ON-COMMAND EXOSKELETON FOR COUNTERMEASURE MICROGRAVITY EFFECTS ON MUSCLES AND BONES.

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Summary: Human travel to Mars would involve very long exposure to microgravity environment and require countermeasures to decrease the deleterious effects on the muscles and bones. Studies have shown that exercise is an effective countermeasure and a lightweight, compact, low-power exoskeleton is needed to perform on-command high- or low-intensity exercises that, unlike existing systems, do not impede the performance of duties. Generally, there are three types of available exercise machines used by space crew to maintain their fitness including the Crew Exercise Vibration Isolation System, Treadmill Vibration Isolation System / Second ISS Treadmill, and the Advanced Resistive Exercise Device. These machines have the limitations of very large mass (some weigh about a ton), large operating volume, and cumbersome designs that require damping of generated vibrations and compensation of large center of mass shifts during use. These systems also require the crew to leave their duties to perform the exercises, and they involve periodic costly maintenance.

Upon landing on Mars, the astronauts may need assistance in their mobility if the deterioration is excessive. This may be accomplished by an exoskeleton that is capable of on-command impeding elements that are integrated with actuators. The augmentation of astronauts' capability may allow them to peform functions that are superior to their intrinsic capability. This could include performing science related tasks that are identified as significant objectives in the Decadal Study.

The exoskeleton mechanism: The exoskeleton would be a suit structure with elements that impede linear and rotary movements as well as augmentation actuators that are operated on-command by the user. The exoskeleton structure would be made adjustable to fit the size of the users. Since it is a wearable device its required space inside the crew's vehicle would be relatively small and consists of elements that are integrated with the joint drive assemblies. Preliminary development has already been done and demonstrated by members of the team [1, 2] (see Figure 1).

Control of the exoskeleton would be intuitively performed by the user and would be supported with a sensor system to provide redundancy and robustness. The sensors placed on the exoskeleton would include miniature position and torque sensors on the joints. Miniature force/touch and myoelectric sensors would be placed on the human to measure the muscle activities (flexion or extension).

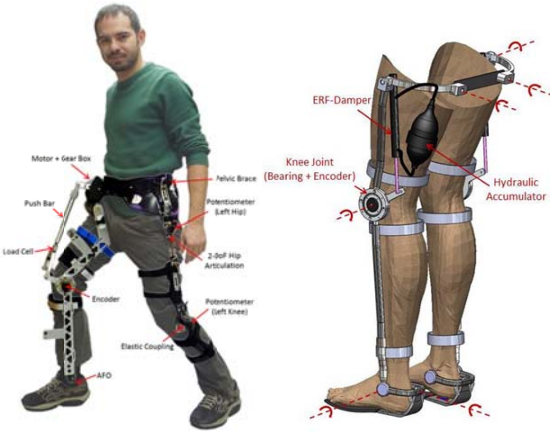

Figure 1: A wearable lower body exoskeleton system [1].

A key to the operation of the impeding/actuating elements would be the use of electro-rheological fluid (ERF) based mechanisms, piezoelectric actuators, spring mechanisms for energy storage and recycling, as well as RFID sensors. Using ERF-based mechanisms would enable controlled compliance of the exoskeleton that, when needed, would be activated electrically to rigidize the structure, components, and the interface between the actuators and the user joints. These fluids rapidly (in microseconds) become increasingly viscous as a function the electric field to which they are subjected. Thus, the exoskeleton would act as a "transparent" system until it needs to be activated, either as an impeding machine for exercise or as motions augementer. When operating as an actively-controlled mechanism, it would reduce the metabolic energy input that astronauts would exert. The exoskelton system would store and release mechanical energy to reduce power consumption and harvest energy for storage in batteries. Storing and releasing the captured elastic energy would be done by flexure spring structures and ERF mechanism that would be integrated with the joint drive assemblies.

Benefits of on-command exoskeleton: This exoskeleton technology would enable a simulator to "feel" mechanical conditions both virtually or remotely (in tele-presence mode). Such a simulator could benefit medical therapy in space, which may be a critical need in a mission to Mars since medical urgent care procedures may be required and return to Earth for treatment may not be a viable option. To deal with unpredictable health problems, the medical crew would need the capability to practice the necessary procedures in virtual environment to maximize the probability of success. Further, a wide range of applications are envisioned that would benefit from the developed technology, including: a) Haptic interfaces and force-feedback devices for use in virtual reality training simulators and/or tele-presence tasks, as well as user interfaces of computers and instruments; b) Instruments and devices with excellent vibration suppression capability; c) Rehabilitation and patient-assistive medical devices; and d) Sports and entertainment devices [3, 4].

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