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Wearable Robotic Devices to Improve Worker Health and Safety

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U.S. DEPARTMENT OF ENERGY | Environmental Management

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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DOE-EM Mission Challenges

- Many of the most challenging EM sites/tasks remain to be assessed and remediated
- EM environments present unique hazards to workers
  - PPE protects workers from external hazards
  - Musculoskeletal and ergonomic hazards remain
- Due to task/environment complexity and variability, automation and even teleoperation are difficult
- Wearable robotics can augment and protect workers

Workshop Overview

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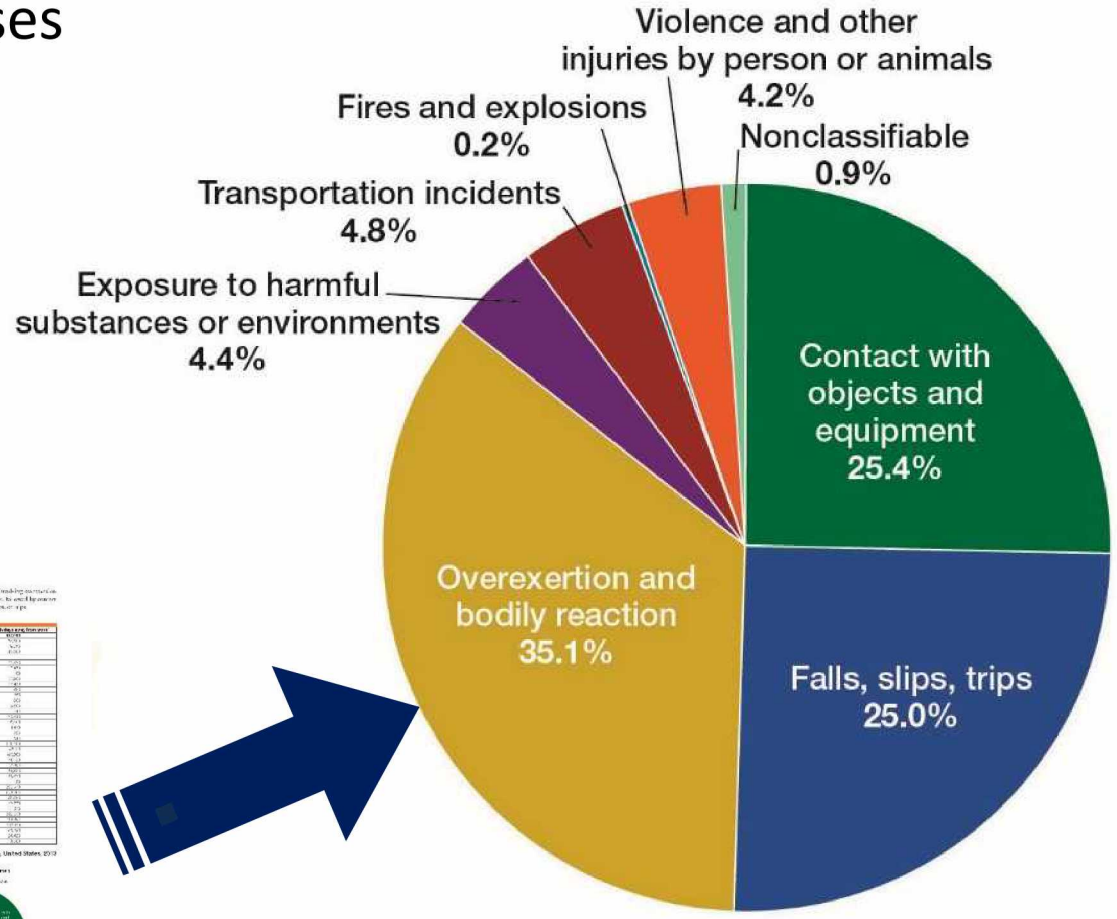
- Injury rates and types
- Potential Benefits of wearable robotics
- Overview of available or emerging devices
- Discussion of necessary development for wider viability
- Examples/demonstration of some existing technologies

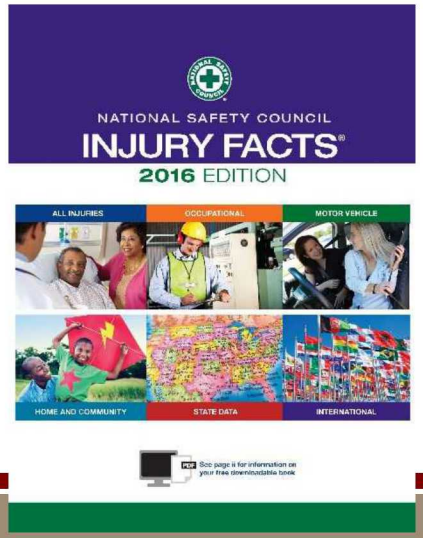
Personal Protective Equipment

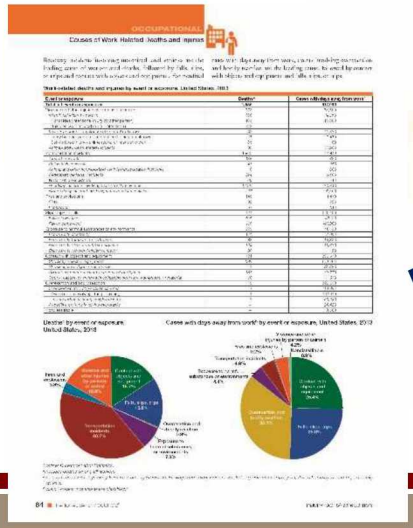
- Traditional PPE effectively protects workers from **external** hazards
  - Limits exposure to facility, task, or environmental hazards
- PPE does not protect workers from hazards to the musculoskeletal systems (**internal** hazards)

Preventing Internal Injuries

- United States injury cases resulting in days away from work

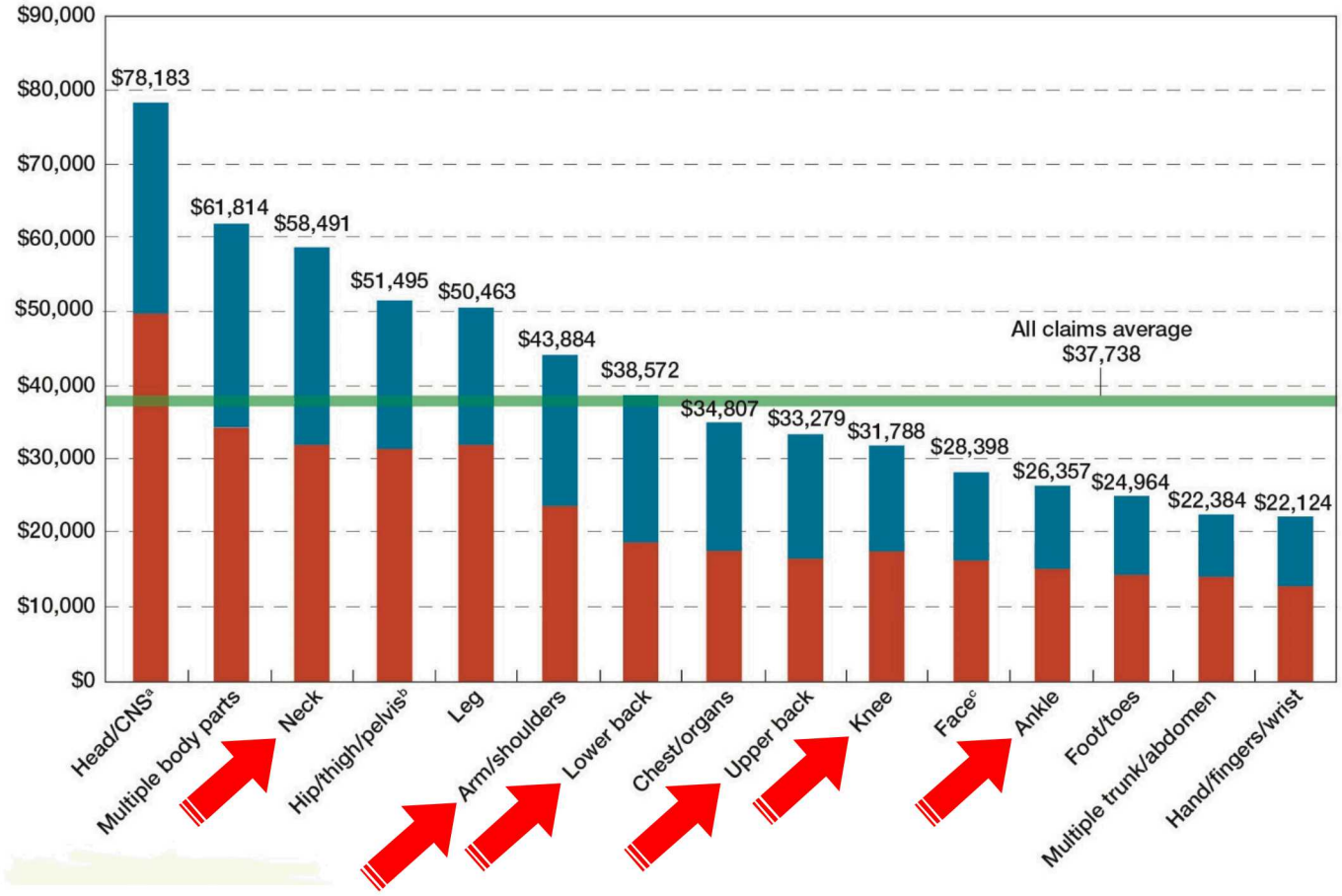


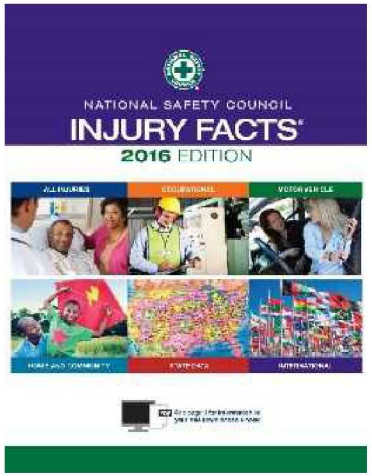




Financial Impact

- Costs by area of body affected

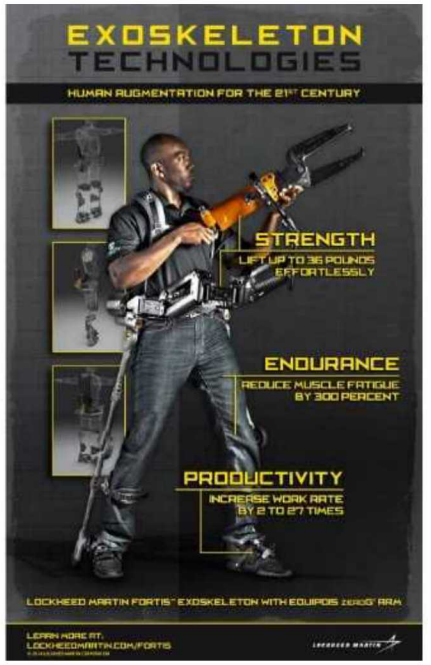




NCCI National Council on Compensation Insurance, Inc.

Robotic PPE

- For most jobs, we cannot simply remove the worker due to task complexity
- Wearable robotics have the potential to protect joints by providing support and augmentation
- If implemented properly, these devices can reduce rates of common musculoskeletal injuries
- Loads are transferred around specific joints to other body areas or the ground
- Could level playing field to allow workers of different ages, genders and sizes to perform more challenging tasks



State of Wearable Robotics Field

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- Wearable robotics have been in development for a few decades
- Early exoskeletons prototypes were complex, powered, multi-joint systems
- Recent, more practical efforts have focused on simpler, often passive systems
- A few systems for specific tasks are now commercially available
- More general systems are emerging

Emerging Application Areas

- Medical/Rehab
  - Powered assistive devices
- Factory/Assembly
  - Generally passive, joint support for repetitive tasks
- Construction/Retail
  - Tool offloading or ergonomics support
- Military
  - Pack offloading, strength/endurance enhancement

Examples of Exoskeleton Applications

Rehabilitation/ Mobility

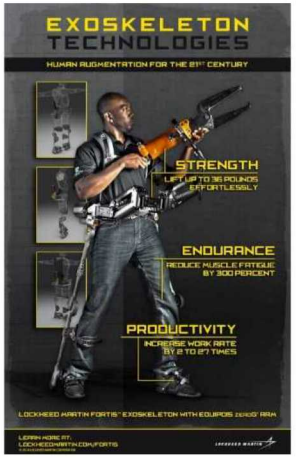
Ekso Bionics

SuitX

MIT Anklebot

Offloading

Lockheed Martin HULC, FORTIS

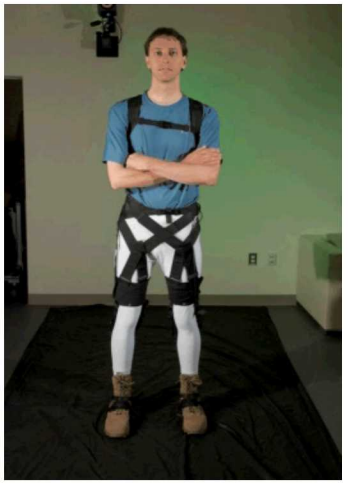


Full Body Augmentation

Cyberdyne HAL

Sarcos XOS

Soft/Conformal



Harvard Soft Exo

SRI Superflex

Tool Offloading Devices

- Transfer weight to ground through exoskeleton
- Worker must carry weight, inertia and friction of the device
- Neither device currently readily available for purchase

Ekso Works

Lockheed Martin Fortis

Arm Support Devices

- Offload arms/shoulders
- Generally used for persistent overhead work in factories
- Some devices commercially available

Levitate Airframe

Ekso Works Vest

ShoulderX

Back Support Devices

- Offload lower back for repetitive lifting
- Generally used in retail or industrial settings
- Some devices commercially available

BackX

Laveo V2

V22 Ergoskeleton

Leg Support Devices

- Strengthen or offload hip and/or knee
- Some devices commercially available

Chairless Chair

Hercule

LegX

Full-body Exoskeletons

- Provides augmentation to several joints
- Devices are still immature, emerging

Cyberdyne HAL

SARCOS Guardian XO

Emerging Wearable Robots

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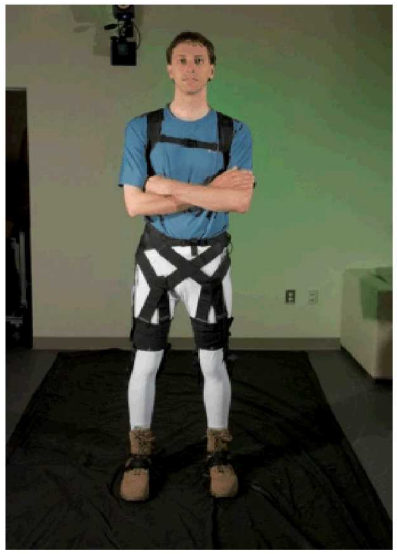
- A variety of other devices are in development and may become viable in coming years
- There is a movement towards soft, passive or quasi-passive, conformal systems



Example Application – DOE-EM

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  - PPE protects workers from external hazards
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Examples of EM Environments

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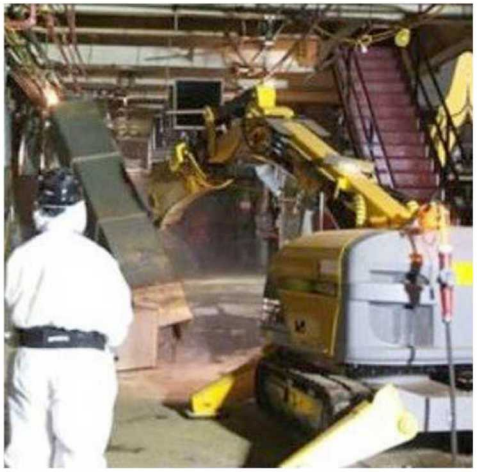

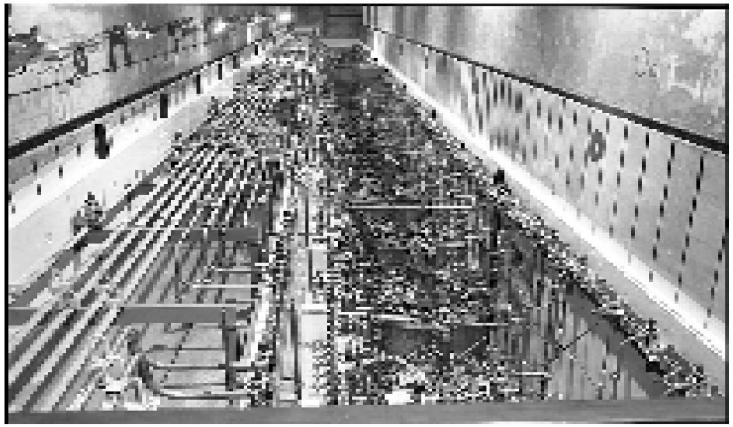

Examples of EM Worker Tasks

- Assessment, inspection, inventory
- Hot cell and glove box manipulation
- Maintenance and repair of equipment
- Demolition, disassembly, size-reduction
- Removal and/or loading of materials
- Emergency response operations
- Soil characterization and handling

Unique EM Wearable Robotics Drivers

- Musculoskeletal injuries are common across the complex
- EM Workforce is aging
- Level playing field for workers of different ages, genders, sizes
- Traditional teleoperation/automation approaches are difficult for many tasks/environments

Unique EM Wearable Robotics Challenges

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- Tasks are less repeatable than, e.g., factory assembly
  - Practical general-purpose exoskeletons are nascent at best
- Substantial mobility required for most workers
  - Weight, friction and inertia must be minimized
- Environments are challenging and variable
- PPE compatibility may be an issue
  - Can systems be decontaminated?

Adoption Issues and Challenges

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- These devices are still very new!
  - Limited testing data available
- Several practical issues must be considered
  - Sizing and fitting
  - Hygeine
  - Compatibility with traditional PPE
  - Ergonomics, effects on other joints
  - Risks and regulations
  - Donning/doffing time, breaks etc.
  - Comfort
  - Varying levels of worker acceptance
  - Etc.

Implications for USW

- These devices have potential to provide significant health and safety benefits if used properly
- Most existing devices are highly tailored to specific tasks
  - Less useful for worker who perform a variety of tasks
- Implementation is not trivial
  - Consider pilot programs to determine viability followed by larger-scale implementation
  - Worker buy-in and feedback essential
- Some devices may provide benefits now or soon
- Monitor emerging devices with more versatility