Portable Load Measurement Device for use during ARED Exercise on ISS

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Background

Figure 1: ARED

- The Advanced Resistive Exercise Device (ARED) (Fig.1) is unique countermeasure hardware available to crewmembers aboard the International Space Station (ISS) used for resistance exercise training to protect against bone and muscle loss during long duration space missions.
- ARED instrumentation system was designed to measure and record exercise load data, but:
  - Reliably accurate data has not been available due to a defective force platform.
  - No ARED data has been recorded since mid-2011 due to failures in the instrumentation power system.
- ARED load data supports on-going HRP funded research, and is available to extramural researchers through LSDA-Repository.
- Astronaut Strength, Conditioning, and Rehabilitation specialists (ASCRs) use ARED data to track training progress and advance exercise prescriptions.
- ARED load data is necessary to fulfill medical requirements.
- HRP directed task intends to reduce to program risk (HRP IRMA Risk 1735), and evaluate the XSENS ForceShoe™ as a means of obtaining ARED load data during exercise sessions.
- The XSENS ForceShoes™ will fly as a hardware demonstration to ISS in May 2014 (39S).
- Additional portable load monitoring devices (PLMDs) are under evaluation in the ExPC Lab.
- PLMDs are favored over platform redesign as they support future exploration needs.

Methods

- XSENS ForceShoe™ measure tri-axial force and torque data at 50 Hz (Fig. 2).
- Ground and Parabolic flight (Fig. 3) evaluations were performed to test the XSENS ForceShoes™.

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Figure 2: XSENS ForceShoe™ and instrumented subject.

Output (per load cell)	Units	
	Fx,y (lb-force)	Fz (lb-force)
Sensing Range	±130	±260
Resolution	0.1	0.1
Single Axis Overload	1146	2248

Table 1: Summary of XSENS Senor Load Monitoring Specifications.

- An X-Y test stand and bungee system with in-line load cells used to apply and measure an input load to compare to ForceShoe™ measurements.
- Custom LabVIEW software developed to record data.
- Body weight + 45, 90, and 135 lb measured on a force plate and compared to ForceShoe™ load measures.

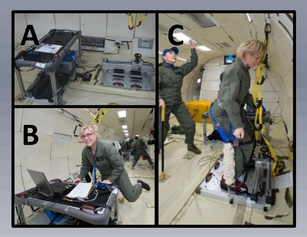

Figure 3: Parabolic Flight Test of XSENS ForceShoe™
A: Support console and test stand with static load force application device.
B: Operator hovering over the support console and data acquisition system.
C:Operator standing in the ForceShoes™ wearing the harness/bungee system.

Results

Table 2: Results of static load measurements in ForceShoe™ vs X-Y test stand, in flight and ground for measurements made from 40-200 lb.

X-Y Test Stand Load	Flight		Ground	
	mean (±SD)	spread	mean (±SD)	spread
Average % of Target (Fz, ±SD)	91.8% (±1.5)	90.4 – 94.4%	102.8% (±0.9)	100.2 – 104.3%
Average % of Target (Fx,y,z, ±SD)	105.0% (±1.8)	102.4 – 107.8%	104.5% (±1.2)	102.6 – 107.7%
	N=6		N=51	

Table 3: Results of static load measurements made while subject was wearing the ForceShoes™ and bungee pull down load was applied during standing.

Bungee Load	Flight Day 2		Flight Day 4*	
	mean (±SD)	spread	mean (±SD)	spread
Average % of Target (Fz, ±SD)	99.3% (±2.8)	94.6 – 101.7%	89.4% (±0.2)	89.2 – 89.6%
Average % of Target (Fx,y,z, ±SD)	103.7% (±1.9)	101.8 – 106.6%	92.8% (±1.3)	91.8 – 94.2%
	N=5		N=3	

*ForceShoes™ were zeroed during 2g pull out creating an offset in the data.

Table 4: Results of load measurements made while subject was wearing the ForceShoes™ and standing on a force plate. Analysis included BW, three additional weight loads, and set of deadlifts from 5 subjects.

HILT Eval	HILT Evaluation	
	mean (±SD)	spread
Average % of Target (Fx,y,z, ±SD)	101.2% (±0.8)	98.1 – 103.7%
	N=25	

- ForceShoes™ demonstrate accuracy and low variability (<5%) between measures.
- Subjects reported acceptable comfort and ease of use.
- Custom software and ForceShoe™ hardware operate well in simulated microgravity environment.
- Recommended for flight demo aboard ISS to monitor ARED exercise loads.

ISS Force Shoe Demo

Figure 4A: Concept of test protocol for T2 measurement.

Figure 4B: Concept of test protocol for ARED measurement.

- Subjects (n=4)will perform 1 T2 session (Fig. 4A) and 4 ARED sessions (Fig. 4B).
- A number of static load measures will be collected on the T2 by adding/subtracting spacers to the bungee assembly decrease/increase the pull down load.
- During ARED sessions static and dynamic activity will be performed during squat, deadlift and bicep curl.
  - A series of static loads will be collected in increments of 25 lb, from 0-500 lb.
- Transition to operational use will be assessed upon completion of the in-flight hardware demo.

Other PLMDs

- Additional PLMDs are under evaluation in the ExPC lab, as described in Fig. 5.
- Goal is to identify a device that will meet both research and daily operational needs.

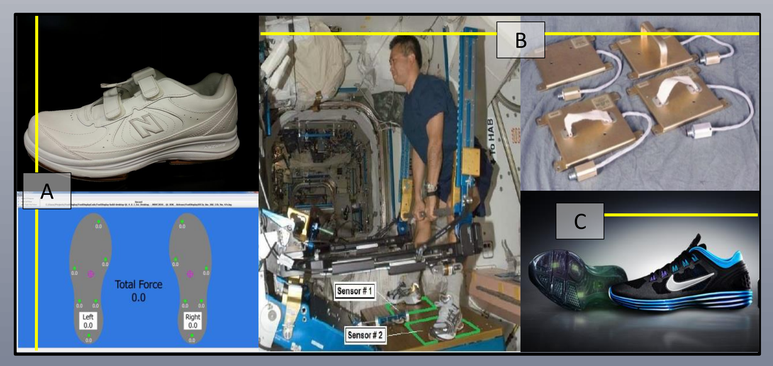

Figure 5: PLMDs under evaluation.
A) JSC Robotics X1 Force Shoe
B) Aurora Flight Systems Force Plates (SBIR Phase I completed)
C) Nike Hyperworkout+ Shoe (SAA)
*USARIEM/MIT LL instrumented boot not shown here.