

1. Challenges of Spaceflight Experiments in Biology

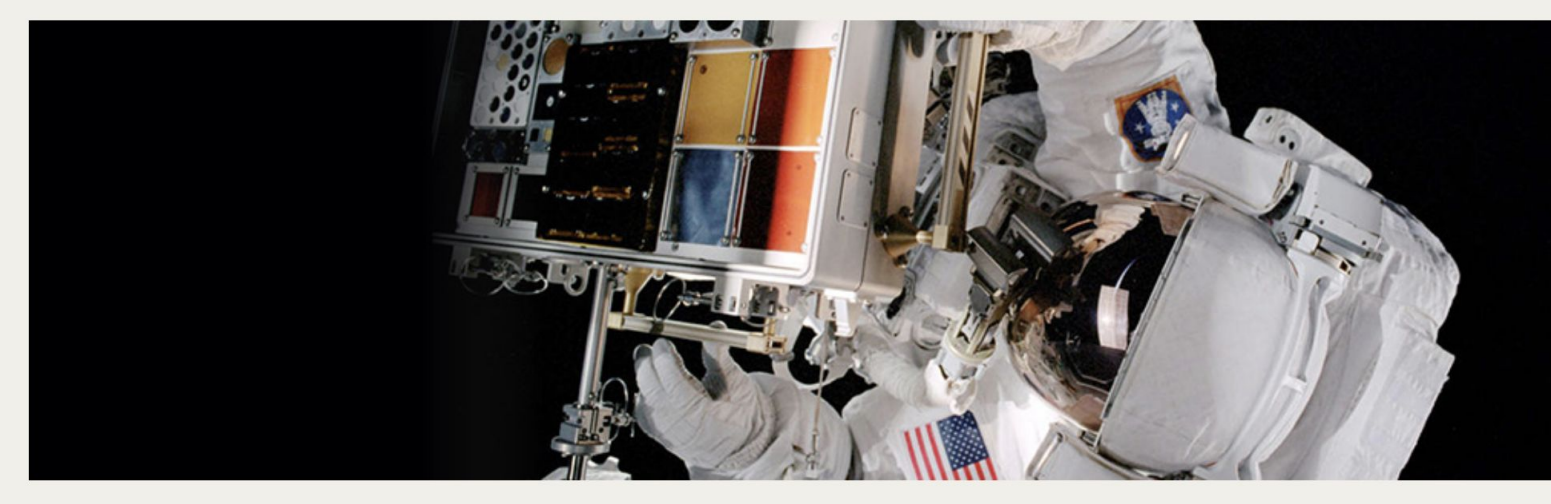
- Biological research in space is costly and brings with it inherent limitations in terms of human and scientific resources.
- In order to conduct experiments, researchers must accommodate various restrictions: size, duration, lack of control over the spaceflight environment and opportunities to replicate experiments, safety, crew time, and sample return [2].
- There is a pressing need for samples and data gathered from these experiments to be reusable as long into the future as possible.
- NASA currently plans to deorbit the International Space Station in 2030.
- Aiming to address these challenges, the GeneLab Strategic Plan [5] suggested the pursuit of community-designed reference experiments in space biology.
- But what is a “reference experiment”?

2. Origins and Current Use of the Concept

“Ultimately the GeneLab platform will enable community-driven reference experiments to generate standard, common, and open reference datasets to act as a powerful resource for scientific throughput and innovation” [5].



Decadal Survey on Biological and Physical Sciences Research in Space 2023-2032



- In September 2020, the concept of ‘research campaign’ was introduced for the upcoming *Decadal Survey in the Biological and Physical Sciences in Space (2023-2032)*. These campaigns “may integrate multiple missions and multiple disciplines to tackle an overarching scientific or exploration goal” [6].
- In the context of considerations about the crucial role of Open Science for the next decade in space biology, three white papers took up the reference experiment concept [3, 4, 7].
- “The specific details for each reference campaign, such as target species, beyond stressing the need for multi-generational, multi-replicated designs, will not be discussed herein as these should be the subject of broad community and stakeholder input ...” [3].

3. Open Science Practices in Space Biology

- GeneLab has been successful as an open data repository, as a platform to analyze spaceflight data, and as a novel way to promote community-building through its Analysis Working Groups and educational programs.
- Collaborations examining datasets, enabled by GeneLab, have yielded novel insights about the effects of spaceflight on biological systems [1].
- However, one important element of the original Strategic Plan has not so far been implemented: the pursuit of community-designed reference experiments in space biology.



4. Goals and Organization

Goals of Reference Experiments: Maximize Scientific Payoff

- Generate “standard, common, and open reference datasets” [5].
- “Translate the limited number of flight opportunities into hundreds of investigations to advance knowledge and discovery” (ibid.).
- Enable the “development of new scientific hypotheses not previously conceived and novel experiments not previously envisioned” (ibid.).

Organization

- Collaboration between various members of the spaceflight research community” [3].
- Supports larger number of investigators.
- Designed by large, interdisciplinary teams to include different perspectives.
- Allows for a broader identification of the theoretical and experimental gaps that need to be filled and how best to do so.

5. Features of a Reference Experiment

A reference experiment’s features are “the subject of community and stakeholder discussions based on the current state of the art at the time of implementation” [4].

Content

- Some key questions to consider: What types of organisms should be investigated? What types of species? What part of the life cycle? How many generations? For what purpose? With or without any treatments? What kind of hardware should be used? What level of replication?

Sample Processing and Preservation

- Ensure highest possible standards for sample processing/biobanking.
- Draw on large pools of combined expertise, especially as tissue samples are small.

Metadata

- Development of metadata standards is a major challenge in spaceflight experiments.
- “The importance of the reference experiment data will prompt the key discussion about the metadata that should be provided to make these experiments useful into the future. Setting some minimal metadata requirements for each spaceflight experiment is essential but will only be sustainable if these requirements are agreed upon by the community” [4].

Data Processing

- Datasets are intended to serve as a **reference**: they should be centrally processed, in the most advanced ways possible.
- Need to ensure future usability, broad compatibility, machine readability.

6. Conclusion

- Reference experiments can successfully address issues relating to sample preparation and longevity, data quality and standardization, and reproducibility and replicability of experiments and results.
- We conclude that NASA should seriously consider implementing space biology reference experiments while doing so is still possible and within the framework of the upcoming Decadal’s concept of research campaigns.
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