National Aeronautics and Space Administration

Advanced Exercise Concepts for Exploration

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Challenge

Current exercise countermeasure equipment used on the International Space Station will not be suitable for future exploration missions because of unprecedented limitations in mass, volume, and available power.

Charter

NASA's Human Health Countermeasures Element is tasked to provide guidance to groups external to NASA's Human Research Program (HRP) in the development of advanced exercise concepts. Currently, there are many design reference missions being considered, which include the possibility of both short- and long-duration missions. It is the goal of HRP to build a portfolio of potential technologies to meet the crew health requirements of these missions.

Requirements

The exercise device requirements have been constructed using years of NASA ground and International Space Station exercise and human physiology data and are meaningful within the context of microgravity human health maintenance. Even with that experience, this effort is in its early stages, and requirements should be considered preliminary and subject to change if needed based on changing mission and/or scope and as the exercise and performance portfolio gaps are addressed.

Reduced mass, reduced volume, and full functionality are the focus of the device requirements. The goal is not to restrict technology development, but to provide a useful guide for developers to work toward and provide consistent design criteria across development efforts.

Requirements consist of general device requirements, resistive requirements, and aerobic requirements.

The general device requirements encompass the physical requirements needed for an exercise device to fly on an exploration mission. These requirements include mass, stowage volume, operational volume, stowage and setup times, and lifecycle requirements, among others.

The resistive requirements address the need for the exercise device to allow for resistive workout mechanisms. These requirements address specific exercises that need to be achieved (i.e., squats, heel raises, and dead lifts), maximum force requirements, and adjustability, among others.

The aerobic requirements cover specific needs the exercise device needs to fulfill that are related to an aerobic workout. These requirements include minimum aerobic work rates, setup and adjustment times, and power generation, among others.

References

Weaver, A., "Advanced Exercise Device Development Requirements," NASA Internal Document, In press, Dec. 2011.
Weaver, A., "Digital Astronaut Project Model Selection within the Advanced Exercise Concept Hardware Development Lifecycle," NASA Internal Document, In press, Jan. 2012.

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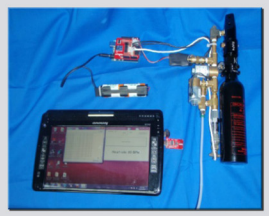
Overview of Current Advanced Exercise Equipment

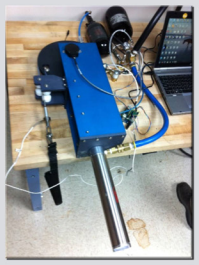
Power-Generating Ergometer—ZIN Technologies
Device is an adjustable load cycle ergometer utilized in NASA Desert Research and Technology Studies in 2008 to 2010.

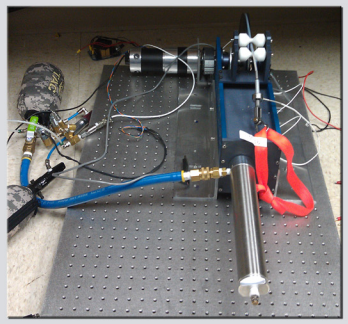
Gas Spring Device—ZIN Technologies
Device primarily focuses on high load resistive exercises with a secondary focus to provide a means for aerobic exercise.



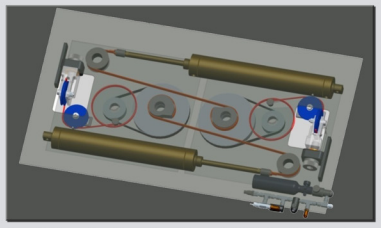
Powered Options for Pneumatic Exercise Devices—ZIN Technologies
Device uses a high pressure air source and less than 5W of power with digital control of load set points.

Cam Air Spring Device—ZIN Technologies
Device is designed as a modular, scalable bench top unit to provide near-perfect-linear loading with a cam profile designed to produce a constant torque output from the varying piston force.

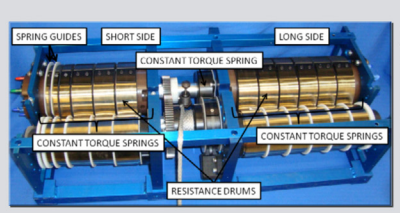




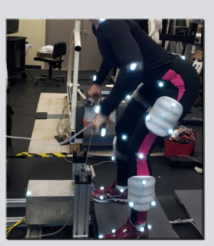
Eccentric to Concentric (E:C) Overload Assist Device—ZIN Technologies
Device combines the benefits of a passive system, providing near-linear loads at a range of values, with the ability to add an E:C overload aspect to the exercise.



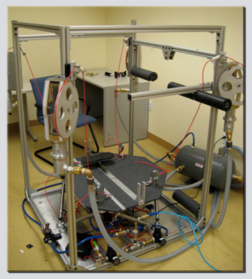
Dual Gas Spring Device—ZIN Technologies
Device builds off gas spring technology to utilize two identical devices allowing for increased resistive loads, two cable outputs, and increased resolution at low loads.



Constant Force Resistive Exercise Unit Valeo (SBIR Phase 2)—PI: Paul Colosky
Device was found to have alignment issues, low fatigue life of springs, and excessive friction. Any further development of spring technology should consider life limitations due to fatigue and inherent load variability.

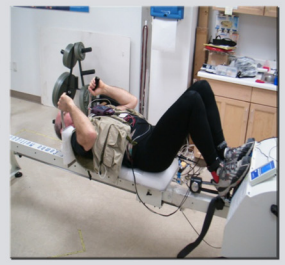


Servomotor Device Streamline Automation (SBIR Phase 2)—PI: Stelu Deaconu
Device is a servo-motor based system with closed-loop force feedback control that simulates the inertial component of 'free weights' and has a user-selectable eccentric overload.

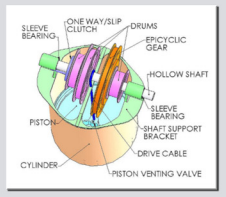


NSBRI Combined Countermeasure Device PI: Thomas Lang
Device combines balance and coordination training with resistance exercises designed to target specific muscle groups at the hip and lower extremity.

NSBRI Flywheel "Multi-Mode Exercise Device" PI: Greg Adams
Device provides endurance and resistance exercise training and has proven effective in increasing work capacity and muscle size and strength in the lower leg and thigh at low exercise doses.

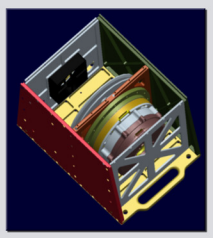


Inertia Wheel Exercise Device Wyle Laboratories
Device is designed to allow both aerobic and resistance exercise with no external power utilizing a flywheel and two pulley-belt systems housed in an aluminum enclosure.



Innocentive Challenge Solver Concept PI: Jeff Davis
Device utilizes a vacuum cylinder with epicyclic gearing to generate variable resistive loads.

Variable Load Device
NASA JSC Software Robotics and Simulation Division
Device provides the equivalent of an entire set of weights in a breadbox-sized package and is capable of weight and inertia simulation and rowing-type exercises.



Miniature Exercise Device
NASA JSC Software Robotics and Simulation Division
Device will demonstrate key motion system concepts utilizing the joint technology from NASA's Robonaut.

Linear Magneto-Rheologic Device
NASA JSC Software Robotics and Simulation Division
Utilizes an exoskeleton using linear magnetic rheological fluid dampers at the joints.

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