Novel Exercise Hardware Requirements, Development, and Selection Process for Long-Duration Spaceflight


Background

As NASA aims to travel beyond low Earth orbit (LEO) the constraints placed upon exercise equipment onboard space vehicles increase. Proposed vehicle architectures, for transit to and from locations beyond LEO, call for limits to equipment volume, mass, and power consumption that are significantly more stringent than device requirements for the international space station (ISS). While NASA has made great strides in providing for the physical welfare of the crew, the equipment currently used onboard the ISS will not conform to the expected mass, volume, and power constraints of long-duration transit vessels. The goal of the Advanced Exercise Devices (AED) project is to maintain the resistive and aerobic capabilities of the current ISS suite of exercise equipment, while making reductions in size, mass, and power consumption to make the equipment suitable for travel beyond LEO and future long-duration missions.

Generalized AEC Development Timeline

Requirements Development

The goal of the device development is to demonstrate, onboard the ISS, the ability of a compact device to provide an acceptable resistive load during a long-duration mission. The functional requirements were developed with a Mars transit mission as the targeted device application. Some of the high-level requirements for the device include:
- Mass < 100 lb
- Stored volume < 2.0 ft³
- External power: ≤ 50 W
- Repair: 1-year service life
- Resistive load: Provide 20 to 600 lb of resistive load and an adjustable eccentric overload
- Load ratio: Required eccentric-to-center load ratio of at least 1:5:1

Human-in-the-Loop Testing

- All devices had to undergo some level of human testing to be considered for evaluation.
- Typical human evaluations collected subjective data from the user (feel, comfort, pain, etc.) to complement objective engineering measures.
- For devices evaluated in-house by NASA, the standard resistive test protocol is shown in this section. A typical set consists of a minimum of three repetitions.

Device Evaluations

Seven devices were evaluated in August 2013 against the functional requirements.

Combined Countermeasure Device (CCD)

The CCD contains surface and gravity-induced training with resistive devices through the use of a stationary platform.

Controlled Resistance Exercise Device (CRED)

The CRED is a centrifuge-based system that simulates inertia and provides a user-selectable eccentric overload.

High Eccentric Resistance Overload Device (HERD)

The HERD consists of two air springs and assist motors and can provide 600 lb of resistive load and an adjustable eccentric overload.

Multimedia Exercise Device (M-MED)

The M-MED provides both endurance and resistance training through the use of a flywheel and an eddy current brake.

Wine Flywheel

The Wine Flywheel uses two different pulley systems to provide both aerobic and resistance modes in a system requiring no external power.

Multitask, Multiaxis Isokinetic Dynamometer (M-MID)

The M-MID provides up to eight motors allowing for either free motion by the subject or prescribed motions programmed into the software.

Downselect

- Based on the known information from these devices, the AED team scored each device against the functional requirements.
- The Exercise panel, consisting of subject matter experts from various NASA organizations, included the HERD and the M-MED from the seven listed above for further evaluation.
- Two new devices are currently ready for human-in-the-loop testing. A final device decision will be made during 2014 after these devices have been tested.