

Title: Novel Musculoskeletal Loading System for Small Exercise Devices

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Long duration spaceflight places astronauts at increased risk for muscle strain and bone fracture upon return to a 1-g or partial gravity environment. Functionally limiting decrements in musculoskeletal health are likely during Mars proving-ground and Earth-independent missions given extended transit times and the vehicle limitations for exercise devices (low-mass, small volume, little to no power). This is particularly alarming for exploration missions because astronauts will be required to perform novel and physically demanding tasks (i.e. vehicle egress, exploration, and habitat building activities) on unfamiliar terrain. Accordingly, NASA's exploration roadmap identifies the need for development of small exercise equipment that can prevent musculoskeletal atrophy and has the ability to assess musculoskeletal health at multiple time points during long-duration missions.

**Problem:** Most small exercise device concepts designed for exploration class vehicles provide resistance loading with a single-cable. However, spine, hip, and lower body musculoskeletal strength is best protected by performing resistance exercises with two-point loading at the shoulders (i.e. barbell squats and heel raise). Importantly, two-point loading is not possible with a stand-alone single-cable exercise device. Splitting or rerouting the single-cable to provide two-point loading is not a simple task. In order to provide safe and effective loading the cable cannot interfere with exercise range of motion, the load needs to be equal on both shoulders, and cannot be moved too far in front of or behind the feet.

**Purpose:** To develop a novel low-mass, low-maintenance, and rapid deploy pulley-based system that can attach to a single-cable small exercise device to enable two-point shoulder loading and the ability to perform exercises such as squats and heel raises.

**Results:** A pulley-based Musculoskeletal Loading System (MLS) prototype was designed, built, and tested while attached to a single-cable exercise device. During preliminary human load testing the MLS was attached to a flywheel device and instrumented with in-line load cells on both sides of the bar. Test subjects reported smooth movement with the load spread evenly between both shoulders throughout the entire range of squat motion. The load cell data demonstrated measureable symmetric loading on both sides of the bar.

**Continuing Effort:** This project recently received IR&D funding for continued hardware development and testing. The aim of the second phase of development is to miniaturize the prototype device, decrease the mass, decrease the friction in the system to improve load quality, and add the ability to measure muscle strength throughout spaceflight missions. Engineering fit and function evaluations and human testing is planned following hardware fabrication. The hardware will be ready for flight certification and technology demonstration on ISS at the end of the next project period. The MLS could enhance exercise countermeasures on small, single cable exercise devices and save cost, space, and energy during future exploration missions.