Applications of continuous location and temperature monitoring in spaceflight and analogue research with mouse models

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Introduction

Many animal models in spaceflight and spaceflight analogue research are used to study the health effects and hazards of space travel. Rodent models, specifically mouse models, are very commonly used in this research and mice dominate the animal-based research work on the International Space Station (ISS). Animal welfare and health is a priority with all animals used in spaceflight research, but it is held in especially high priority for mice flown to the ISS. Due to the extreme time, funds, and labor needed to complete spaceflight research with animal models, it is also a high priority to obtain as much data and scientific information from each animal as possible. Because of these two priorities, remote monitoring capabilities provided by microchip-sensing equipment has been pursued as a tool for ground and flight-based spaceflight research involving mice. Here, we describe the potential of incorporation of a home cage monitoring system that continuously tracks the movement, location, and temperature of each mouse in the cage via microchips.

Basics of the system

The system, a UID product, uses a plate with a grid of radio-frequency identification (RFID) scanners that rests below the cage and sends the temperature, cage/resource location, and movement activity to a linked controller equipped with data analysis software.
The mouse matrix home cage monitoring system offers remote, passive collection of **continuous digital biomarker data** for research animals. Researchers and veterinary staff can access **movement, location, and body temperature data without disruption** of the animals via RFID microchip readers embedded in matrix plates below the cages.

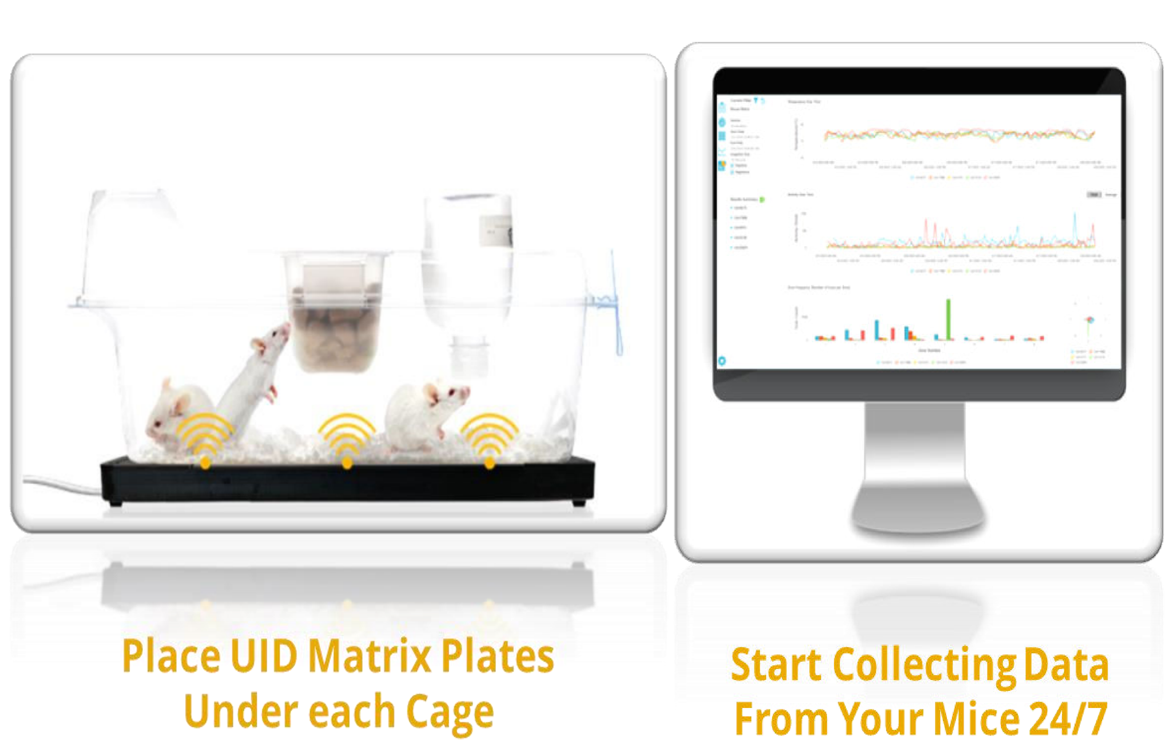

Figure 1. Monitoring system for RFID chipped mice. Image adapted from UID's Mouse Matrix website.

Relevance to our work

For our research purposes, this system can not only provide higher resolution health and behavioral data, but also dramatically improves animal welfare with non-invasive measurements that do not disrupt the animals' sleep cycles or activities, which will be particularly useful for spaceflight studies. This system can be used for many spaceflight and spaceflight analogue experiments, including:

- Compare responses to flight hardware
- Test flight diets and preferences
- Evaluate social interactions between animals
- Test flight hazard countermeasures
- Improve remote monitoring - **advances animal welfare standards!**

This system will be seamlessly incorporated into current, funded radiation projects and would support funded rodent research flight experiments investigating housing/behavior and crew training. It will greatly enhance capability of future microbiology research for host/pathogen studies and has applications for behavioral, toxicology, cardiovascular, nutrition, and immunology studies.

This system elevates the **ACF capabilities** by **increasing the research output** of each *individual* animal with limited additional effort and is **scalable for future research needs**. This illustrates the potential for collaboration with flight studies, including with our international partners at JAXA, who study individually house animals, shown in Figure 2.

Data acquired from the tracking plates can be used to create a set of metadata for testing machine learning analysis.

This approach has potential for use in an experimental setting evaluating multiple treatment and/or disease conditions.

Figure 2. Singly housed mouse in JAXA habitat. Shown is a mouse in the Japanese spaceflight habitat, which could be retrofitted for tracking plates.

Flight applications

Flight experiments using mice can incorporate the mouse matrix system to improve animal welfare and expand data acquired throughout the flights. This would provide higher resolution, longitudinal spaceflight analogue-induced pathophysiological effects potentially preceding overt clinical sign manifestation underlying infection and exposure, providing critical health data for research and animal welfare purposes.
A challenge to incorporating this system is the nature of the spaceflight environment. The habitats used for mice are shown in Figure 3 and include many metal components that would interfere with the radiofrequency signal from the chips and need to be replaced. The microgravity environment also provides a challenge for distance of the chips from the plates.

Figure 3. Flight habitat for mice. Shown are the habitats for mice in flight, with foodbars on the far walls and the water system in the center.

Near term future directions

The clear translatability of the use of this technology to enable improvements in the use of research animals in space health studies will give the **principal investigators, staff, and trainees** experience with a higher standard of animal care and preclinical model research quality. **The proposed approach and animal monitoring technology will become the standard of animal model research for ground and space studies, particularly for deep space missions.**

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