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Pilot Deployment and Testing of Exoskeleton Devices at the Hanford Site – 23168

Jason Wheeler *, Michal Rittikaidachar *, Kayle Boomer **, Theodore (Ted) Wooley **, Ron Calmus **, Mike Jones **, David Wood *, Divina Calderon *, Savannah Bradley ***
* Sandia National Laboratories
** Washington River Protection Solutions
*** Sandia National Laboratories / Arizona State University

ABSTRACT

Workers at the U.S. DOE's Hanford Site perform a variety of tasks in a uniquely challenging environment. Tank farm workers at the site are required to wear extensive personal protective equipment (PPE) while executing maintenance, sampling, and other tasks critical to the clean-up mission. The physical demands of this work can lead to acute and/or chronic fatigue, pain, or injury. Exoskeleton devices, largely developed for other industries such as manufacturing, construction, and retail, are becoming commercially available that may be able to reduce the risk of fatigue and injury to workers at Hanford and other nuclear waste management sites. For these devices to find utility in these environments, appropriate combinations of tasks and devices must be identified. Additionally, considerations unique to the clean-up community such as compatibility with PPE and contamination management must be carefully considered. In recent months, a pilot study of these devices at the Hanford site has begun to address these challenges. Four unique devices have been delivered to the site. Workers have begun testing the equipment and providing feedback on their experience. Initial feedback shows a wide range of opinions, including a few tasks and situations that hold promise for broader deployment.

INTRODUCTION

The U.S. Department of Energy's Office of Environmental Management (DOE-EM) is responsible for the cleanup of the country's nuclear legacy. The Hanford Site, in eastern Washington, represents one of the most challenging cleanup operations in the EM complex. A variety of complex cleanup operations are ongoing at the site including decommission of obsolete facilities, solid waste management and disposal, and maintenance of the underground tanks that store millions of gallons of liquid waste. Workers at the site must perform many physically challenging tasks, often while wearing substantial personal protective equipment (PPE) to protect them from external hazards. As with many other DOE-EM sites, the Hanford workforce is aging. This combination of factors creates a situation where musculoskeletal injuries are a consistent challenge. DOE-EM and Hanford site managers are committed to providing the best tools to reduce the risk of injury, fatigue, and pain to the workforce.

Figure 1: Tank farm workers at the Hanford Site performing maintenance work while wearing extensive PPE, including SCBA respirators.

In recent years, exoskeleton devices have begun to be used in a few industrial settings to reduce strain on workers' muscles and joints. An exoskeleton is a device that is worn by a person and provides support or force to assist the wearer or transfers a load from one body area to another. Exoskeletons can be active (powered with motors, batteries, etc.) or passive (using only springs and unpowered mechanisms). While both active and passive devices are becoming available, passive devices are far more common in industrial settings due to lower cost, weight, and maintenance. To date, exoskeletons have been deployed primarily in manufacturing, construction, and retail settings, and have found the most utility when worn by workers performing highly repetitive tasks. Work at Hanford and other nuclear waste management sites has some commonalities with these industries, along with some important differences. In particular, the contamination and associated PPE present at Hanford require careful consideration when introducing any new technology. A wearable device will need to be compatible with the PPE, and if worn outside the PPE, may need to be decontaminated. Additionally, work at the Hanford site tends to be more complex and diverse that that often found in manufacturing or constructions settings.

To begin to understand if and how exoskeleton devices may benefit workers at the Hanford site, a pilot study of several commercially available devices was recently kicked off. This effort is a collaboration between Washington River Protection Solutions (WRPS) and Sandia National Laboratories (SNL), with support from DOE-EM's Office of Technology Development and has the potential to determine how well the current state of exoskeleton technology meets the needs of Hanford and other DOE sites. Not only can potential deployment opportunities be identified, but the limitations of the technology can also be clearly identified, so that future iterations are better suited to the nuclear cleanup community's needs.

METHODS

Like most tools, an exoskeleton device may provide some benefit to a worker but may also impose some new challenge or limitation. In the case of wearable devices, additional weight and encumbrance may be imposed on the user, and time and effort are required to don and doff the device. The device's benefits must outweigh these impacts if it is to be beneficial. Direct feedback from the workforce is an irreplaceable way to better understand these trade-offs. Due to different jobs, body types, and perspectives on technology, it is anticipated that a range of opinions will be evident. In the following sections, we describe the delivery, demonstration, and initial testing of four wearable devices at the Hanford site to collect direct feedback from workers.

Exoskeleton Devices

Four commercially available devices were delivered to the Hanford site by SNL (Figure 2). SNL had previous experience with these and other devices and recommended these four exoskeletons as good candidates for initial evaluation based on site tasks, cost, and availability. The following devices were part of the pilot study:

- Back-X (SuitX, Emeryville, CA), a passive device that assists bending and lifting. When the person bends forward, a spring is loaded that can then restore that energy as the person returns to an upright position. The device can also be used to offload lower back muscles if a person is bent forward for an extended period.
- Apex (Herowear, Nashville, TN), another passive bending and lifting assistive device. The intended functions are similar to those of the Back-X, but the Apex uses bands behind the person to store energy and interfaces to the user with all soft components.
- Shoulder-X (SuitX, Emeryville, CA), a passive shoulder support device. A spring near the shoulder can support the weight of the arms for a person who is working overhead or with arms extended for long periods.
- Chairless Chair (Noonee, Wendlingen, Germany) a passive leg exoskeleton that allows the

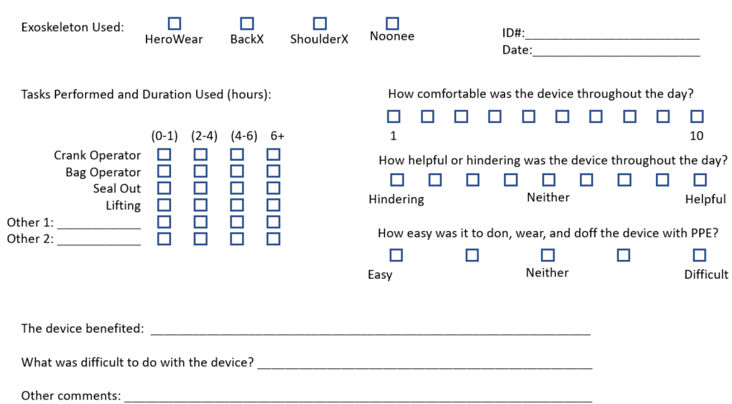
person to sit at various heights on demand.

Each device, including proper sizing and fitting, was demonstrated to workers and managers at Hanford prior to the study.

Figure 2: Exoskeleton devices deployed at Hanford site, from left to right: Back-X, Herowear Apex, Shoulder-X, Noonee Chairless Chair

Pilot Testing

Several workers tried on one or more devices during the initial demonstrations and provided informal feedback. To gather more complete data about the utility of the devices in realistic work scenarios, pilot testing was completed in both cold (non-radiation) and hot work environments. A questionnaire (Figure 3) was developed that each person who used a device would fill out after completion of a task with an exoskeleton. The worker would indicate which tasks they were completing in addition to how they felt about the comfort and helpfulness of the device. The specific tasks listed are based on the specific group of workers initially tested, who specialize in sampling operations performed in glove bags (plastic enclosures with sealed glove ports) on the tank farm. As of October 2022, a total of 15 unique individuals tried on at least one device and five of those tried more than one device in a cold area. Initial testing of a small number of workers in hot areas also occurred (Figure 4) and more detailed feedback is being collected over a longer period to better understand the practical issues and challenges associated with real work situations.



Exoskeleton Used: ☐ HeroWear ☐ BackX ☐ ShoulderX ☐ Noonee

ID#:____________________
Date:____________________

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: ______________________________

What was difficult to do with the device? ________________________

Other comments: ______________________________

Figure 3: Questionnaire filled out by each user of an exoskeleton device at Hanford.

Figure 4: Initial deployment of an exoskeleton (Chairless Chair) in tank farm sampling operations.

RESULTS

Questionnaire results from the 15 workers who tried an exoskeleton in the cold work areas are shown in Table 1. A total of 26 responses were provided because some individuals wore more than one device. As can be seen from the responses, the aggregate perceptions were generally positive, with both comfort and helpfulness being rated above neutral for each device. It is worth noting that individual responses varied widely, with responses across the entire available scale.

Table 1: Questionnaire responses from initial testing of four wearable devices at the Hanford site.

Device	Average Comfort Rating (1-10)	Average Hinder/Helpfulness Rating (-4 - 4)	# of Responses
Noonee	7.2	2.0	5
BackX	6.7	2.1	7
ShoulderX	7.2	1.4	5
HeroWear	8.3	2.9	9

CONCLUSIONS

Workers in nuclear waste management jobs have uniquely challenging jobs that put them at risk of musculoskeletal injury, and they deserve the best tools to protect themselves. Exoskeletons, while still a relatively new technology, are becoming available that may reduce fatigue and injury risk. For these to find utility in the field, feedback from workers is essential. The present work describes an initial attempt to deploy and gather feedback about four commercial exoskeletons in a nuclear cleanup environment. While initial feedback about the devices has been generally positive, further work is ongoing to determine appropriate tasks and devices, ensure compatibility with PPE and decontaminability, and ensure reliability. Additionally, the pilot program is expanding to other work groups at Hanford and elsewhere in the DOE-EM complex. We anticipate that this work will identify novel applications of this technology that can improve job quality, while also identifying limitations in the current state of the technology that can be improved in future iterations.

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