

Candidate Exercise Technologies and Prescriptions

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Presentation Overview

1. Exercise Countermeasures Project Overview
2. Candidate exercise technologies being funded by the HRP Exercise Countermeasures Project
3. Analog exercise hardware
4. New studies to optimize current and future exercise prescriptions



Exercise Countermeasures Project (ECP) Mission



ECP provides a single focal point for all exploration exercise countermeasure activities

Flight

- Determine current status of in-flight and post-flight exercise performance capability and goals/target areas for protection with the current in-flight exercise program (informs Space Flight Health Standards)
- Utilize flight platforms to evaluate candidate exploration technologies/protocols (e.g., devices, prescriptions)
- Complete functional testing pre-post STS and ISS missions, to determine impact of physiologic decrements on performance of anticipated exploration tasks

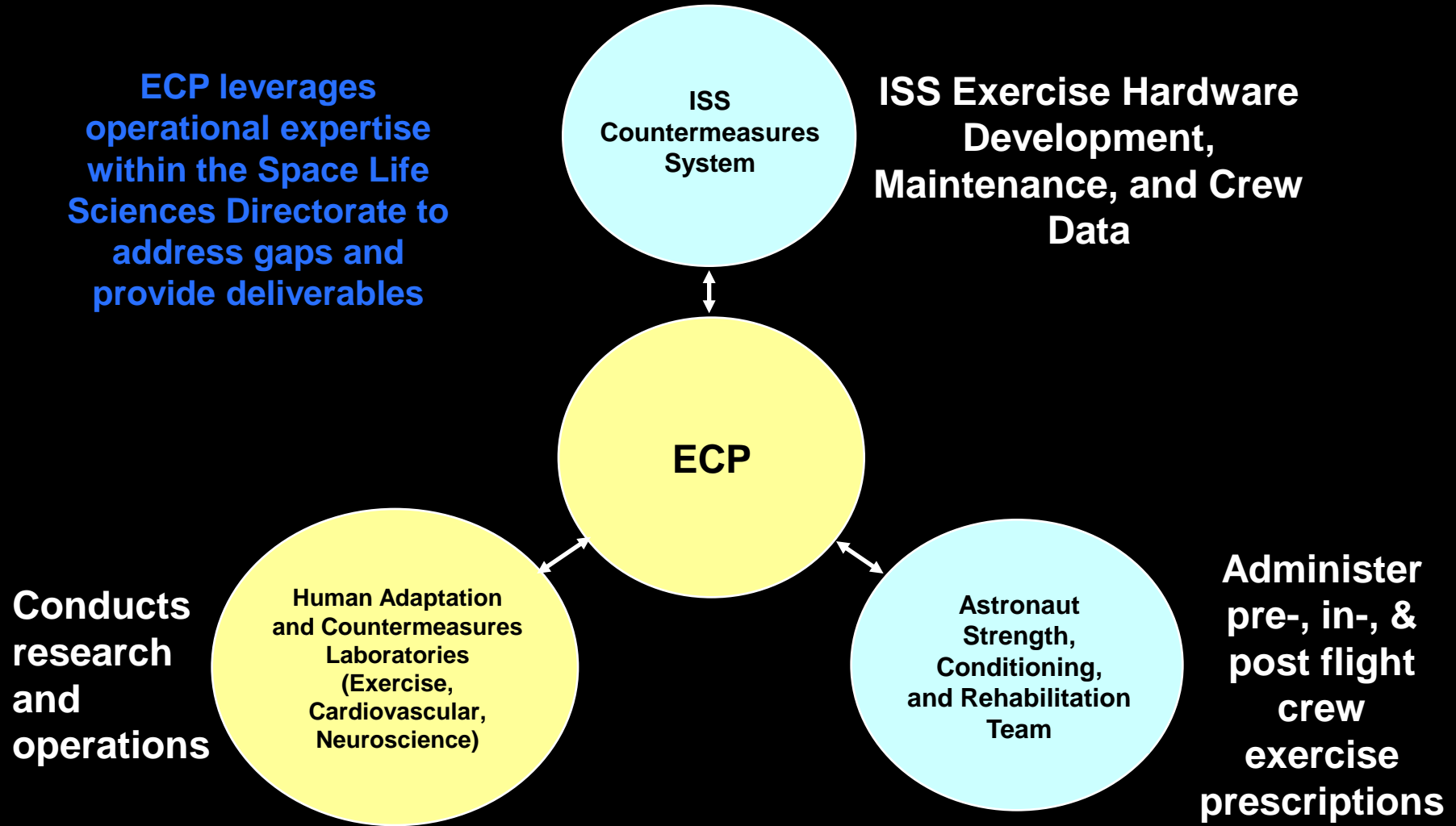
Ground

- Conduct studies to identify improved 0-g exercise prescriptions, factors of influence for mission performance
- Conduct task assessments to identify physiological requirements for exploration mission tasks
- Conduct analog studies to evaluation candidate technologies.
- Complete integrated studies with other candidate countermeasures (e.g., pharmaceuticals, etc.)





Project Interfaces





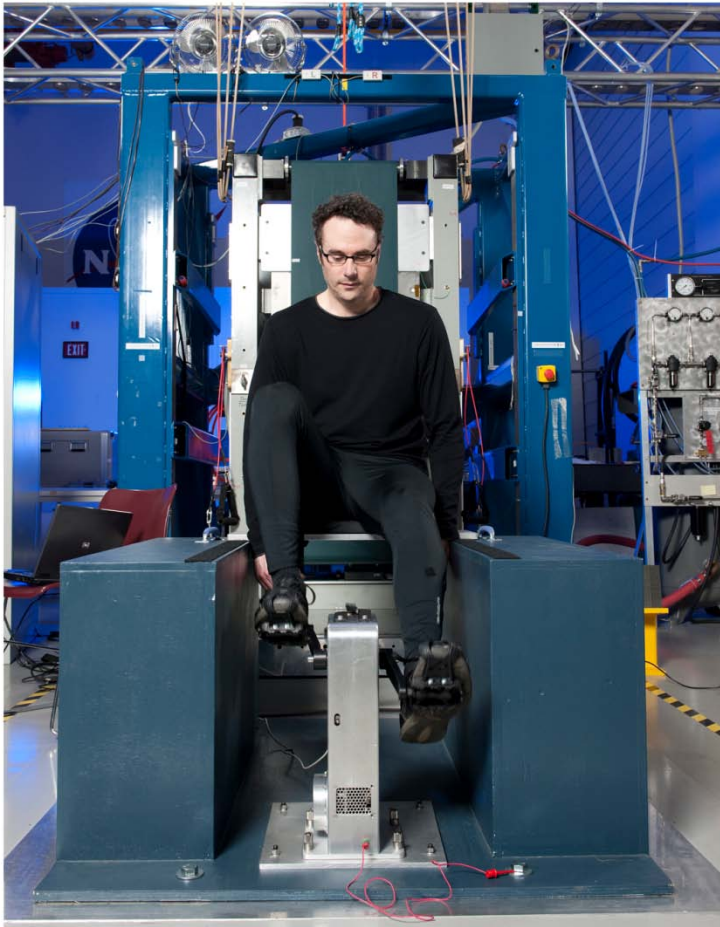
Advanced Exercise Concepts

- ECP is advancing “breadboard” or candidate exercise concepts that may be suitable for exploration transit or surface vehicles/habitats
- Efforts centered out of NASA’s Glenn Research Center (Cleveland, Ohio)
 - Compact (compared to ISS US exercise hardware)
 - Minimal vehicle resources (power, size)
 - Multi-function (performs both aerobic and resistive exercise within one device)
 - Same capability as ISS US exercise hardware (ARED, T2, CEVIS)
 - Technology Readiness Level 6 (system/subsystem model or prototype demonstration in relevant environment)
 - Reliable, easy to use
 - Greater behavioral health aspects
 - Evaluate in ground, analog, and/or flight testing



Lunar Electric Rover (LER) Ergometer Human Subject Test Demonstration

NASA C-2010-2011

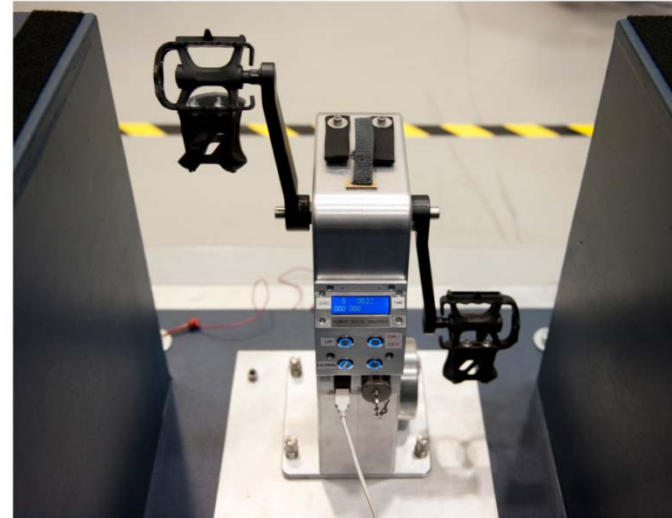


National Aeronautics and Space Administration
Glenn Research Center at Lewis Field



Lunar Electric Rover (LER) at NASA JSC

NASA C-2010-2023

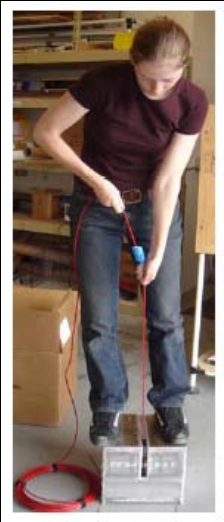


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Ergometer generates power during use for recharging batteries, provides aerobic and resistive modes, data logging capability – displays Watts, Voltage, Calories, Elapsed Time



Advanced Exercise Concepts for Exploration



Valeo Constant Force Spring prototype (Phase 1 SBIR device shown here)

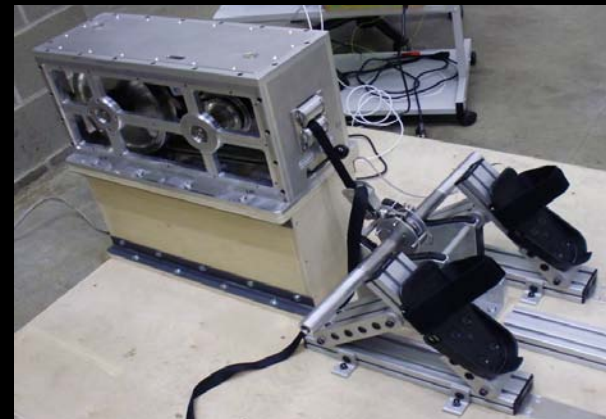
Advanced Exercise Concept (Zin Technologies Gas Spring)



Adams/Tesch next-generation flywheel (NSBRI study)



Streamline Automation Electric Servo-Motor based prototype (Phase 1 SBIR device shown here)



Wyle Inertial Wheel proof of concept



ECP Innovation Activities



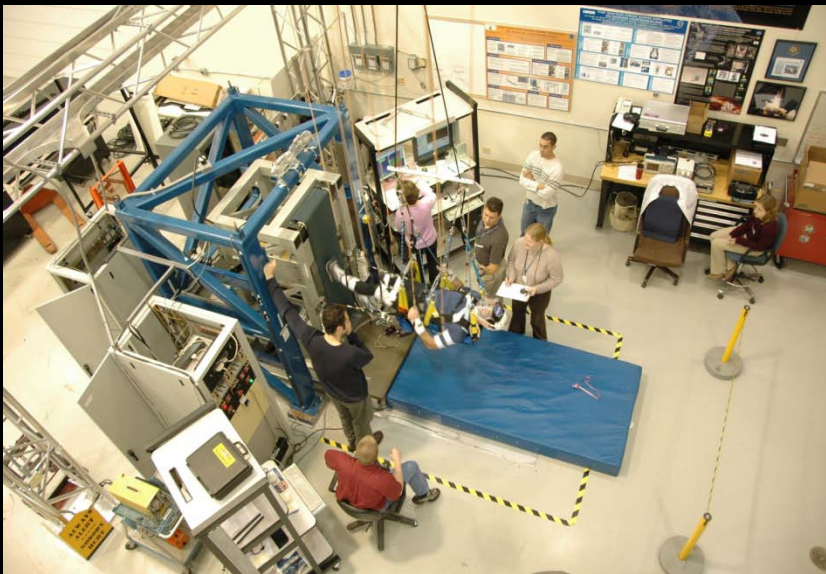
- Innocentive™ is a world leader in prize-based open innovation, with a community of over 180,000 registered “solvers”
- ECP posted a technical challenge on the Innocentive.com website in December 2009 entitled, “Mechanism for a Compact Aerobic and Resistive Exercise Device”.
 - Solicit novel engineering solutions to generate high loads and stroke rates for possible infusion into next generation exercise device concepts.
- Over 100 proposals received by Innocentive™, screened to 60 complete proposals which were reviewed by ECP.
- One award was recommended for full funding in May 2010 (pneumatic suction device/epicyclical gear). Pending legal reviews and disclosure of Solver to NASA.





Exercise Countermeasures Laboratory (ECL)

- Provides unique 3 Degree of Freedom interface (floating treadmill) for Vibration Isolation System (VIS) dynamic characterizations, high-fidelity human-device-vehicle interface simulation
- Provides unique ground-based simulation of in-flight (0-g) and surface (fractional-g) loading, including lunar (10 deg. pitch) and martian gravity
- Supports development and validation of advanced exercise countermeasure devices, requirements, and exercise prescriptions for Space Exploration including devices beyond treadmill modality



eZLS (enhanced Zero-Gravity Locomotion Simulator) at NASA Glenn Research Center



Analog Exercise Hardware

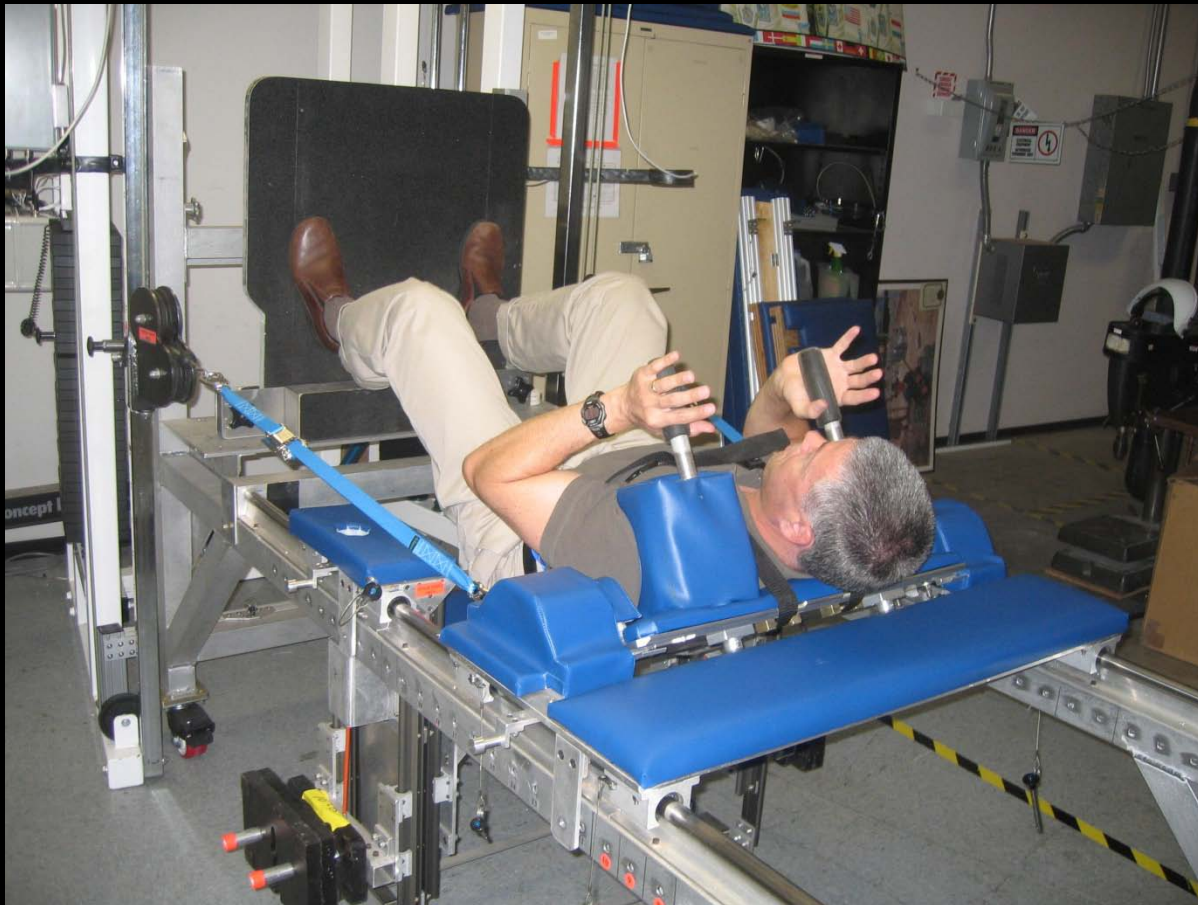
Stand alone zero-gravity locomotion Simulator (sZLS) in place at NASA's Flight Analog Research Unit, University of Texas Medical Branch (UTMB), Galveston, TX





Analog Exercise Hardware

Horizontal Exercise Fixture (HEF) is currently undergoing modifications to complete a supine squat motion during long duration bedrest studies.





Harness Station Development Test Objective

G. Perusek, NASA GRC, PI



Glenn Harness tested by crewmember on T2 Treadmill during ISS Exp. 21

- 16 sessions with TVIS Harness, 16 sessions with Glenn Harness (starting at ~FD30)
- Every 4th session do specific protocol:
 - 15 min at load of 60% of body weight (BW) at the normal routine speed
 - 3 min at 60% BW – 3 mph
 - 3 min at 60% BW – 6 mph
 - 3 min at 90% BW – 3 mph
 - 3 min at 90% BW – 6 mph
- Collect load data and comfort ratings
- 3 ISS crew participants to date (7 total planned)



Glenn Harness Back view showing load sensors and Instrumentation



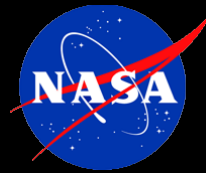
New Studies to Optimize Current and Future Exercise Protocols

Integrated Aerobic and Resistance Training Study (“Sprint”)

- **Flight Study (L. Ploutz-Snyder, Ph.D., Principal Investigator)**
 - N=40 (20 active subjects, 20 control subjects)
 - Commence with Exp. 27/28 crew (pending crew consent)
 - New type of hybrid study – part operations, part research
 - Maximizes the use of new instrumented ISS exercise equipment (ARED , T2)
 - Increase exercise intensity with decreased frequency & duration
 - 3 days/week instead of 6 days/week resistance exercise
 - **Periodized, aerobic exercise 6d/week**
 - 30 min continuous on resistance days
 - High intensity intervals on alternate days (15-35 min)
 - **Varies resistance exercise mode & intensity to better target a wide variety of muscles and bones.**
 - **Optimizes countermeasure to mitigate physiological changes associated with spaceflight.**
 - **Receives information from multiple HHC studies to optimize countermeasure**



New Studies to Optimize Current and Future Exercise Protocols



Sprint- Integration of Aerobic and Resistance Exercise – Total Time

Resistance	35-60 min		35-60 min		35-60 min		
Aerobic Interval		32 min		15 min		35 min	
Aerobic Continuous	30 min		30 min		30 min		

Note: Time savings up to 3 hours/week compared to current exercise time
At least 4 hrs, preferably 8 hrs separating exercise sessions

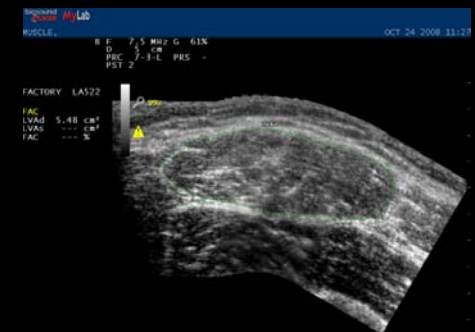
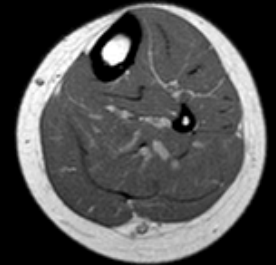


New Studies to Optimize Current and Future Exercise Protocols

Integrated Aerobic and Resistance Training Study (“Sprint”)

• Outcome measures

- Muscle
 - Pre/In/Post-flight assessment of muscle size (MRI / Ultrasound)
 - Muscle Function
 - Strength, power, endurance, CAR, steadiness
 - Muscle biopsy
 - Single fiber size, contractile function, type, capillary density, metabolic enzymes
- Bone
 - Pre/Post DEXA and qCT (hip, spine)
- Cardiovascular
 - Pre/In/Post-flight VO_2 max & HR response to submax load
 - Ventilatory threshold pre/post-flight
 - Cardiac function with ultrasound





New Studies to Optimize Current and Future Exercise Protocols

Integrated Aerobic and Resistance Training Study

- **Bedrest Study (L. Ploutz-Snyder, Ph.D., Principal Investigator)**
 - Same exercise prescription and outcome measures as flight study
 - N=15 exercisers, N=15 controls
 - **Functional Tasks Test (FTT, J. Bloomberg, Ph.D., PI)** protocol to be completed on all bedrest subjects to map performance with physiologic changes in all groups.
 - 2009 NASA Research Announcement bedrest protocol entitled, **“Testosterone and Leucine Supplementation as Gender Specific Countermeasures against Musculoskeletal Losses during Space Exploration” (R. Urban/UTMB, PI)** will utilize another N=15 and share data FTT and “Sprint” bedrest subjects.
 - sZLS, HEF, modified commercial resistance exercise stations, supine ergometer to be used to mimic ISS exercise hardware suite.
 - Plan to start bedrest studies in the Fall of 2010.





New Studies to Optimize Current and Future Exercise Protocols

Biomechanical Analysis of Treadmill Locomotion on ISS

- **Flight Study (John DeWitt, Ph.D., Principal Investigator)**



- Current exercise prescriptions are based on hypothesis training effects are similar between ground and spaceflight.
 - No in-flight kinematic biomechanical evaluations of treadmill exercise have occurred
 - (FOOT, Cavanagh, examined GRF)
- N= 6 ISS crew participants, starting with Exp. 27/28 (pending crew consent)
- Collect motion capture and force data during nominal treadmill exercise (at different speed/load combinations)
- Data collected prior to and every 30 days in-flight
- Modeling approach to approximate Joint Torque
- Ability to quantify load and/or speed effects upon exercise efficacy
- Improved crew health and increased efficiency in exercise time.



New Studies to Optimize Current and Future Exercise Protocols

Biomechanical Analysis of Resistance Exercise Using the ARED

- **Flight Study (John DeWitt, Ph.D., Principal Investigator)**
 - Objective to determine joint loading and torque during in-flight ARED exercise and identify the best exercises for use during crewmember exercise during long-term missions.
 - Ground Pilot Study - 6 subjects (3m/3f of various size) with many exercises; objective is to determine flight study exercises (*In Progress*)
 - Flight Study - Up to 6 subjects with exercises determined to be best for providing joint loading (*Plan to start in early 2011*)
 - Flight Data Collection
 - 3D motion capture (marker-less, options under review)
 - options under review)
 - ARED force sensors
 - Lifemod (Lifemodeler, Inc) muscle modeling system
 - Quantification of joint loading during in-flight resistance exercise
 - Ability to rank exercises in terms of benefit
 - Potential tool for exercise assessment during all future flights





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Back Up Slides



Glenn Harness Design Changes

- “S”-shaped padded shoulder straps which avoid sensitive regions of the neck and shoulder while minimizing chest compression
- Subject self-adjustment of load distribution, with the majority of the load applied to the hips (70:30)
- Waist belt with cupped and canted regions to apply load to the iliac crests and lumbar shelf. Split padding feature, stiff outer shell, removable lumbar padding
- Pre-curved and padded waist belt for customized fit (S,M,L male/female) – no complicated adjustment for size differences
- Load attached to multiple points and transferred over the semi-rigid shell of the waist belt for load distribution

