Sandia National Laboratories

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Exoskeletons for DOE-EM and other Hazardous Operations

RadWaste Summit 2023

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U.S. DEPARTMENT OF ENERGY

NNSA

US DOE Office of Environmental Management

- **Responsible for clean-up of national nuclear legacy**
  - 15+ sites across the country
  - Thousands of workers performing physically challenging work
  - Work includes waste processing, storage, environmental remediation, and decommissioning activities
  - Decades of work remain
- **Work DOE-EM Sites Present Unique Safety Challenges**
  - Extensive PPE generally required to protect from external hazards
  - Musculoskeletal injuries remain common
  - PPE (including SCBA) can increase ergonomic strains
  - Much of the work is complex and non-repetitive
  - Workforce is rapidly aging

DOE-EM and Other Nuclear Cleanup Worker Challenges

- **Nuclear Cleanup Workforce Safety Challenges**
  - Environments and tasks are complex, making automation or teleoperation difficult or impossible
  - Environments can be very hot/cold
  - Body temp and heartrate are often monitored prevent overexertion

- **Examples of challenging tasks**
  - Maintenance, construction, demolition
  - Material movement of large/awkward sizes
  - Manual excavation
  - Lead blanket (45-90 lbs) movement
  - Glove box / hot cell operations
  - Warehouse operations
  - Custodial services
  - Etc.

DOE-EM Wearable Robotics Program Overview

- Funded by DOE-EM Office of Technology Development and led by Sandia
- Team members from DOE Labs, academia, and industry
- Working with EM sites to evaluate and deploy commercially-available exoskeletons
- Biomechanical analysis of commercial and experimental systems
- Developing novel systems for potential future challenges

SRNL SAVANNAH RIVER NATIONAL LABORATORY
OPERATED BY SAVANNAH RIVER NUCLEAR SOLUTIONS

FIU FLORIDA INTERNATIONAL UNIVERSITY

Sandia National Laboratories

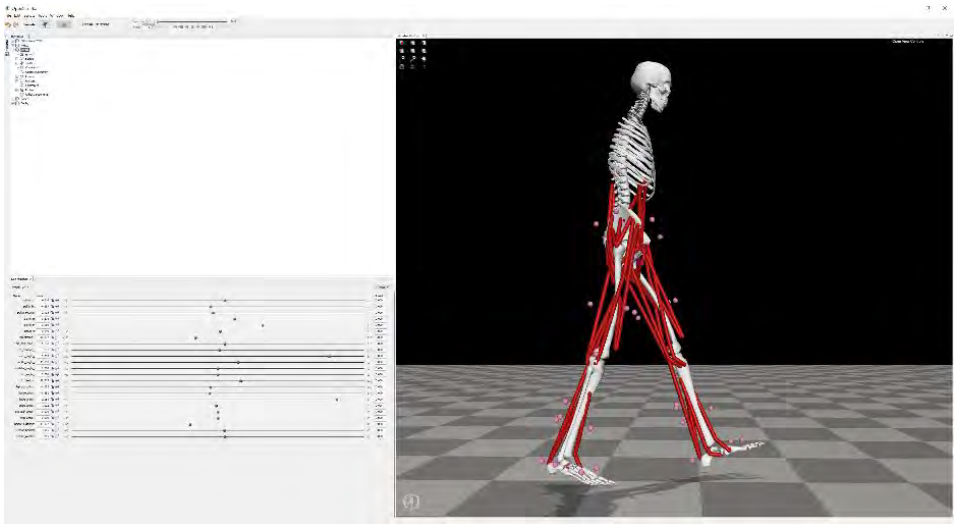
Georgia Tech

Los Alamos NATIONAL LABORATORY EST. 1943

ihmc FLORIDA INSTITUTE FOR HUMAN & MACHINE COGNITION

DOE-EM Exoskeleton Testbed

- Established at Sandia to evaluate exos specifically for DOE tasks
- Many commercial devices available for testing
- Test equipment includes:
  - Motion capture
  - Instrumented treadmill
  - Metabolic measurement
  - EMG
  - Surveys
- EM site tasks can be emulated with relevant PPE to assess device compatibility and effectiveness



EM Site Wearables Pilot Programs

- **Sandia National Labs is working with Washington River Protection Solutions to evaluate the potential impact of wearable devices at the Hanford site**
  - Provides objective evaluation of commercial technologies
  - Also working with SRS, WIPP, OREM, and other EM sites
- **Pilot program activities include:**
  - On-site technology demonstrations
  - Emulation of site tasks in Sandia testbed
  - Mock-up work with wearable devices at sites
  - Surveys to assess worker perception of the technology
  - Working with site safety teams to develop approval procedures for on-site use of wearables

Wearable devices: Shoulder and Arm Support

Ottobock ShoulderX

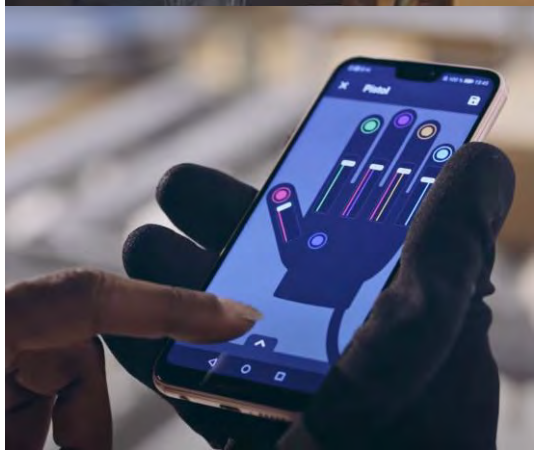
Assistance Type: Passive
Advertised Use Cases: Overhead tasks

Ekso Evo

Assistance Type: Passive (Gas Springs)
Advertised Use Cases: Overhead tasks

ErgoSante Hapo MS

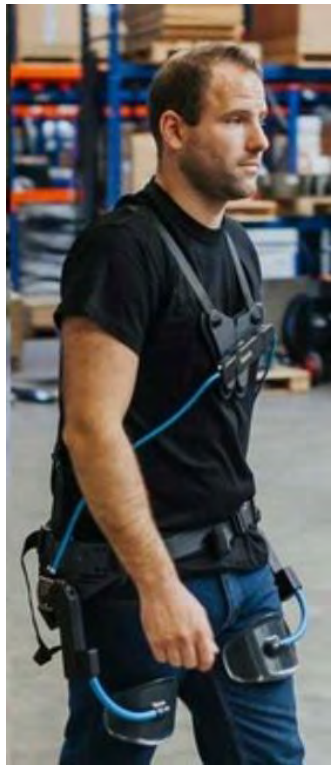
Assistance Type: Passive (Springs)
Advertised Use Cases: Work requiring arms at height of 0 to 135 degrees



BioServo's Ironhand

Assistance Type: Active (DC Motor Cable System)
Advertised Use Cases: All activities requiring gripping

Wearable devices: Back Support



Laevo V2.5

Assistance Type: Passive (Gas Springs)
Advertised Use Cases: Bending, leaning, carrying

ErgoSante Hapo

Assistance Type: Passive (Springs)
Advertised Use Cases: Bending, lifting

Herowear APEX

Assistance Type: Passive (Elastic bands)
Advertised Use Cases: Lifting, bending, crouching, carrying

SuitX BackX

Assistance Type: Passive (Torsional Springs)
Advertised Use Cases: Lifting, carrying, bending

Wearable devices: Lower Body

DEPHY Exoboot

Assistance Type: Active (DC Motors)
Advertised Use Cases: Walking/Hiking

Lockheed Martin ONYX

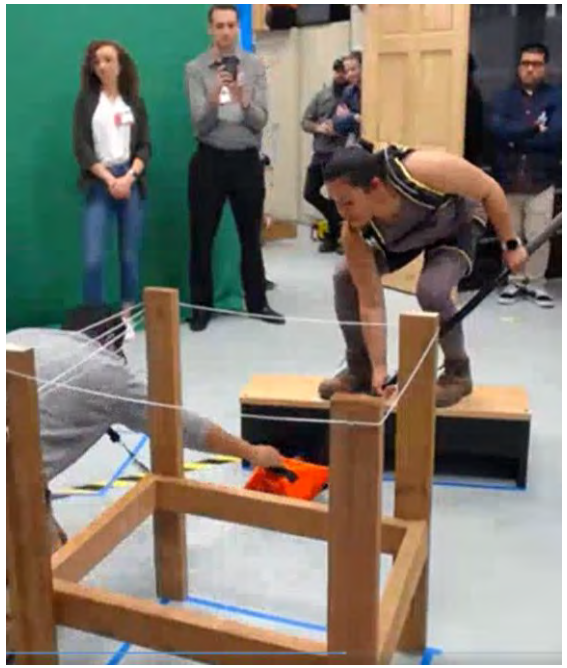
Assistance Type: Active (DC Motors)
Advertised Use Cases: Walking/Hiking, carrying heavy load

Noonee Chairless Chair

Assistance Type: Passive
Advertised Use Cases:
“Activities that can be performed in sitting position”

Next Steps

- Manual shoveling study being prepared at Exo Testbed
- Hanford interactions continue, including working with safety teams to develop approval plans for device deployment
- SRNL and LANL are working with other sites on similar activities
- FIU and IHMC continue development and testing of novel systems



Hanford Wearables Pilot Program Activities

- A few task have been initially evaluated with workers at the site, including
  - Sampling in glove bags
  - PPE laundry
  - Manual excavation
- Workers complete surveys to assess perception of the devices

Exoskeleton Used: ☐ HeroWear ☐ BackX ☐ ShoulderX ☒ Noonee

ID#: _____

Date: 10-11-22

Tasks Performed and Duration Used (hours):

	(0-1)	(2-4)	(4-6)	6+
Crank Operator	☐	☒	☐	☐
Bag Operator	☐	☐	☐	☐
Seal Out	☐	☐	☐	☐
Lifting	☐	☐	☐	☐
Other 1: _____	☐	☐	☐	☐
Other 2: _____	☐	☐	☐	☐

How comfortable was the device throughout the day?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☒ ☐ ☐

1 10

How helpful or hindering was the device throughout the day?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☒ ☐

Hindering Neither Helpful

How easy was it to don, wear, and doff the device with PPE?

☐ ☒ ☐ ☐ ☐

Easy Neither Difficult

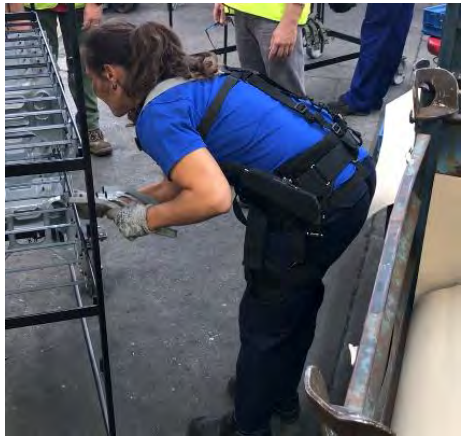
The device benefited: It was nice to step back and have a ~~bit~~ little sit down.

What was difficult to do with the device? No

Other comments: The straps on the chest harness had a lot of rubbing under the arms.

Pilot program survey results to date

- Four devices tested in various tasks
  - Noonee Chairless Chair
  - Back-X
  - Shoulder-X
  - Herowear Apex
- Workers complete surveys to assess perception of the devices



Number of instances*	Device	Comfort (1-10)	Hinder/Helpfulness (-4 to 4)	don/wear/doff ease** (-2 to 2)
7	Noonee	6.8	1.6	1.2
9	BackX	7.3	2.0	2.0
8	ShoulderX	7.7	2.3	0.4
14	HeroWear	8.3	1.9	2.0

Note:

*refers to the total number of survey responses, regardless of the number of questions answered.

**don/wear/doff numbers only available from Jan2023 visit

DOE-EM Testbed Activities

- Completed a study for tank farm workers wearing SCBA
- Three lower-body devices tested over several tasks in simulated shift
  - DEPHY Exoboot
  - Lockheed Martin ONYX
  - Noonee Chairless Chair
- Metabolics, kinematics, and subjective feedback recorded
- Survey results for two participants:

	Exoboot	Onyx	Noonee	No Exo
Comfort	1	4	2	3
Overall Helpfulness	1	4	2	3
Walking	1	2	4	3
Hand Dexterity Test	3	4	1	2
Weighted Walking	1	2	4	3
Weightlifting	2	4	3	1
Incline	1	3	4	2
Rest	2	4	1	3

	Exoboot	Onyx	Noonee	No Exo
Comfort	2	3	4	1
Overall Helpfulness	2	1	4	3
Walking	3	2	4	1
Hand Dexterity Test	2	3	4	1
Weighted Walking	3	2	4	1
Weightlifting	3	1	4	2
Incline	3	1	4	2
Rest	3	1	4	2