

Abstract

During 16 years in low-Earth orbit, the suite of exercise hardware aboard the International Space Station (ISS) has matured significantly. Today, the countermeasure system supports an array of physical-training protocols and serves as an extensive research platform. Future hardware designs are required to have smaller operational envelopes and must also mitigate known physiologic issues observed in long-duration spaceflight. Taking lessons learned from the long history of space exercise will be important to successful development and implementation of future, compact exercise hardware.

The evolution of exercise hardware as deployed on the ISS has implications for future exercise hardware and operations. Key lessons learned from the early days of ISS have helped to:

- Enhance hardware performance (increased speed and loads)
- Mature software interfaces.
- Compare in-flight exercise workloads to pre-, in-, and post-flight musculoskeletal and aerobic conditions.
- Improve exercise comfort.
- Develop complimentary hardware for research and operations.

Current ISS exercise hardware includes both custom and commercial-off-the-shelf (COTS) hardware. Benefits and challenges to this approach have prepared engineering teams to take a hybrid approach when designing and implementing future exercise hardware. Significant effort has gone into consideration of hardware instrumentation and wearable devices that provide important data to monitor crew health and performance.

TVIS

Treadmill with Vibration Isolation System

- 12/3/2000 – Installed.
- 11/22/2009 – Stowed.
- Top speed – 10mph.
- VIS – Active and would share power with treadmill motor.
- Subject loading – several times switched between Subject.
- Loading Device (SLD) and Bungees.

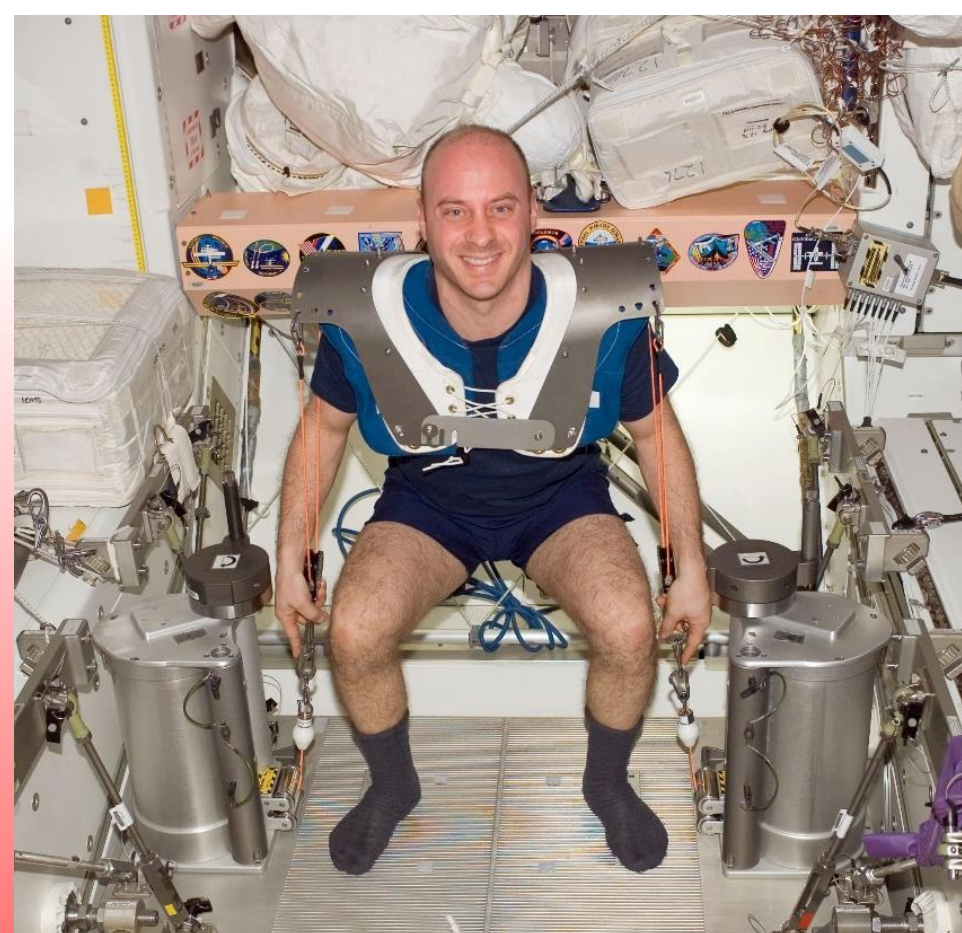


1,051 hours ran on TVIS covering a distance of 4,664 miles

iRED

Interim Resistance Exercise Device

- 12/12/2000 – Installed.
- 8/7/2009 – Stowed.
- Top load – 150lbs in each canister (300 pounds combined).
- Flex packs create resistance in each canister.



Approximately 998,930 repetitions were completed on iRED.

CEVIS

Cycle Ergometer with Vibration Isolation System

- 3/27/2001 – Installed.
- Currently in use today.
- Top load – 350W.
- Vibration Isolation System (VIS)– Passive with Large Isolators.
- Crew can strap themselves to the seat with a seatbelt or float and hold the frame behind the cycle while riding.



Approximately 2,384 hours have been spent cycling with an average load of 162±55 Watts

T2

Second Generation Treadmill

- 9/30/2009 – Installed.
- Currently in use today.
- Top speed – 12.5mph.
- VIS – Passive with accelerometers to detect when the treadmill bumps the frame.
- Subject loading – currently loaded with Bungees.



5,716 hours ran on T2 with an average speed of 6.7±2.2mph

ARED

Advanced Resistance Exercise Device

- 1/6/2009 – Installed.
- Currently in use today.
- Exercise Bar Load: 0-650lbs
- Exercise Cable Load: 0-150lbs.
- Resistance provided through use of two vacuum cylinders.
- Exercise bench and heel raise attachments are provided.



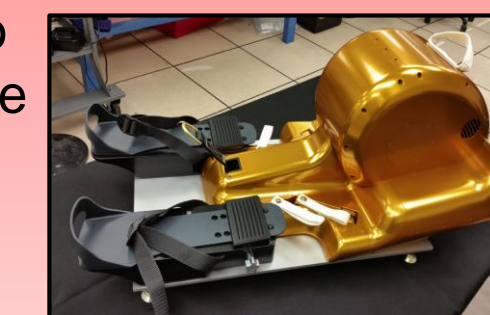
Approximately 1,582,792 repetitions have been completed on ARED to date.

Exploration Exercise Hardware

- Reduced vehicle footprint size (only few cubic inches larger than a shoebox).
- Retains the prime objective of protecting astronaut health & reducing risk of injury for crew members.
- Multiple devices were developed. HRP performed a down select of 4 presented devices.

MED2 (Miniature Exercise Device -2):

- Launched to ISS on Orb-6 as part of the 2x2015 1E Hardware Challenge at JSC.
- 2/2017 – Hardware checkout. MED2 attaches to the ARED Footplate, which allows use of the ARED VIS.
- Spring 2017 – Science Checkout. Evaluation of the biomechanical form (n=6) on MED2 compared to ARED; for high, med, and low loading.
- MED2 provides resistance and rowing exercise capabilities, which allows an assessment of operational volume studies to inform MPCV design.



Exploration Class Exercise Hardware

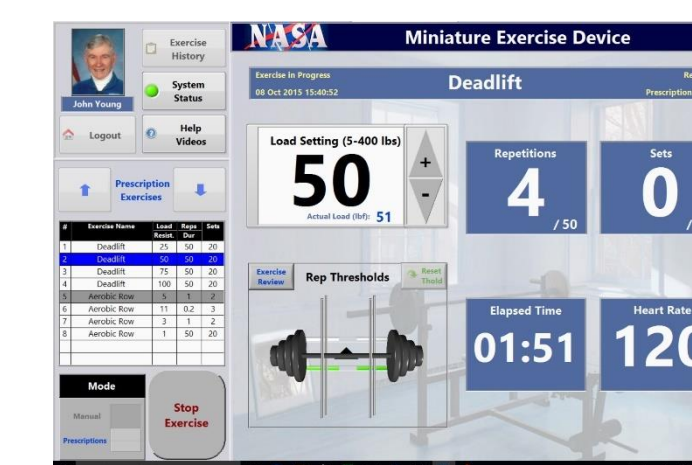
(Exploration Exercise Equipment Project) EEEP is managing the review and down select of Exploration Class Exercise Hardware. These devices will be flown in the Orion capsule, Cis-Lunar Habitats, and Mars transit vehicles. The Exercise Physiology and Countermeasures Laboratory (ExPC) performs human-in-the-loop tests on developing hardware. The ISS and ground analogs are being utilized as test beds for maturation of these devices.



Software Interface

NextGen CMS Software GUI

- Software is being designed as a common interface for all CMS hardware, reducing training time, maintenance costs, and increasing user familiarity.
- During the NEEMO 21 mission, an initial usability study was conducted, resulting in valuable feedback from aquanauts.
- NextGen software will be deployed with MED2 during upcoming evaluation on the ISS.



Complimentary Hardware

PPFS

- Gas analyzer for use on ISS for VO₂max test.

Bluetooth

- Use for physiologic (heart rate, respiratory rate, skin temperature, etc) and environmental (radiation, CO₂, acoustic) monitoring.

MLS

- A device agnostic loading system to split a single cable device into a dual cable device. Accelerometers and load cells in the exercise bar creating a "smart bar".

- Force Shoes (X2 & Xsens) and EDLS-ISS Force Plates for ARED
- Provide center of pressure and load to generate Ground Reaction Forces during static and dynamic resistive exercises.

On the horizon...

- Virtual training environments.
- Virtual training coaches and partners.
- Hybrid reality platforms.

