Somalia (Moran et al. 2018). Between 2017-2018, the vast majority of flights were taken by a small minority of flyers, with less than 12% of the population taking 66% of flights in the United States (Klower et al. 2020; Sarabipour 2021). We argue that it is critical that space scientists rethink their contribution to global carbon budgets. Fully virtual conferences would eliminate >99.9% of our conference-related emissions, but other alternatives (such as holding in-person or hybrid conferences every second or third year; or using regional hubs instead of a single location) can reduce emissions by 75-95%.

By incorporating local meetups and training events during hybrid national conferences, we can advance local networking and collaboration while still engaging with the greater global community. Greater mentorship opportunities for early career researchers is possible with certain hybrid meeting styles. Groups like Mentoring365 offer a virtual mentoring experience, but lack in-person interaction. We propose adding a local networking aspect to scientific annual conferences through regional hubs. The regional hub model includes holding in-person events in several localities at the same time, where participants log into and participate in a larger virtual meeting. This sort of a scientific conference would, by design, bring together a handful of people in each location, thereby reducing headcounts to levels that have been recommended during a pandemic, reducing the spread of disease.

Conclusion

Sustainability and equity are intertwined and vital considerations for which each one of us are responsible. There is research that can be done now to instigate necessary change. Each of these measures outlined above would help us move towards a more equitable, sustainable, and accessible future on Earth, and in space.

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