Images: NASA, 2025

Open Science in Space Biology
Paola Castaño

Towards A Philosophy of Open Scientific Practices: Comparing Research Environments
PHIL_OS Conference
April 28, 2025

University of Exeter

Technical University of Munich

This is the story of a repository that could have remained as a data archive but has become a crucial living core of the space biology research program.

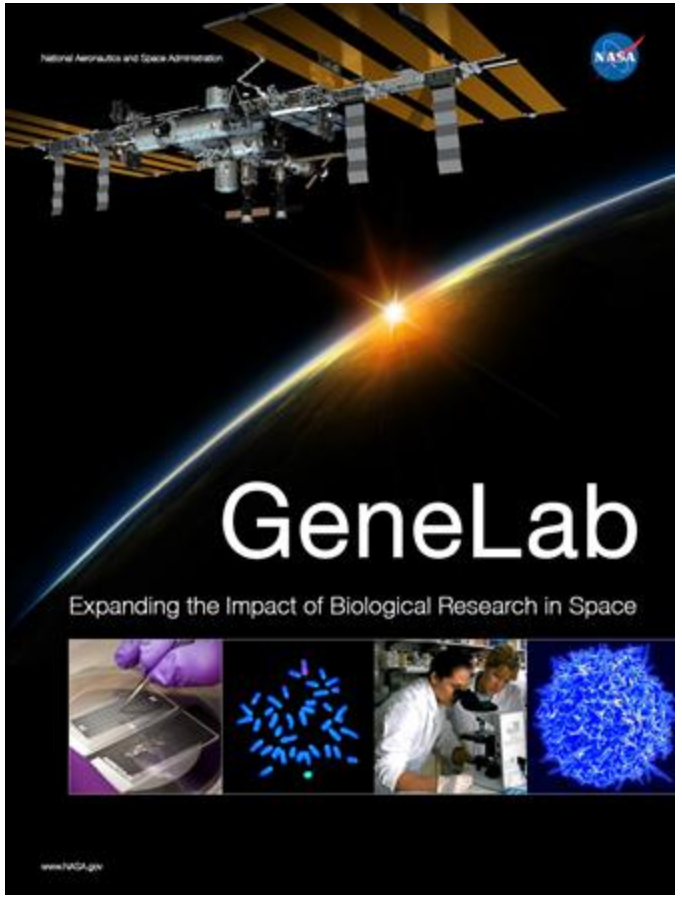
Institutional mandate + Infrastructure + Management + Community + Epistemic outcomes

NASA, 2023

Overview GeneLab/OSDR

NASA GeneLab (2014)

- Database, specimen repository, and collaboration space for omics data from biological investigations in space → Enable “cross-talk amongst valuable experimental biology resources” (GeneLab Strategic Plan 2014, 2).
- Goals: to develop “an integrated repository and bioinformatics data system for analysis and modeling;” to engage “the broadest possible community of researchers, industry, and the general public to foster innovation;” and to strengthen “international partnerships by leveraging existing capabilities and data sharing” (GeneLab Strategic Plan 2014, 1).



Strategic Plan 2014

Analysis Working Groups – AWGs (2018)

GeneLab Website. Meeting AWGs, 2019

GeneLab Website, 2022

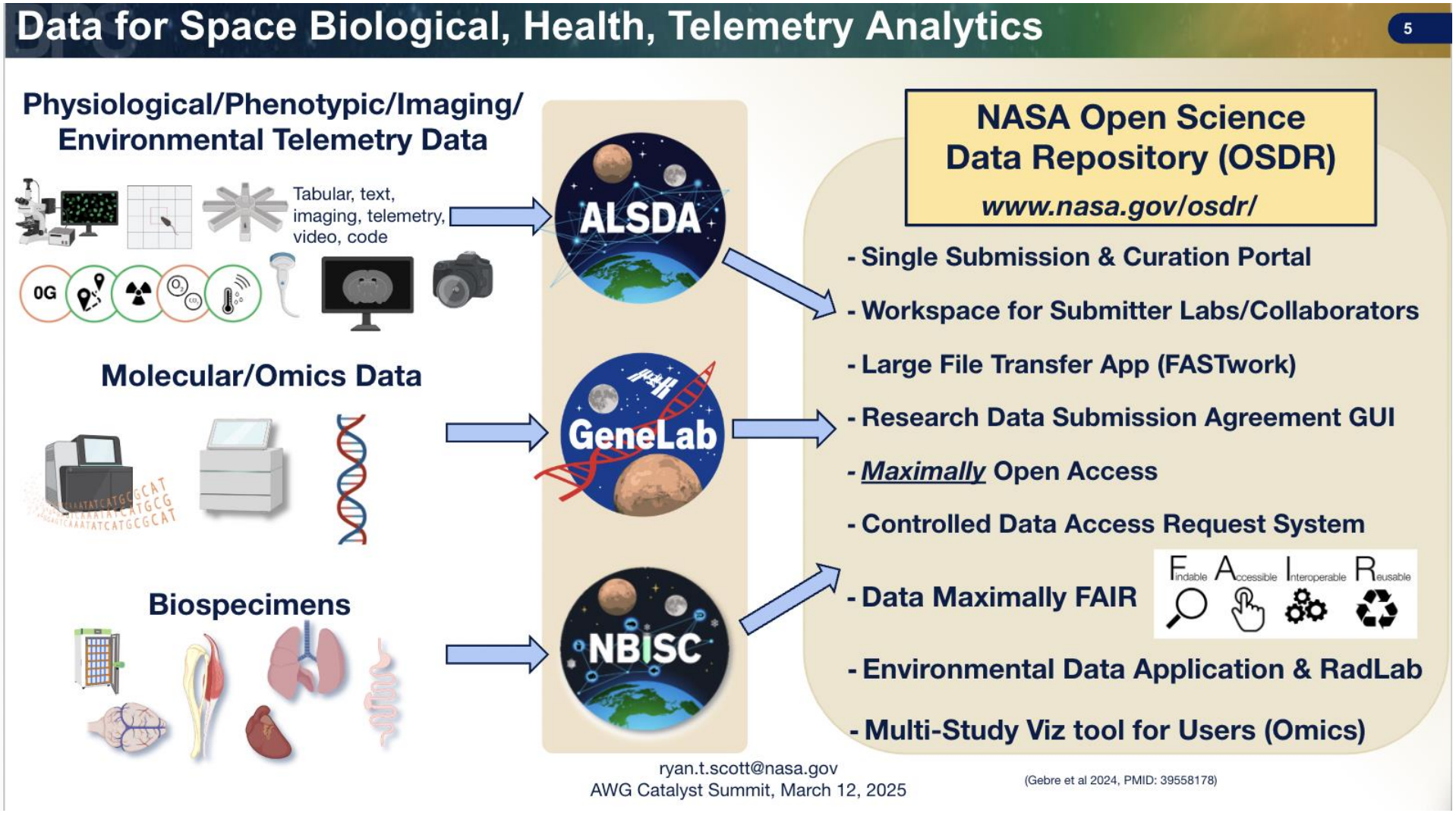
- Initially tasked with optimal analytical workflows for data, resulting in consensus bioinformatics pipelines to process and standardize all raw omics data, significantly enhancing dataset reusability" (Sanders et al. 2024)

- Two main activities (AWG Charter 2025):

1. Members provide feedback on scientific standards for reuse (subject and assay metadata; processing pipelines; dataset formats and uniformed structures for machine-readability).
2. Members collaborate to mine-reuse OSDR data to conduct scientific investigative analyses, which sometimes leads to peer-reviewed publications. :

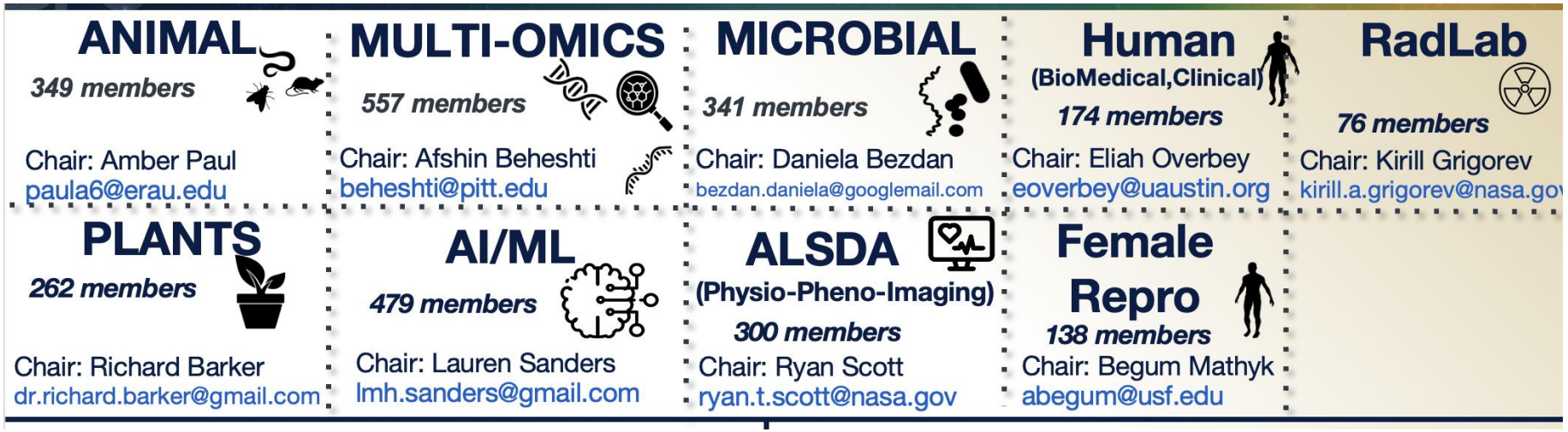
- AWGs as an institutionalized community of data users (How?)

Integration into the Open Science Data Repository (2022)



Slide Ryan Scott, AWG Catalyst 2025

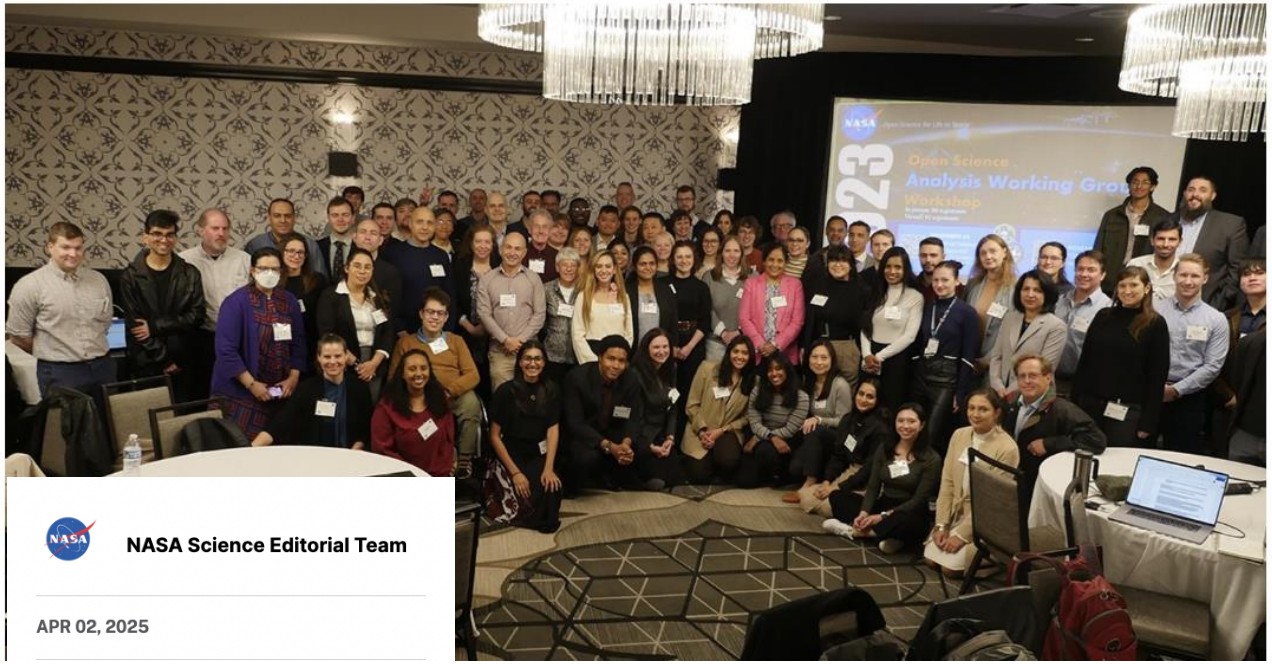
Expansion of the AWGs(2023)



Ryan Scott, 2025

The AWGs as part of NASA Citizen Science (2025)

Citizen Scientists Use NASA Open Science Data to Research Life in Space



NASA Science Editorial Team

APR 02, 2025

Request to join the Open Science Data Repository (OSDR) Analysis Working Group (AWG)

Are you interested in participating in an AWG? Before completing this membership participation form, please learn more about the AWGs, then review the Analysis Working Groups Charter to familiarize yourself with expectations. Please note, participants cannot use AWG membership as a means to claim any direct affiliation with NASA.

Anyone is welcome to join the AWGs who wishes to engage in its two main functions and activities. When requesting to join, please add a statement describing your interests, experiences, background, and training.

Career Level *

- ◯ High School
- ◯ Undergrad
- ◯ Grad School (pursuing Master's)
- ◯ Grad School (pursuing PhD)
- ◯ Post-Doctoral
- ◯ Early Career
- ◯ Mid-Level Career
- ◯ Senior or Executive Level, Senior Scientist
- ◯ Citizen Scientist
- ◯ I prefer not to answer

Expertise *

Examples: Bioinformatics, bioimaging, molecular biology, space biology, machine learning

Your answer

Current Projects

Description or link(s) to your current (or previous) project pages like github, google scholar, etc.

Your answer

Background and expertise statement. *

We are trying gauge your background and expertise to help make sure you find projects and collaborations that suit your interests.

Please add a statement describing your interests, experiences, background, and training.

Your answer

Characterizing the AWGs

- “The AWGs aspire to scientific excellence and participation in AWGs is strictly on a volunteer basis” (AWG Charter 2025)

- What kind of scientific collectives are these Analysis Working Groups? What do they do?

  - *“A form of scientific crowdsourcing.”*
  - *“A collaborative, large, open network of folks that, from lots of different backgrounds, are working on solving space biology-type issues.”*
  - *“A good venue for people who do not have access to funding for spaceflight research.”*
  - *“There are different motivations to join, but there is a weight to NASA and people join to help NASA go further into space by understanding how space affects biology.”*

NASA 2021

NASA OSDR AWG Workshop - American Society of Gravitational and Space Research Washington DC, November 2023

Methods

NASA OSDR AWG Workshop - American Society of Gravitational and Space Research
Washington DC, November 2023

- Participant observation in 71 AWG meetings (45 of them with the Plants AWG), and 52 events hosted by OSDR, NASA TOPS, NASA Biological and Physical Sciences Division, and the National Academies of Sciences, Engineering, and Medicine.
- Survey: 70 respondents
- Interviews with 20 members of the AWGs.
- Three oral histories (more to come)
- Collaboration viewpoint paper *New Phytologist* and paper on metrics for *Royal Society Open Science.*

OCSDO
OFFICE OF THE CHIEF SCIENCE DATA OFFICER

2024 NASA OPEN SOURCE SCIENCE DATA REPOSITORIES WORKSHOP REPORT

Science Mission Directorate

January 10, 2025

Virtual attendees during the break-out sessions.

Viewing Liz Blaber (Ext)'...

Certificate of Completion

This certifies that on the
8th day of July, 2022

Paola Castaño

has successfully completed the NASA GeneLab
for High Schools Summer Training Program.

GeneLab for High Schools

Sigrid Reinsch, Ph.D.	Elizabeth A. Blaber, Ph.D.	Robert D. Vik
Director, Education and Outreach	*GL4HS Co-Director*	*Space Biology Portfolio Manager*
NASA Ames Research Center	*Rensselaer Polytechnic Institute*	*NASA Ames Research Center*

National Aeronautics and Space Administration

TOPS NASA OPEN SCIENCE

CERTIFICATE
OF ACHIEVEMENT

THIS CERTIFICATE IS PRESENTED TO :

Paola Castaño

This certificate is awarded for completion of **NASA's Open Science 101** curriculum. Thank you for your contribution to the Open Science community.

This certificate was awarded
Oct 09, 2024

Dr. Nicola Fox
NASA Associate Administrator
Science Mission Directorate

TRACKING COMMUNITY BUILDING IN OPEN SCIENCE

Christina M. Johnson[1], Paola Castaño[2], Kristen Peach[3], Xavier-Lewis Palmer[1], Ryan T. Scott[1], Daniela Bezdan[8–9] Rachel Gilbert[1], Danielle K. Lopez[1], Stephen Lantin[4], Lauren M. Sanders[5–6] Afshin Beheshti[5–6], Richard Barker[5], Sigrid Reinsch[6], Nitin K. Singh[7] , Melanie J. Correll[4], Nathaniel Szewczyk[10], Sarah Wyatt[10], Gbolaga O. Olanrewaju[10], Rafael Loureiro[11–5], Chad Vanden Bosch[11], Gilbert Cauthorn[12], Lovorka Degoricija[1], Sylvain V. Costes[6]

Goal: Expand the understanding of the effects of spaceflight on cells, tissues, and organisms.

Open and FAIR* Data

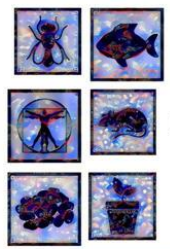
User Communities

OSDR Analysis Working Groups

AWG	Members
Animal	135
Multiomics	355
Plants	127
Microbes	137
ALSDA	287
AI/ML	149

OSDR Team

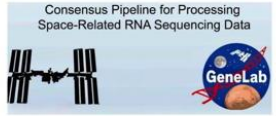
Curation
Data Democratization
Archiving



Validation of analytical processes
Sharing of expertise
Harmonization of results across space biology experiments
Re-analysis
Publication

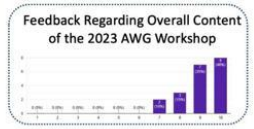
Open Science Data Repository's Analysis Working Groups (AWGs)

Optimize processing of raw data from OSDR

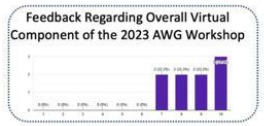


Overbey et al., iScience 24, 102361 April 23, 2021

Feedback on OSDR user experience, data collection, metadata standards, and analysis readiness of OSDR data.

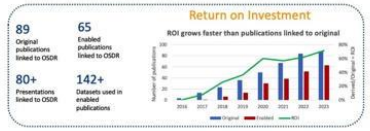


0=Poor, 10=Excellent



0=Poor, 10=Excellent

Maximize data re-use for new knowledge discoveries.



- 5 nasa grants awarded to AWG members
- 2 publication campaigns

Foster a scientific community

- Expanding access to NASA research for people with diverse backgrounds.
- Participation by students from the GeneLab for High Schools Program.
- Community-building events: In-person and virtual workshops, AWG Symposium, Meet the Experts, TOPS Open Science 101.
- Supporting PhD students in the completion of their degrees.
- International collaboration initiatives: ESA Space Omics Topical Team, International Standards for Space Omics Processing and JAXA Flaghsip project.

How can Open Science (OS) Promote Good Research Practice?

- OS leads to good research practices through open and FAIR data and communities of users who engage with the data.
- The evidential value of OSDR's data depends on the combined work and expertise of the curation teams and the AWGs.
- The consolidation and expansion of AWG communities is key to continue bringing new expertise and insights to space biology and biomedical research.

Open Science Training

Evidential value of OSDR data

*FAIR: Findable, Accessible, Interoperable, Reusable

Join an AWG
https://osdr.nasa.gov/bio/awg/join.html

Author Affiliations

1 KBR; 2 University of Exeter; 3 Bionetics; 4 University of Florida; 5 Blue Marble Space Institute of Science; 6 Space Biosciences Division, NASA Ames Research Center;7 California Institute of Technology, Jet Propulsion Laboratory, Biotechnology and Planetary Protection Group; 8 Institute of Medical Genetics and Applied Genomics, University of Tübingen; 9 NGS Competence Center Tübingen (NCCT), University of Tübingen; 10 Ohio University; 11 Winston-Salem State University; 12 University of North Dakota.

Expanding the Space Biology Community: NASA Open Science Data Repository's Analysis Working Groups

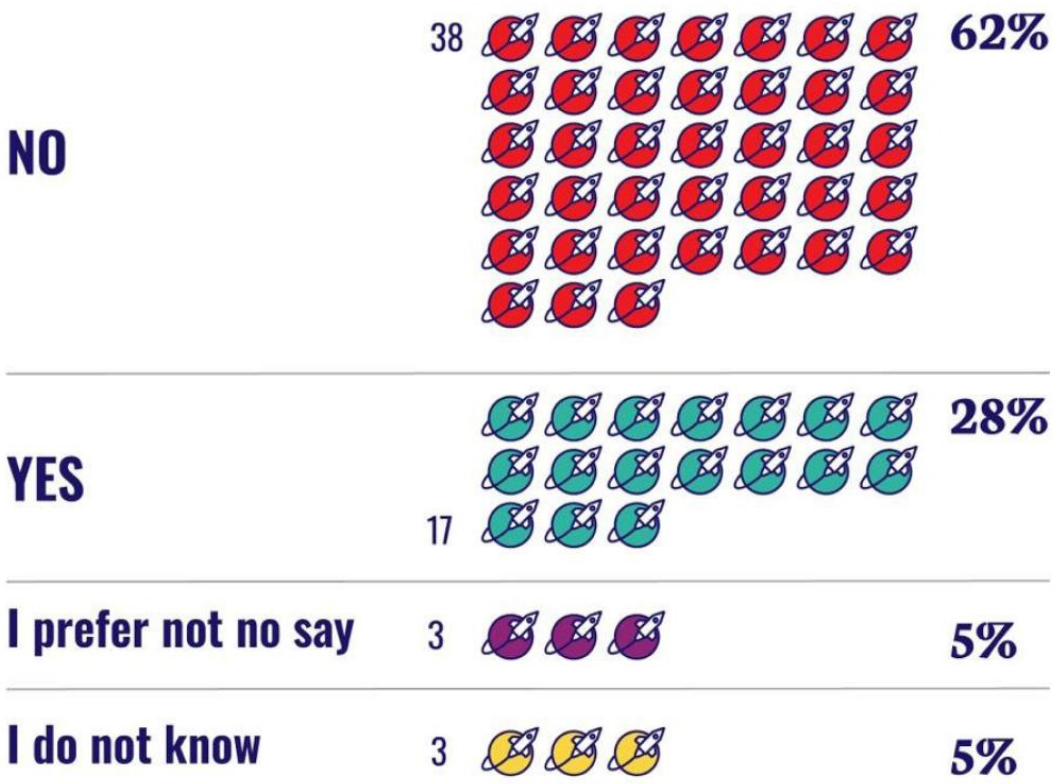
Survey Report

Paola Castaño

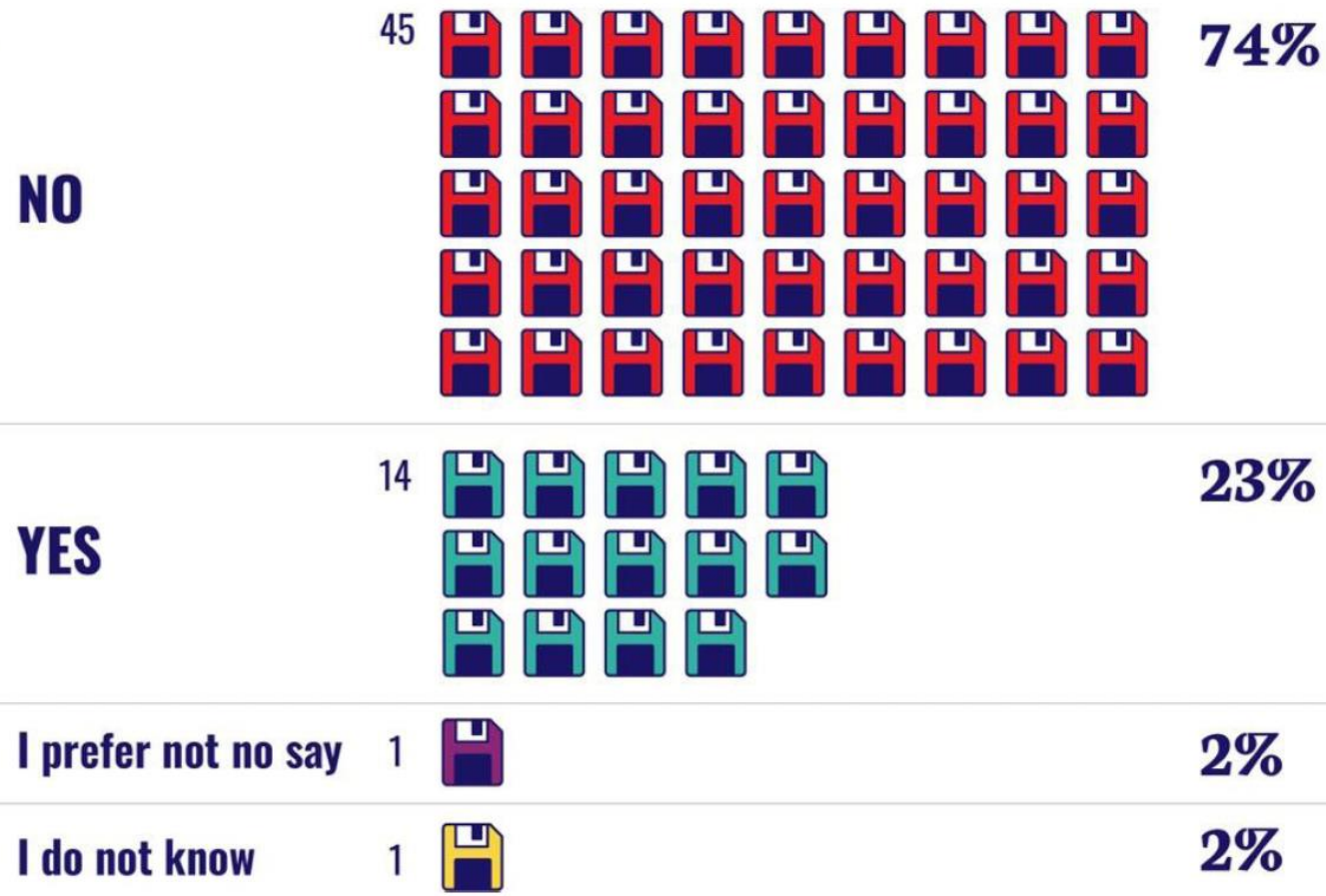
European Research Council
TECHNISCHE UNIVERSITÄT MÜNCHEN
University of Exeter
Egenis, Centre for the Study of Life Sciences
Philosophy of Open Science for diverse research environments

Expanding the Space Biology community: beyond the investigators funded by NASA to conduct spaceflight experiments

Are you or have you been part of a team that has designed and flown (or is already approved to fly) a spaceflight experiment?

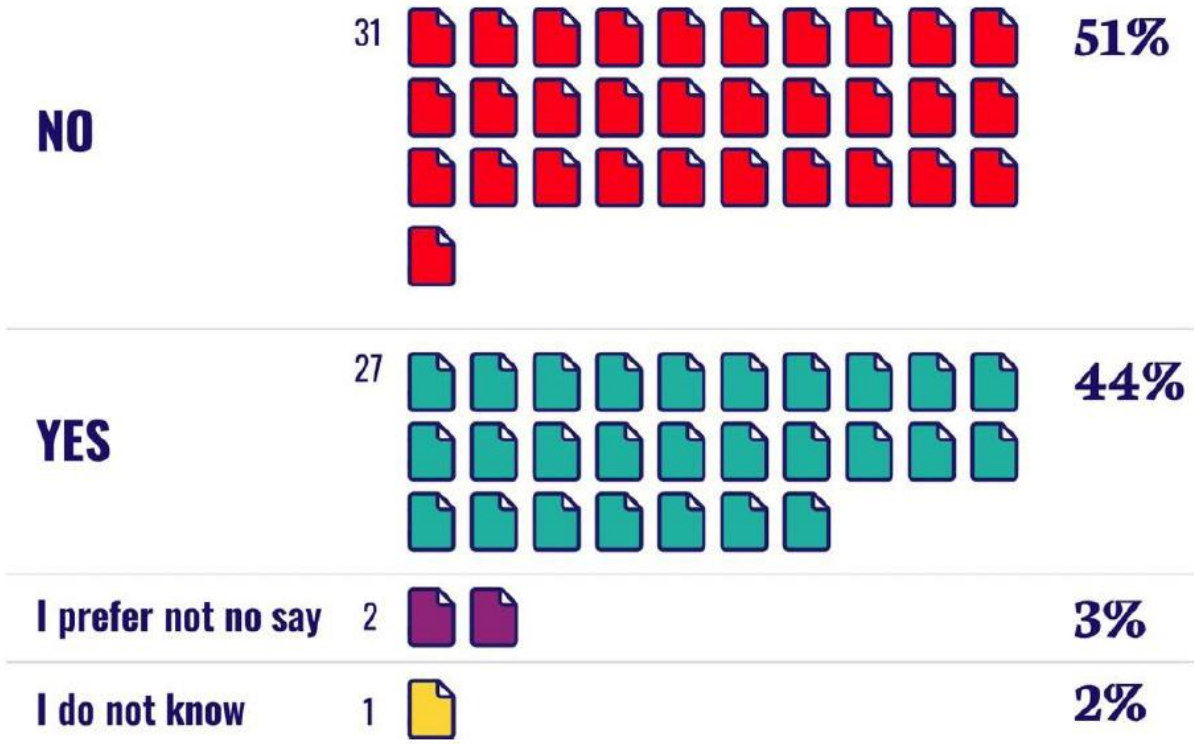


Have you deposited your data into NASA's OSDR (GeneLab, ALSDA, NBISC, BSP)?

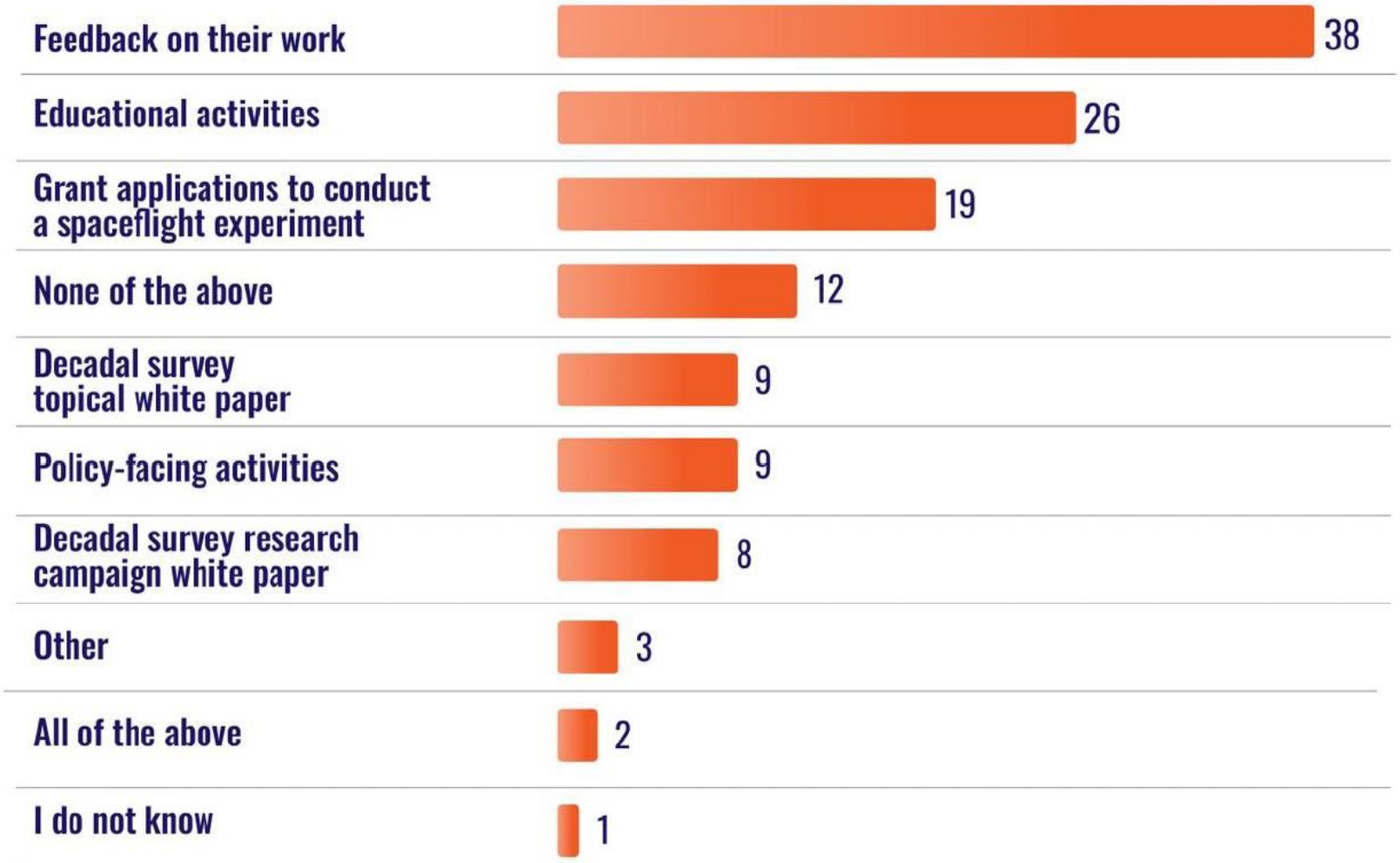


Diverse and Positive Experiences of Participation

Have you been a co-author in any peer-reviewed publication (accepted for publication or already published) resulting from your work in your AWG or AWGs?



In which of the following activities have you collaborated with members of your AWG or AWGs



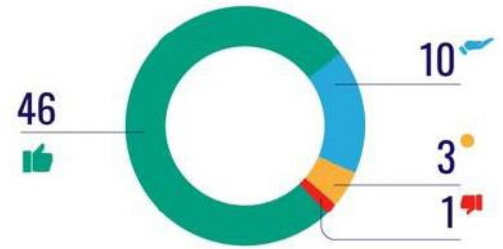
Considering the main AWG in which you participate, please evaluate the performance of the groups in these aspects:

Poor — Satisfactory — Good

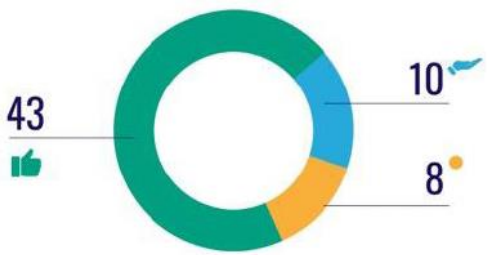
I do not know

I prefer not to say

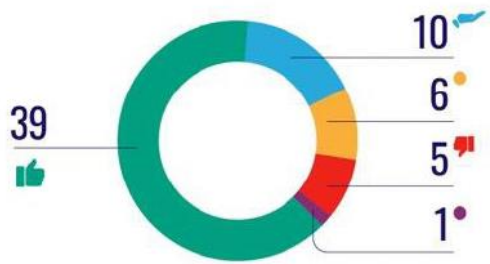
Integrating expertise from different disciplines



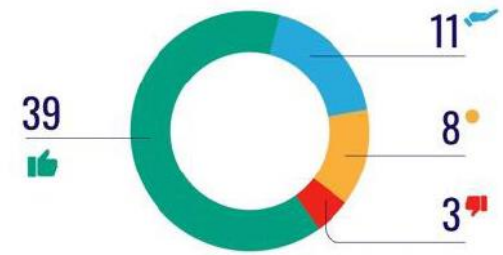
Gaining new insights from existing data



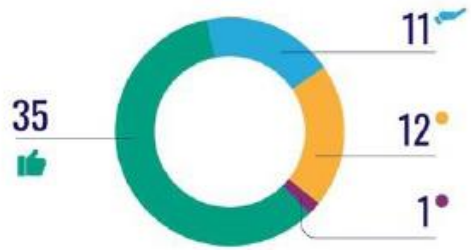
Involving students



Keeping a core membership

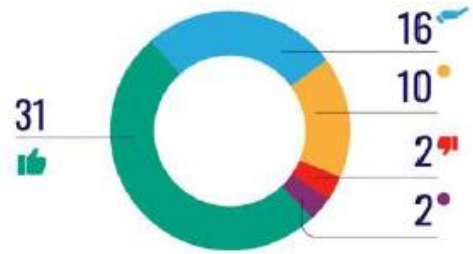


Publishing papers re-analyzing OSDR data

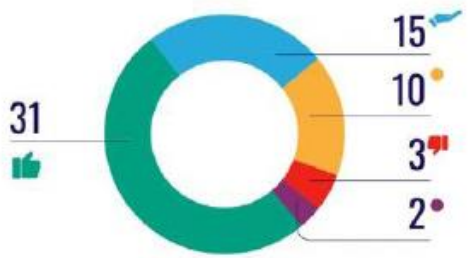


Seeking support from OSDR with specific datasets or technical

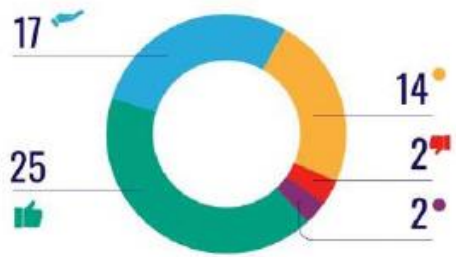
Developing new methods



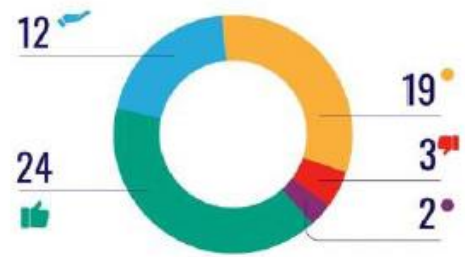
Developing new models



Designing new experiments



Writing grant proposals



Key Findings

1. **The AWGs are expanding the space biology community** bringing researchers into the field not previously involved with spaceflight research, expanding the realms of expertise relevant for space biology, including a more diverse range of individuals, and engaging researchers with experience in open science outside of space biology.

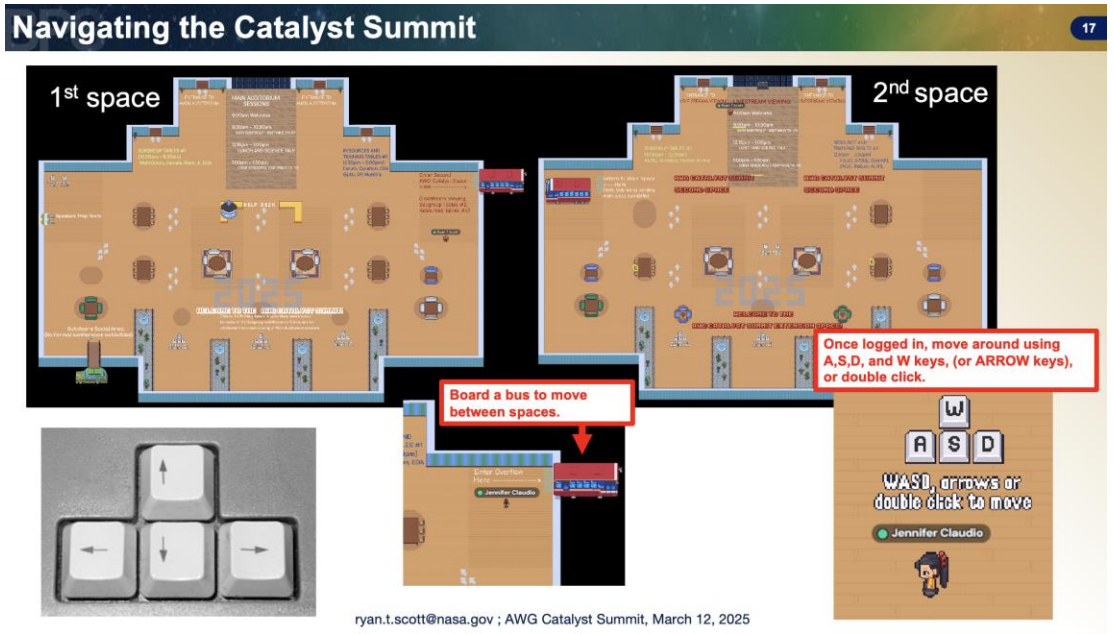
2. **Experiences of participation in the AWGs are predominantly favorable and diverse in their aims and modalities.** There is not a single or a primary expected result of participation from the members' perspectives, but rather sustained interactions among them which lead to different outcomes.

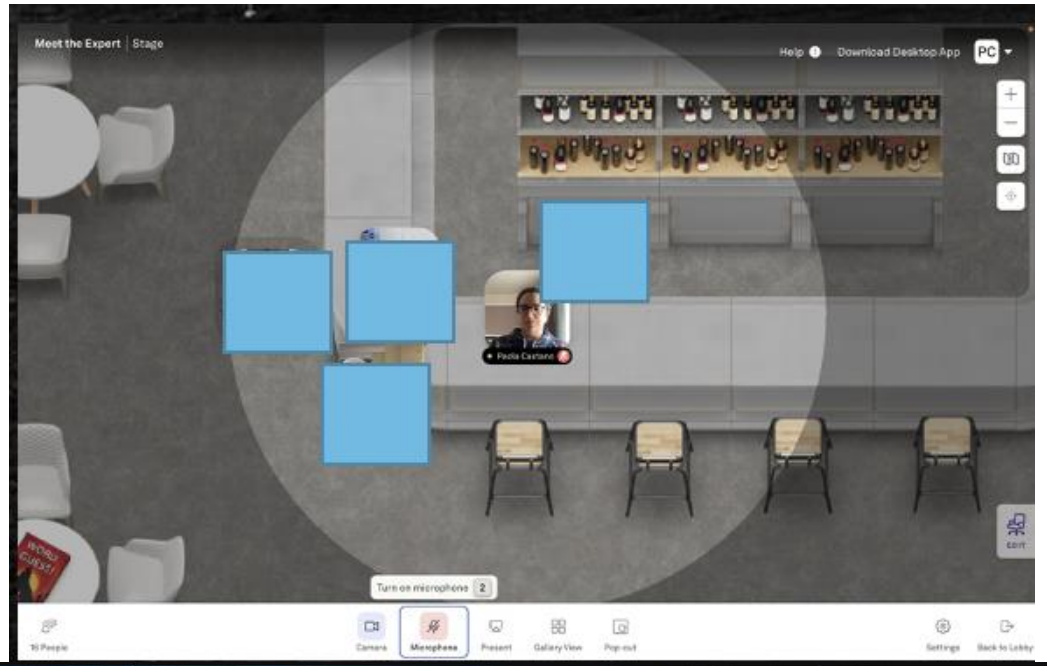
“Communities don’t just happen”

OSDR Tutorials

How-To Guides

- Access Data in the Open Science Data Repository (OSDR)
- Navigate an OSDR Study Page
- Request Controlled Access Datasets from OSDR
- Use the OSDR Public AWS S3 Bucket
- Create a NASA Guest Account
- Use the OSDR Workspace
- Data Submission Guide
- Explore Data Visualizations
- View and Download Environmental Data
- Use the RadLab Portal and Data API





Screen captions, 2022-2025

This is the ‘Forum-Space’ for OSDR AWG members to collaborate, find projects, ask questions, and post/find opportunities. All logged in AWG members can also DM/chat with each other here. Here is the Forum-Space Homepage and pinned top post is the maintained list of all current projects.

As of April 2025, there are 9 AWGs: AI/ML, ALSDA (Ames Life Sciences Data Archive; Physiological, Phenotypic, Biomedical, Imaging, Behavioral, ie non-omics), Animal, Female Repro, Human, Microbial, Multi-Omics (across species, across 'omics data types), Plant, and RadLab (focused on radiation telemetry & radiation biophysics).

This community ‘forum-space’ is supported through the Blue Marble Space Institute of Science (BMSIS). AWG members began joining this community forum-space platform in May of 2024.

Anyone is welcome to join who wishes to engage in the two main functions and activities of the AWG. Here is the AWG membership charter. To post-engage-chat within this ‘forum-space’, you first need to join the AWG.

Request to join the AWG here: https://form

Your Participation Counts

The conversations we have here set the tone for every new arrival. Help us influence the future of this community by choosing to engage in discussions that make this forum an interesting place to be — and avoiding those that do not.

Discourse provides tools that enable the community to collectively identify the best (and worst) contributions: bookmarks, likes, flags, replies, edits, watching, muting and so forth. Use these tools to improve your own experience, and everyone else’s, too.

Let’s leave our community better than we found it.

Formal and Informal Practices

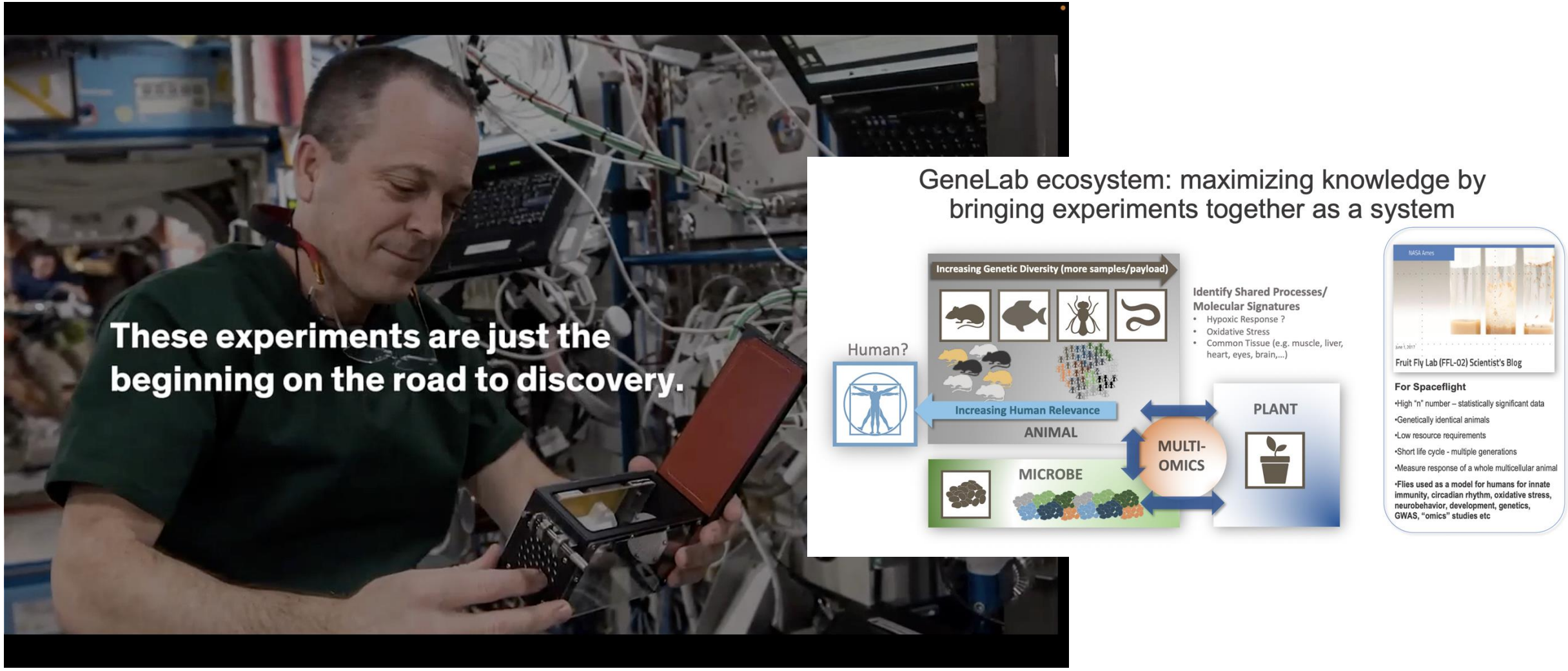
Formal Practices

- Formal status within GeneLab
- Charter
- Code of conduct
- Forum Space
- Some funding for publication costs
- Annual Symposium
- NASA brand

Informal Practices

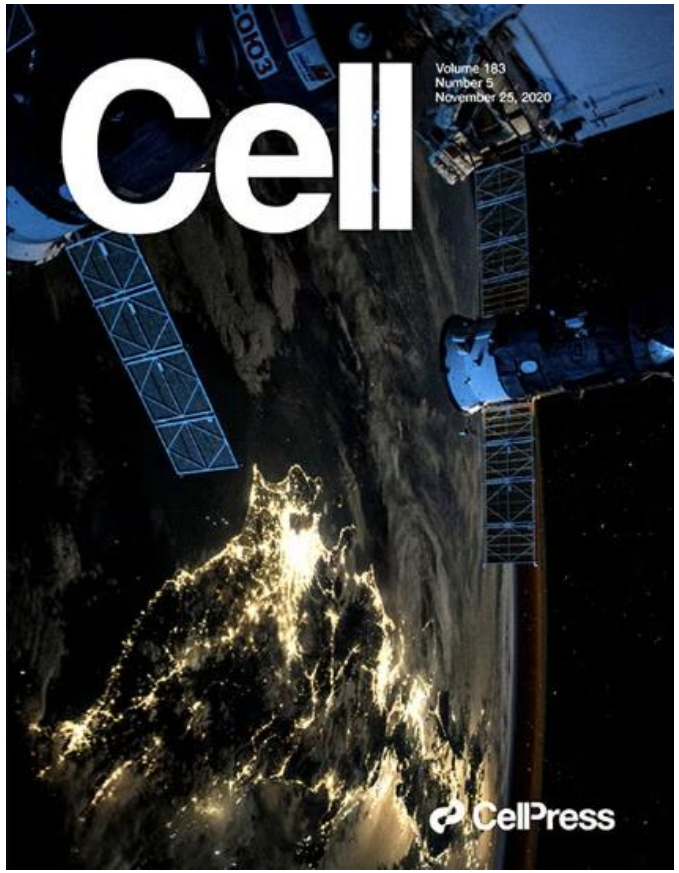
- No funding for operation: Voluntary participation
- Open in principle to anyone
- Large degree of self-organization
- Participation does not result in affiliation with NASA

Interrogating and Integrating Datasets

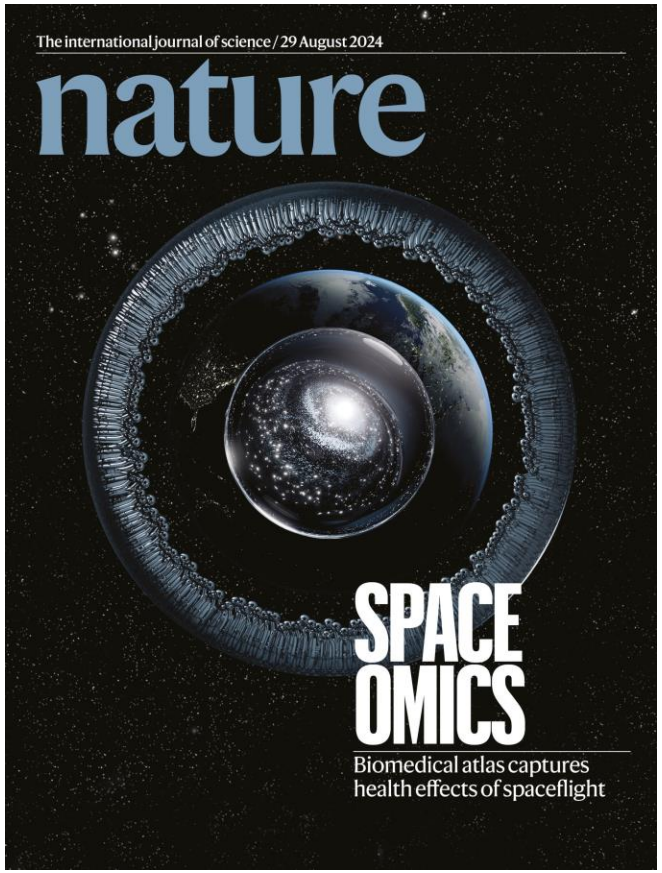


Screenshot NASA OSDR Website, 2025

Publication Campaigns



“The Biology of Spaceflight”, 2020
29 papers / 9 using OSDR data



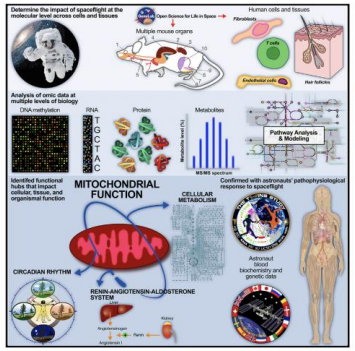
“Space Omics and Medical Atlas”, 2024
45 papers / 100 AWG members

Cell

Article

Comprehensive Multi-omics Analysis Reveals Mitochondrial Stress as a Central Biological Hub for Spaceflight Impact

Graphical Abstract



Authors

Willian A. da Silveira, Hossein Fazelinia, Sara Brin Rosenthal, ..., Christopher E. Mason, Sylvain V. Costes, Afshin Beheshti

Correspondence

afshin.beheshti@nasa.gov

In Brief

A comprehensive multi-omics analysis from 59 astronauts and hundreds of samples flown in space provides insight into fundamental biological mechanisms affected by spaceflight and highlights mitochondrial dysregulation as a central hub for space biology.

nature

Article | Open access | Published: 11 June 2024

The Space Omics and Medical Atlas (SOMA) and international astronaut biobank

Eliah G. Overbey, JangKeun Kim, Braden T. Tierney, Jiwoon Park, Nadia Houerbi, Alexander G. Lucaci, Sebastian Garcia Medina, Namita Damle, Deena Najjar, Kirill Grigorev, Evan E. Afshin, Krista A. Ryon, Karolina Sienkiewicz, Laura Patras, Remi Klotz, Veronica Ortiz, Matthew MacKay, Annalise Schweickart, Christopher R. Chin, Maria A. Sierra, Matias F. Valenzuela, Ezequiel Dantas, Theodore M. Nelson, Egle Cekanaviciute, ... Christopher E. Mason + Show authors

iScience

Article

NASA GeneLab RNA-seq consensus pipeline: Standardized processing of short-read RNA-seq data

Eliah G. Overbey [1 39], Amanda M. Saravia-Butler [2 3 39], Zhe Zhang [4], Komal S. Rathi [4], Homer Fogle [5 3], Willian A. da Silveira [6], Richard J. Barker [7], Joseph J. Bass [8], Afshin Beheshti [37 38], Daniel C. Berrios [3], Elizabeth A. Blaber [9], Egle Cekanaviciute [3], Helio A. Costa [10], Laurence B. Davin [11], Kathleen M. Fisch [12], Samrawit G. Gebre [3 37], Matthew Geniza [13], Rachel Gilbert [14], Simon Gilroy [7], Gary Hardiman [6 15]... Jonathan M. Galazka [3 40]

npj | microgravity

www.nature.com/npjmgrav

ARTICLE OPEN

Check for updates

Meta-analysis of the space flight and microgravity response of the Arabidopsis plant transcriptome

Richard Barker[1], Colin P. S. Kruse[2], Christina Johnson[3], Amanda Saravia-Butler[4,5], Homer Fogle[4,6], Hyun-Seok Chang[1], Ralph Møller Trane[7], Noah Kinscherf[1], Alicia Villacampa[8], Aránzazu Manzano[8], Raúl Herranz[8], Laurence B. Davin[9], Norman G. Lewis[9], Imara Perera[10], Chris Wolverton[11], Parul Gupta[12], Pankaj Jaiswal[12], Sigrid S. Reinsch[4], Sarah Wyatt[13] and Simon Gilroy[1]✉

communications biology

ARTICLE

Check for updates

https://doi.org/10.1038/s42003-023-05213-2 OPEN

Spaceflight induces changes in gene expression profiles linked to insulin and estrogen

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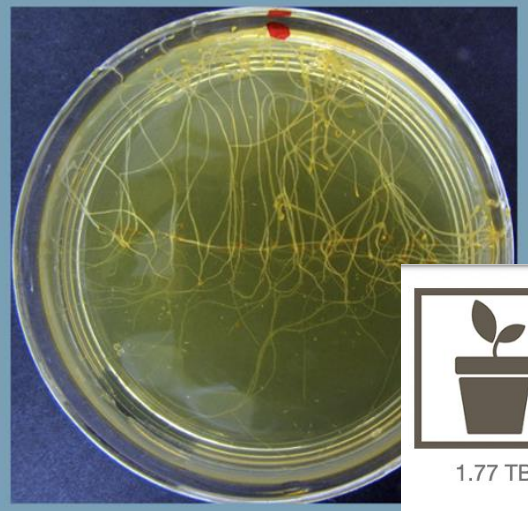
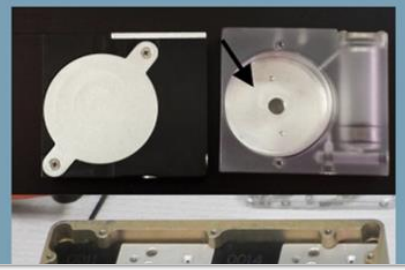
- This is not simply tradition-innovation
- In contrast to large-scale analysis of scientific publications. Maturity of areas of consensus in the field. Closer look at publications show that ‘outsiders’ are actively contributing to establish the baselines of a field (templates for data processing, batch effects to compare datasets, replication of protocols) while opening new domains of investigation.

“Scales of Plant Experimentation”





“Off Earth Atlas” (2025)

1.77 TB

OSD-37 Version 11

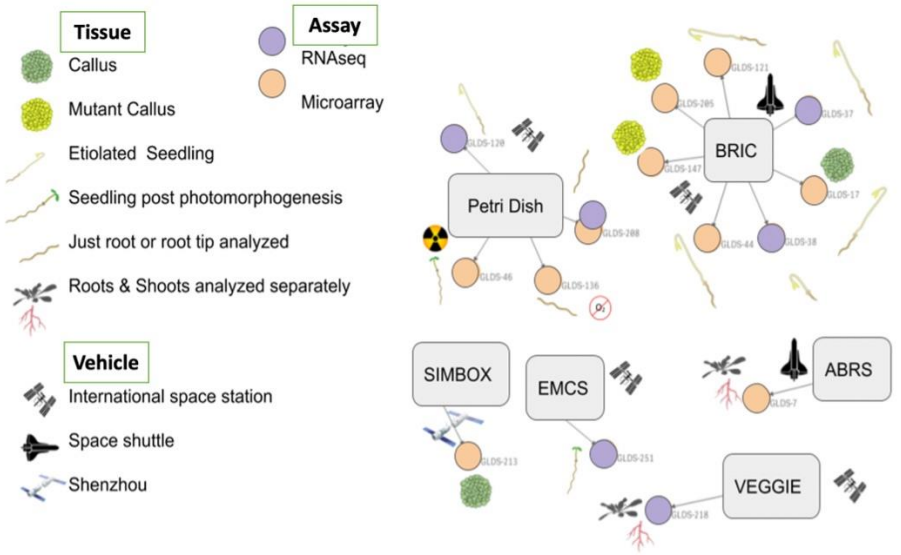
Comparison of the spaceflight transcriptome of four commonly used Arabidopsis thaliana ecotypes

Study

Understanding the ‘Spaceflight Treatment’ in Plant Space Biology: Metadata Workflows as Experimental Practice (with Sabina Leonelli)

- A central challenge in plant space biology is the disentanglement of the various factors involved in the experiments and their tracing to biological effects on the plants (targeted interventions, background factors and confounders)

- Secondary data analysis relying on metadata workflows is providing novel ways to interpret, compare, and potentially integrate results obtained in these experiments.



Barker et al. 2023

Sept 17/2014

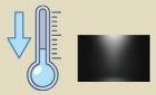
Sept 18/2014

Sept 20/2014

NASA Kennedy Space Center Laboratories: sample preparation protocols

Seeds of sterilized* Arabidopsis thaliana (4 ecotypes) planted in Petri dishes. 64 seeds per 60mm Petri dish with "15 mL of sterile 1/2 strength Epstein's medium supplemented with 1% Phytagel, and 10 mM sucrose, pH 5.7. "

"The seeded dishes were then irradiated* for 12 h" with white light from "a fluorescent fixture at 22°C to synchronize subsequent germination once transferred to the ISS."



"The irradiated dishes were then stored at 4°C in the dark for ~8 h until integration into the flight hardware."

"Each Petri dish assembled into a single stage Petri Dish Fixation Unit (PDFU) cassette under sterile conditions."

"The PDFU liquid injection reservoir was filled with 13 mL RNAlater solution."

"Five PDFUs plus a HOBO data-logger [for temperature] were integrated into the BRIC hardware."

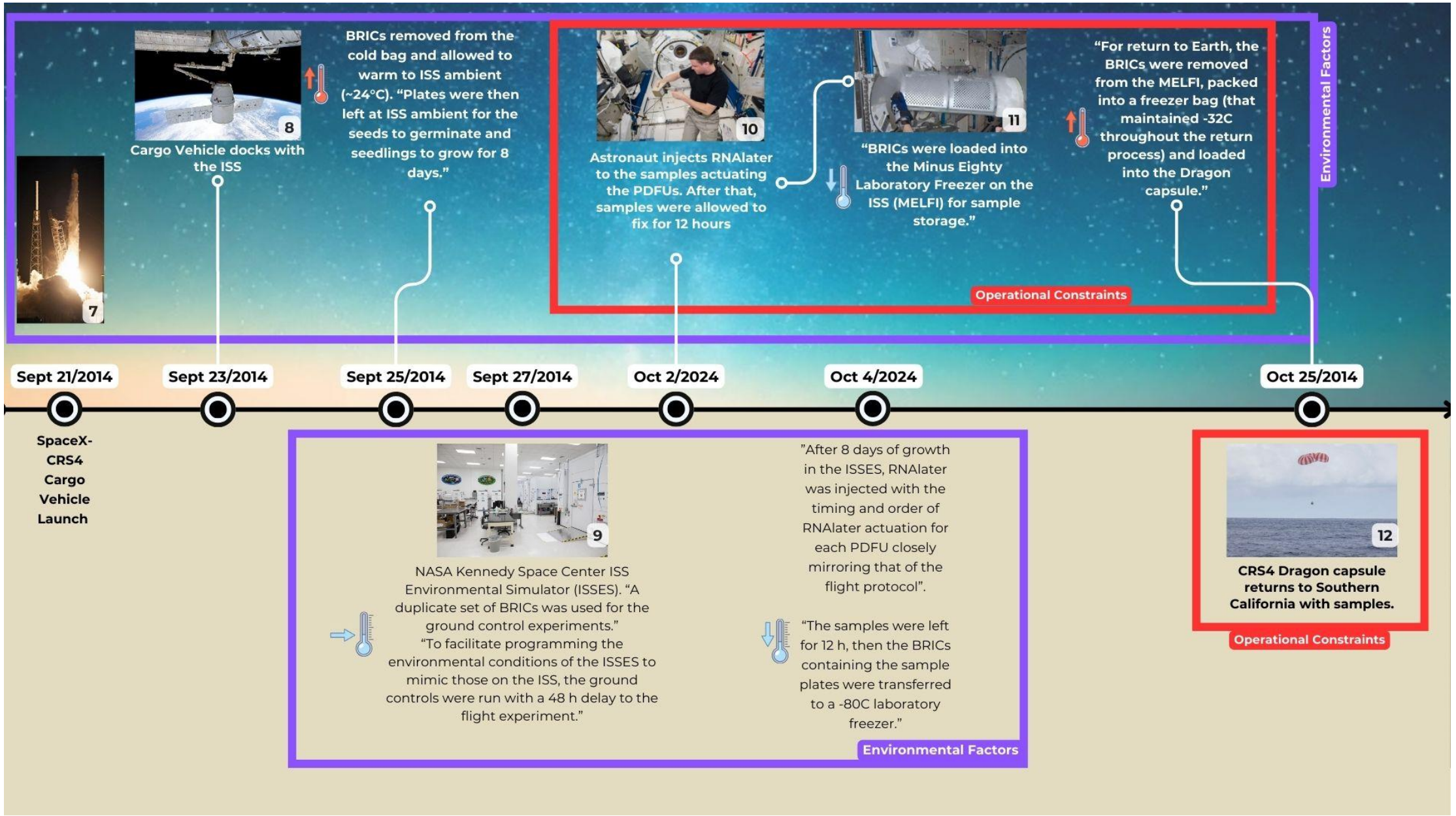
Four BRICS were "stored at 4°C in before launch to inhibit seed germination. "

"The hardware was then transferred in a Double Cold Bag held at 4C, to the Dragon capsule of SpaceX mission CRS-4 where it was stowed 48 hour before launch."

Launch scrubbed due to weather conditions

Operational Constraints

Experimental Design


Environmental Factors
Operational Constraints
Sept 21/2014
Sept 23/2014
Sept 25/2014
Sept 27/2014
Oct 2/2024
Oct 4/2024
Oct 25/2014
SpaceX-CRS4 Cargo Vehicle Launch
Cargo Vehicle docks with the ISS
BRICs removed from the cold bag and allowed to warm to ISS ambient (~24°C). “Plates were then left at ISS ambient for the seeds to germinate and seedlings to grow for 8 days.”
Astronaut injects RNAlater to the samples actuating the PDFUs. After that, samples were allowed to fix for 12 hours
“BRICs were loaded into the Minus Eighty Laboratory Freezer on the ISS (MELFI) for sample storage.”
“For return to Earth, the BRICs were removed from the MELFI, packed into a freezer bag (that maintained -32C throughout the return process) and loaded into the Dragon capsule.”
NASA Kennedy Space Center ISS Environmental Simulator (ISSES). “A duplicate set of BRICs was used for the ground control experiments.”
“To facilitate programming the environmental conditions of the ISSES to mimic those on the ISS, the ground controls were run with a 48 h delay to the flight experiment.”
”After 8 days of growth in the ISSES, RNAlater was injected with the timing and order of RNAlater actuation for each PDFU closely mirroring that of the flight protocol”.
“The samples were left for 12 h, then the BRICs containing the sample plates were transferred to a -80C laboratory freezer.”
CRS4 Dragon capsule returns to Southern California with samples.
7
8
9
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Oct 25/2014

BRICs from the ISS shipped to Kennedy Space Center at -32°C+. At KSC Transferred to a -80°C laboratory freezer where the ground samples were already stored.

"From this point onward, all other manipulations of the samples were identical to the flight material."

Experimental Design

Spaceflight and ground hardware thawed at 4°C to disassemble the Petri dishes from the BRICs.

+ 10mL of RNA fixative added to each dish

Experimental Design

Nov 6/2014

Petri dishes frozen at -20°C in dry ice for transportation

Samples returned to Univeristy Laboratory and frozen at -80°C

Operational Constraints

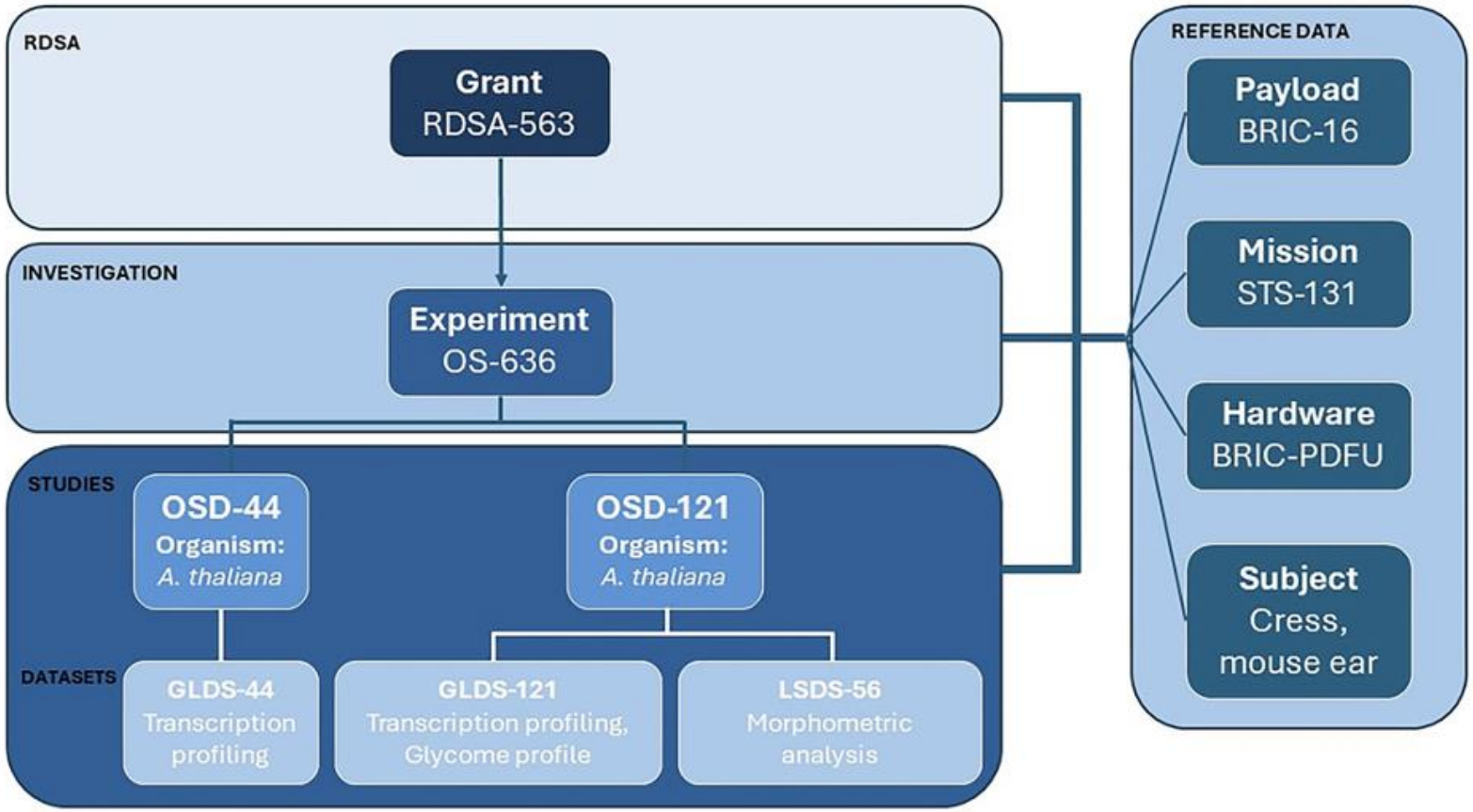
Unspecified Dates

Experimental Design

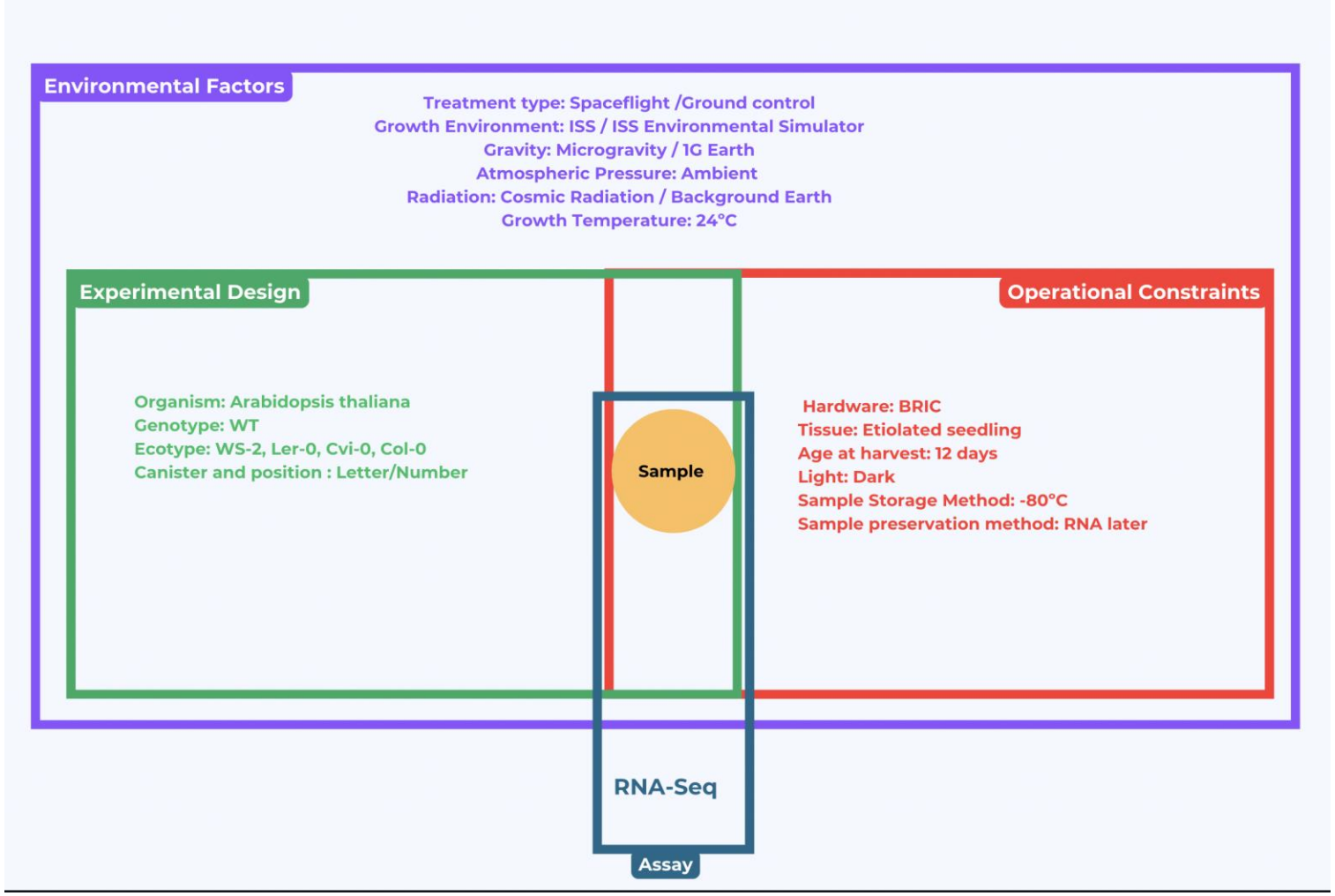
"Samples were removed from the −80°C freezer and thawed at 4°C. Twenty-five seedlings per sample from each plate were then collected using forceps, blotted on sterile filter paper, then added to 500 µL of sterile extraction buffer. Samples were pulverized using a GeneGrinder in 0.5 mL of extraction buffer.

"Total RNA was then isolated using the RNeasy Plant Mini Kit (Qiagen) according to the manufacturer's instructions. Residual genomic DNA was removed by RNase-free DNase I treatment using the TURBO DNase kit (Ambion) according to the manufacturer's instructions (...) Purified total RNA was subjected to rRNA reduction* and a library was created using the Illumina TruSeq RNA Sample Preparation Kit according to the manufacturer's directions."

Assay

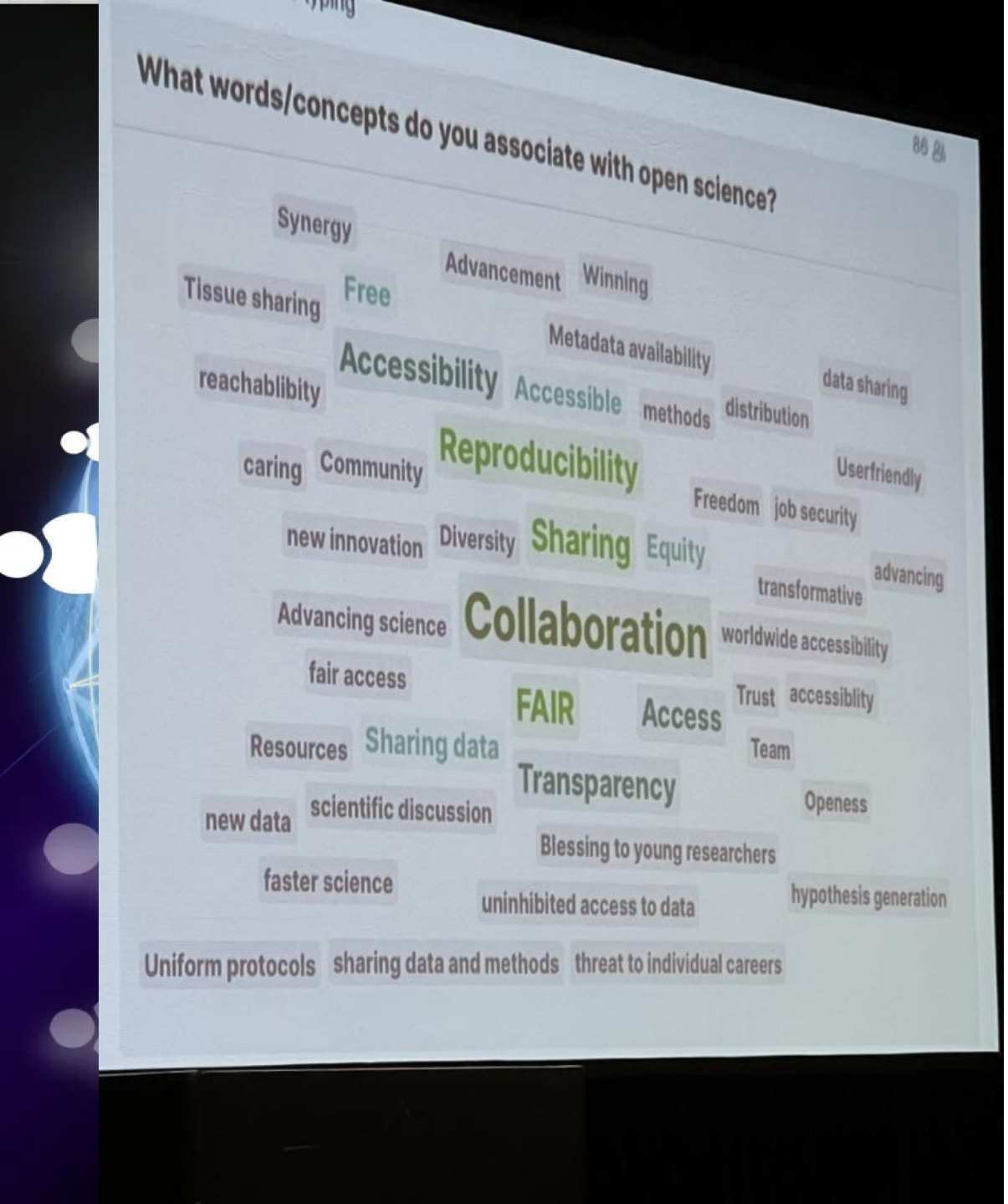


Gebre et al. 2025



Castaño and Leonelli (forthcoming)

“We are trying to help the next generation of researchers identify the extra controls that are needed to deconvolute the the oxidative stress narrative” (Interview 2023)



"I do find it striking that the majority and probably the vast majority of NASA space biology PIs, do not engage with the Analysis Working Groups" (Interview 2023)

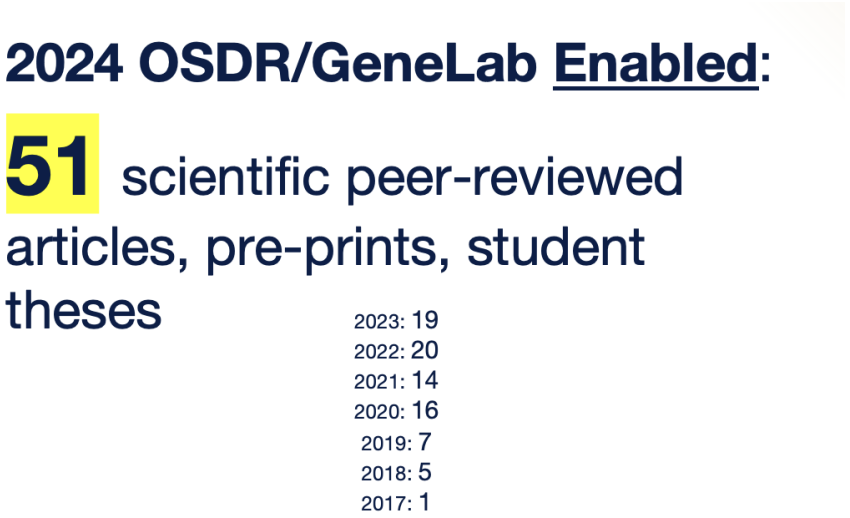
"I have reservations with the idea that it's not necessarily preparing people to be investigators within space biology, because the tools for analyzing some data that somebody else has gathered, are very, very different than the tools needed for gathering the data in the first place" (Interview 2023)

Durability of these networks will depend on future data generation.

Assessing and Monitoring the AWGs

Publications: An important metric for the program

- The program has appropriately emphasized that the AWGs have increased the knowledge generated per experiment, particularly in terms of publications.
- The finding about the diverse and mostly positive experiences of participation calls for the development of new metrics to assess aspects of the groups' other than publications
- What counts as 'productivity' in the groups goes beyond publications and there are other dimensions of AWG members' interactions and work not currently reflected in those figures.



Proposed metrics to capture collaboration as process

- Time-to collaboration: starting from the moment a person joins an AWG or the forum space and when they participate in some key output of the groups).
- Diversity of collaboration/ disciplinary contribution indexes: breadth of expertise that goes into outputs.
- Collaboration lifecycle tracking which would cover the continuity of people's involvement.

NASA OSDR AWG Workshop - American Society of Gravitational and Space Research
Washington DC, November 2023. NASA, 2023

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(Ever-expansive) AWG Community
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