STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Contributing to the DOE EM-3.2, Office of Technology Development: Dashboard / Wearable Technologies Database

DOE-FIU SCIENCE & TECHNOLOGY
WORKFORCE DEVELOPMENT PROGRAM

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EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the U.S. Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2021, a DOE Fellow intern Josue R. Estrada Martinez spent six weeks as a summer internship at DOE-EM Germantown, Maryland, office under the supervision and guidance of Jean Pablo Pabon Quiñones. The intern's project was initiated on July 18, 2021, and continued through August 27, 2020, with the objective of completing tasks relating to two projects under DOE-EM Office of Technology Development.

1. INTRODUCTION

This technical report consists of a description of Mr. Josue Estrada's contributions to two projects developed at the U.S. Department of Energy's Office of Environmental Management (DOE-EM) as part of an internship during the summer of 2021, as well as the practical application and further work that can be performed on these projects. Both projects were done under the mentorship of employees from the DOE-EM Office of Technology Development Headquarters and from the Sandia National Laboratory.

The first project aims to improve upon the Office of Technology Development's reporting and accountability to upper management by developing a dashboard as a data visualization tool, displaying relevant information about the projects overseen by this office. Mr. Estrada's contributions to this project includes kickstarting the development of this visualization tool by designing the structure of the data display, the interactivity of the data, and the methods for transferring these data from the EM field offices and contractors to the dashboard.

The second project aims to aid the implementation of exoskeletons and other wearable technologies in DOE-EM field sites and projects by expanding on Sandia National Laboratory's existing inventory of such technologies. In this project, Mr. Estrada contributed by creating a searchable database which included the existing inventory and new additions to these, as well as researching possible issues regarding the interface of wearable technologies and personal protective equipment, when both are being used simultaneously.

2. RESEARCH DESCRIPTION

2.1 Office of Technology Development Dashboard

The Technology Development Office (TDO) is currently developing a dashboard that will allow research and development (R&D) to be more transparent across the DOE complex. The TDO dashboard will capture all the technology and development activities managed by EM Headquarters and will display relevant data about projects. The goal is to provide more visibility of EM technology development activities, projects, and funding for DOE senior management.

TDO will work with an Information Technology contractor, which will develop and maintain this dashboard in Microsoft Power BI, the interactive data display platform selected for this project. To achieve this, TDO must determine and communicate to the contractor the type of data that needs to be displayed, the graphs that will represent these data, the layout of such graphs and the overall structure of this dashboard. Moreover, TDO must decide and indicate the methods of data retrieval, or the flow of the data from the contractors, laboratories, and universities that carry out the projects to the database from which the dashboard is sourced.

The first contribution to this project was selecting which method of data retrieval suited the situation best. One method that had been initially considered consisted of sourcing the data from the reports that these field offices already provide periodically. Figure 1 shows the flowchart of the data in this method. In this alternative, the contractor would receive these reports and manually identify and extract the relevant data that is required for the dashboard. This method however, presented a few issues, the main one being that due to the diversity in the type of work done by these three kinds of entities, the types of reports received are not uniform. This meant that the contractor would have to manually review reports that vary in style, format, and even reporting schedule and periods, and look for data which, in some cases, is not even present in these.

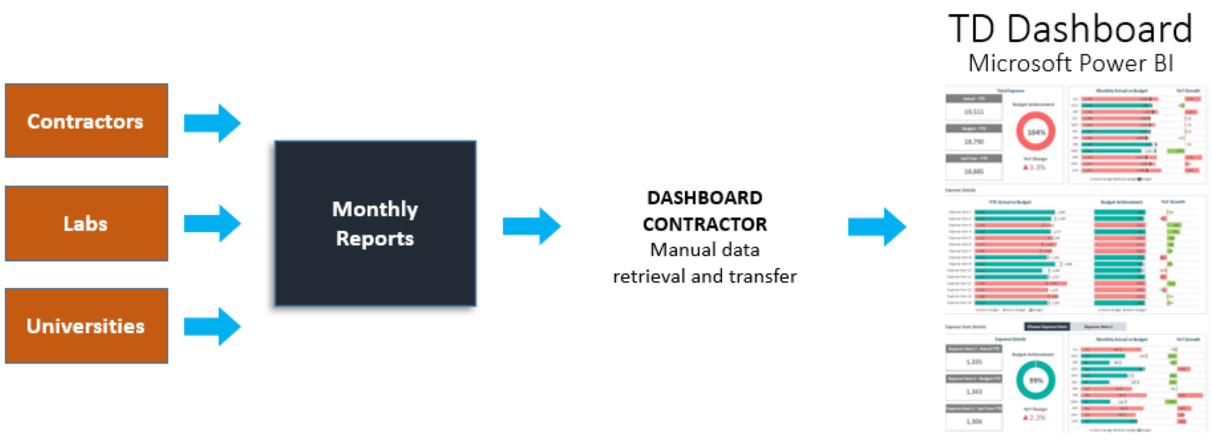

Figure 1. Data retrieval method considered initially.

TDO and the intern proposed an alternative method of data retrieval that utilizes an already existing reporting tool, the Integrated Planning, Accountability, and Budgeting System (IPABS). In this proposed option, the contractors, laboratories, and universities continue to report monthly (or in other periodical intervals) using their current format. However, besides providing these reports, these entities working at the sites are requested to access the IPABS and fill out a specific form which includes the relevant data needed for the dashboard's display. A flowchart of the data in this method is shown in Figure 2. The main benefit of this alternative is that the transfer of data from IPABS to the dashboard can be automated. This automation has been done previously by the contractor for another office in DOE-EM, which brings TDO confidence in this option. This method also increases the standardization of reporting by contractors, laboratories, and universities, which would now be required to break down their projects into tasks with milestones for status reporting purposes.

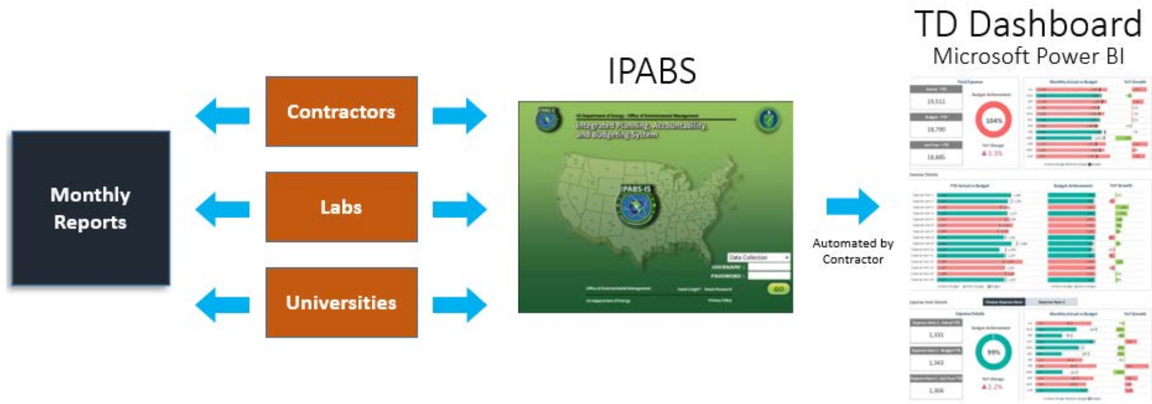

Figure 2. Proposed data retrieval method.

The intern's next contribution to the dashboard project was creating a conceptual design that presents the display pages and structure, the data that will be reflected, and the graphs that will be utilized. All these considerations were based on the requirements laid out by TDO.

The structure of this conceptual design is based on two kinds of display pages. The first of these shown in Figure 3 (which uses sample hypothetical data) is the office overview page. This page encompasses all the projects carried out by the TDO. It includes a breakdown of the distribution of the budget and makes the distinction between budget allocated for Congressionally-appointed, earmark projects, non-earmark projects, and the remaining budget to be targeted. For each of these projects, this page displays the percentage of the allocated budget which has been disbursed as of the date when the dashboard is viewed. These project overviews are color coded to visibly distinguish which projects are on the targeted schedule (displayed in green), and which are behind schedule and/or over-budget (displayed in yellow and red).

The Microsoft Power BI platform allows for interactivity in the display. The TD dashboard will take advantage of this feature by allowing the viewer to click on any of the projects shown in the overview page, which will take them to the second page, or the individual project breakdown. Figure 4 shows this project breakdown level, which goes more into details about each project. This display includes a brief project description that includes the name(s) of the primary investigator(s), their comments regarding the status of the project, and the focus areas as they relate to the Office of Technology Development framework. This page displays a more detailed breakdown of the budget disbursement through the months and quarters throughout the fiscal year, and a project roadmap that breaks down the scope of the work into milestones with projected end dates, as well as information on whether these projections stand or the project is running behind schedule.

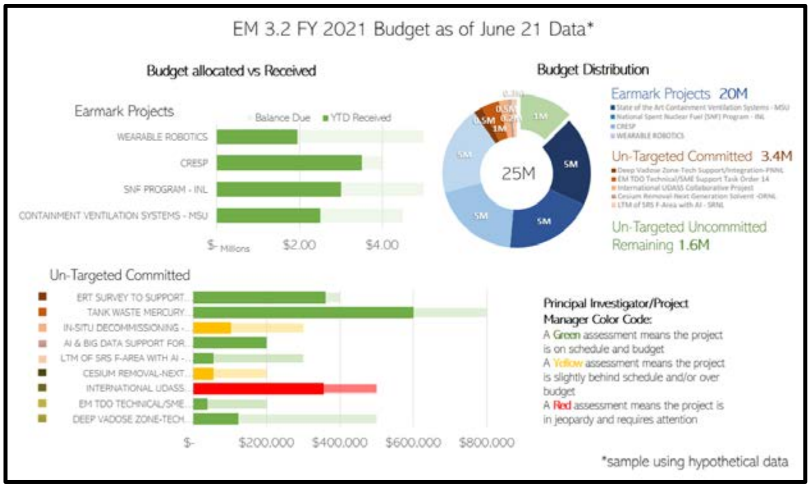

Figure 3. TD Dashboard conceptual design (Hypothetical Data): Overview display.

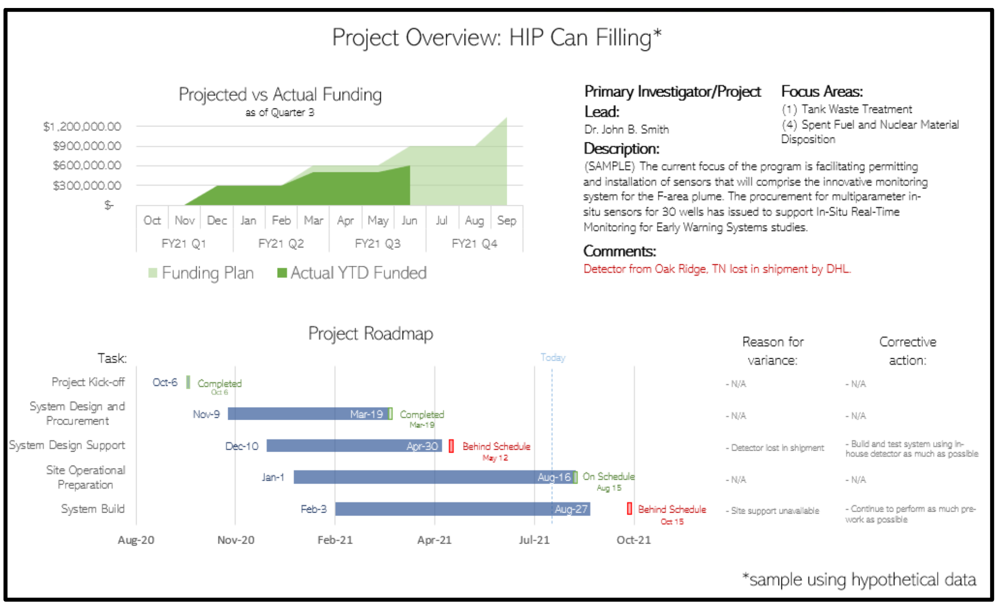

Figure 4. TD Dashboard conceptual design (Hypothetical Data): Project display.

The intern presented this conceptual design to Nicole Nelson-Jean, Associate Principal Deputy Assistant Secretary for Field Operations (EM-3 APDAS), at a briefing during which she approved of the conceptual design, brought up questions to ask the contractor (Accenture Federal Services) about tentative dates and scope of the implementation of the dashboard, and decided upon follow-up actions.

After meeting with EM-3 APDAS, the intern presented the design in a meeting with the contractor during which TDO and the contractor reviewed the concept design and the proposed methods for gathering the data from the contractors, National Laboratories, and universities. At that point, TDO clarified the contractor's questions about the specific sources for each of the data. The Office of

Technology Development's dashboard is still in develop and is targeted for deployment in the next fiscal year (FY22), and will serve as a sample model that can be applied to other offices in the future.

2.2 Database of Wearable Technologies

The DOE-EM's Office of Technology Development leads a project that seeks to implement existing exoskeletons and other wearable technologies at DOE-EM sites, as well as develop such new technologies for specific tasks in DOE-EM projects. The goal of this project is to alleviate the strain of repeated physical work and to prevent short- and long-term negative effects due to activities such as heavy lifting and overhead and repetitive movements.

As part of this project, the Sandia National Laboratory developed an inventory of existing public-domain exoskeletons and wearable technologies on the market as a baseline for selection and reference. The intern's first contribution to this effort was to include this inventory in a new database using Microsoft Access. This platform was selected due to the ease of its interactive functions such as searching and filtering. Figure 5 shows this Access database, which includes fields for reference including the cost of the product, the intended consumer type, the tasks that can be assisted by the technology, the type of actuation (active vs passive) and contact information for the developer company.

tbl_Main

ID	Company	Device Name	Consumer	Cost	Body	Tasks	Actuation	Email	Link	Year
13	Hyundai	HUMA	Public		Legs	Facilitate walking, running, or going up a	Active		https://www.hyundaimotorg	1967
14	Hyundai	Walking Assist	Public		Legs	Facilitate walking with additional force	Active		https://www.hyundaimotorg	1967
15	Comau	Mate	Industrial		Arms	Upper body activities	Passive	ROBproducts@	https://www.comau.com/en	1973
16	Daiya	Daiya Glove	Industrial		Hands	Grip assistance	Active		https://www.daiyak.co.jp/pr	1978
17	Sarcos	Guardian XO	Industrial		Full Body	Reduce the risk of occupational injury, i	Active		https://www.sarcos.com/prc	1983
18	CyberGlove Sytems LLC	CyberGrasp	Industrial		Hands	Grasp simulated 3D models	Active		http://www.cyberglovesyste	1990
19	CyberGlove Sytems LLC	CyberForce	Industrial		Hands	Sense 3D models	Active		http://www.cyberglovesyste	1990
20	CyberGlove Sytems LLC	CyberTouch	Industrial		Hands	Interact with simulated objects	Active		http://www.cyberglovesyste	1990
21	CyberGlove Sytems LLC	CyberGlove	Industrial		Hands	Hand movements to joint-angle data	Active		http://www.cyberglovesyste	1990
22	Lockheed Martin	FORTIS	Industrial	7149.00	Hands	Decrease tool weight	Passive	4.LMparts@lmc	https://www.lockheedmartin	1995
23	Mawashi	UPRISE	Military		Back	Redirects load weight to ground	Passive	info@mawashi.	https://www.mawashi.net/e	1997
24	RB3D	Hercule	Industrial		Legs	Strength assistance	Active		https://www.rb3d.com/en/e	2001
25	Atoun	ATOUN Model Y	Industrial		Back	Picking up and lifting	Active		http://atoun.co.jp/powered-	2003
26	Cyberdyne	HAL Lumbar Type	Industrial		Back	Support	Active		https://www.cyberdyne.jp/e	2004
27	Cyberdyne	HAL Single Joint	Public		Legs	Assistive force to knee or ankle	Active		https://www.cyberdyne.jp/e	2004
28	Cyberdyne	HAL Lower Limb Type	Public		Legs	Imrpove lower limb function	Active		https://www.cyberdyne.jp/e	2004
29	Ekso Bionics	Ekso Vest	Industrial	6000.00	Arms	Chest to overhead activites	Passive	customerrelatic	https://eksobionics.com/eks	2005
30	Bioservo	Ironhand	Industrial		Hands	Grip assistance	Active		https://www.bioservo.com/	2006
31	Bioservo	Carbonhand	Public		Hands	Grip assistance	Active		https://www.bioservo.com/	2006
32	Bioservo, NASA	RoboGlove	Industrial		Hands	Strength and stamina	Active		https://technology.nasa.gov/	2006
33	BionicPower	PowerWalk	Military		Legs	Kinetic energy harvester	Passive		https://www.bionic-power.c	2007
34	SuitX	shoulderX	Industrial	4000.00	Arms	Overhead activities	Passive	sales@suitX.cor	https://www.suitx.com/shou	2011
35	SuitX	backX	Industrial	4000.00	Back	General movement	Passive	sales@suitx.cor	https://www.suitx.com/back	2011
36	Stronarm Tech	FLX ErgoSkeleton	Industrial		Back	Lifting and postural support	Passive		https://www.strongarmtech.	2011
37	Stronarm Tech	V22 ErgoSkeleton	Industrial		Back	Lifting and postural support	Passive		https://www.strongarmtech.	2011
38	SuitX	LegX	Industrial	5000.00	Legs	Strength assistance	Active	sales@suitx.cor	https://www.suitx.com/legx	2011
39	Exhauss	Exhauss Reliever	Industrial	7000.00	Arms	Overhead activities	Passive	contact@exhau	http://www.exhauss.com/pd	2012
40	Exhauss	Exhauss Hanger	Industrial	7000.00	Arms	Hanging items	Passive	contact@exhau	http://www.exhauss.com/pd	2012
41	Exhauss	Exhauss Transporter	Industrial	7000.00	Arms	Carrying Tools	Passive	contact@exhau	http://www.exhauss.com/pd	2012
42	Exhauss	Exhauss Upper	Industrial	7000.00	Arms	Picking up	Passive	contact@exhau	http://www.exhauss.com/pd	2012
43	Exhauss	Exhauss Worker	Industrial	7000.00	Arms	Handling tools	Passive	contact@exhau	http://www.exhauss.com/pd	2012

Figure 5. Wearable Technologies Database.

The intern used Microsoft Access' query features to design a form that allow users to easily interact with the database (Figure 6). The first of these is a New Entry form that facilitates the inclusion of new entries to the database. This form can also be used to edit and update previous entries. Additionally, the intern created a search form that will allow users to reference the database and find the appropriate wearable technology based on their requirements, including maximum cost and personal protective equipment (PPE) required for the task.

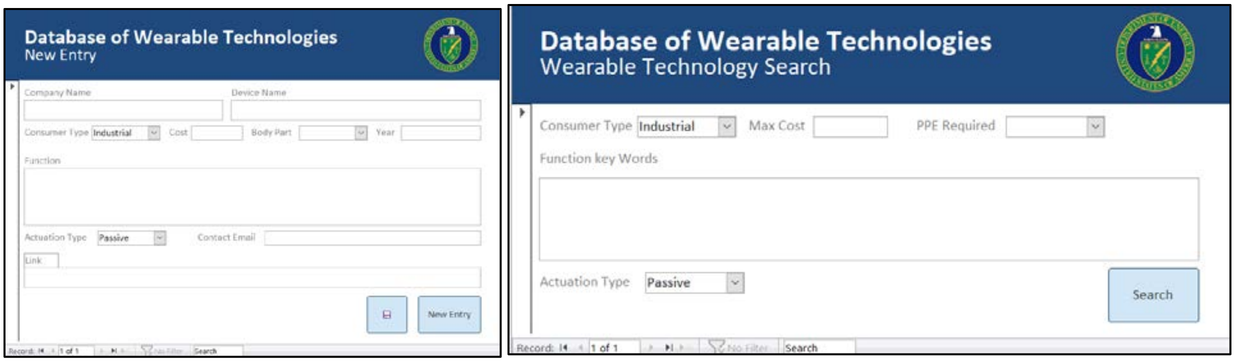

Figure 6.: Wearable Technologies Database: Entry and Search Forms.

2.3 Wearable Technologies and PPE Interfacing Research

The intern contributed to the wearable technologies program by conducting research on possible issues regarding the compatibility of wearable technologies with PPE. Given the nature of the work, many projects at DOE-EM sites, including those targeted by the wearable technologies project, require the use of PPE, including gear ranging from impact-protection helmets to full-body HAZMAT suits. In many cases, these PPE overlap with the body part covered by the wearable technology which can cause either of them to fit incorrectly. For both PPE and wearable technologies, proper fit is a crucial requirement for proper function. Even if both the PPE and wearable fit correctly, their joint use can present unexpected challenges.

While conducting this research, the intern found and attended a virtual Roundtable about integration of Exosuits and PPE, conducted by the American Society for Testing and Materials (ASTM) Exo Technology Center of Excellence. This discussion included leaders in the Exosuits, PPE, and Standards and Testing industries, and covered topics including current developments, challenges, testing methods for integration of wearable technologies and protective equipment, and challenges in standarization and testing. The intern took notes summarizing the topics discussed and conveyed them to the Sandia National Laboratory team and the Technology Development Office.

3. CONCLUSION

This internship provided an excellent opportunity for professional development and exposure to the management side of the Department of Energy's Office of Environmental Management. It gave the intern an overview of the workings of DOE-EM at the headquarters level, including understanding roles, requirements and process of managing budgets and the reporting to DOE senior management and all the way to Congress. The projects carried out familiarized the intern with the administrative structure of the Office of Environmental Management and Federal work in general. The projects worked on during this internship will serve the Office of Technology Development in the future and assist their objective of advancing technologies that assist EM in selecting approaches to resolve the technical challenges facing EM's cleanup mission.

APPENDIX A: ROUNDTABLE NOTES

Exo-Technologies and PPE Interface Challenges
ASTM Exo Technology Center of Excellence Roundtable
August 11, 2021

Panelists:

- Kalavati Bhashyam, Director of Product Management at Harmonic Bionics
- Karola Hagner, Senior Executive at Bundeswehr
- Tricia Hock, Director of Certification Operations at Safety Equipment Institute
- Phillip Mattson, Senior Standards Advisor and DHS Standards Executive
- Brian Shiels, Senior PPE Engineer, ArcWear
- Moderator: Dr. William "Bill" Billotte, Director of Global Exo Technology Programs and the Executive Director of the ASTM Exo Technology Center of Excellence

Summary:

1. Current Status of Exo Suits (Exos) and PPE integration
The big question is PPE over or under exoskeleton.

Example: Bundeswehr's current development efforts involve use of exoskeletons for situations that require chemical, biological, radiological, and nuclear (CBRN) protection. These situations usually use impermeable-type suits with respirator and an air tank. They are developing new suit concept that integrates exoskeleton with a hybrid suit (Skeleton underneath).

Pros of Exos under PPE suits:

- Decontamination: In case of CBRN contamination, Exos remain contamination-free, and PPE is discarded. If Exo does get contaminated (chemically) it must be resilient to decontamination process, including sanitization with soap and water all the way to vaporous hydrogen peroxide.
- Exposed soft Exos are liable to encapsulation. Where contamination is permanently locked in the fabric.

Cons of Exos under PPE:

- Exo Failure in hazardous environments can be complicated. Some situations could require user to remove PPE before removing Exo.
- Possibility of excess heat inside PPE, especially for Exos that have active power or heat generating parts and inside insulated full body PPE suits. However, through testing, you can take into account the reduction in task-related body heat due to the Exo's assistance. (for example, NC State University's: Protection and Comfort Lab through human and instrumented mannequin tests measures respiration rate, skin temperature, core body temperature. Firefighter turnout gear, hazmat clothing. These tests can be performed on a subject with EXO.

Other Challenges of integration:

- Wearing an Exo suit might add difficulty to emergency exiting.
- Added hazards. If the PPE is flame resistant. Is the Exo heat resistant? Is it going to melt and damage the user more?
- Aesthetics and public perception for some applications. Nurses in a survey voted to not use exoskeleton technologies which could make patients uncomfortable. Law enforcement requires a certain recognizability for the community they are trying to serve
- There is a current lack of standards and test methods for integration of Exos and PPE. Do you test PPE and Exo separately, full ensemble, or multi ensemble? This boils down to each specific application.

2. Testing and Standards Development

If the technology is in rapid development, setting an arbitrary performance bar might hampering development. Thus, user interest requirements and performance specifications should drive R&D. Lab benchmark tests can be supported by user reports and feedback.
What performance specifications might look like:

- Hard minimum performance value to determine success, or
- A classifications system. (For example, in case of an emergency exiting, is an emergency exit any harder with than without the exo? 10% slower? 20% slower) to determine tradeoffs.

Challenges of Testing and Standards:
Exo integration alterations to PPE products will void certification. PPE manufacturing fit and wear guide should include guidelines for integration.

Some existing PPE standards can be applied to Exos. Other specific ones related to injury prevention would have to be created.

Exoskeletons test methods and training for their use with PPE. PPE not worn correctly is ineffective. Training of PPE use with Interface with Exoskeleton is required. To develop training standards, a terrain test can be performed, where user must walk through a difficult terrain or work environment. Compare expert performance versus new user and determine how much training is needed to have new user perform like expert.

3. Exoskeletons as PPE

Are Exos a "smart textile", a tool, a medical device, or PPE? Some of these names have Implications as far as regulation policy, testing. It is important what we call them. How do regulations come into play when we determine exoskeletons as PPE?

Toyota NA has used Exoskeletons as part of their ergonomic programs to prevent muscular disorders, strains, and soft tissue injuries. DOW Chemical has used exoskeletons as part of risk mitigation equipment.

Self-certification vs 3rd party certification:
The PPE community understands the need for third party certification. If a skeleton were classified as PPE, would it require third party certification? It is cleaner (better auditing) and gives the user confidence when it is third party-certified.

In the US you have organizations OSHA and NIOSH which determine that if PPE is required for the type of work being done (Primary Hazard) the company must provide it. Injury prevention can thus be considered a secondary hazard. Priority of integration is that the Exo does not interfere with primary hazard protection.

Other requirements: That the exoskeleton does not increase the heat load. To measure this, Bundeswehr is developing a physiological biometric monitoring system as part of their exoskeleton and impermeable suit.

4. Audience Questions

Q. What is the difference between a medical lower body active Exoskeleton vs a military lower body Exoskeleton?
A. The movement and support you want from exoskeleton is totally different: Medical application requires precise and small towards rehabilitation. The military ones require jumping and running and other movements. Medical Exosuits are mostly designed for short therapy sessions while military ones are intended for prolonged periods.

Q. What metric is to be used to determine that Exo is fitted well?
A. Depends on Range of motion of the task performed, how much pressure should be in the fitting when attaching to the person or clothing, and finally, comfort.

Q. At what point does the customization impact the performance of the Exo:
A. We don’t know yet. Both Exo and PPE performance could be impacted but PPE is always the priority.

Closing remarks:
We need test methods and performance requirements. End users and stakeholders need to be involved to set these performance requirements. The community needs to work together.