

# Wearables and Robotic Facility Mapping for Worker Safety



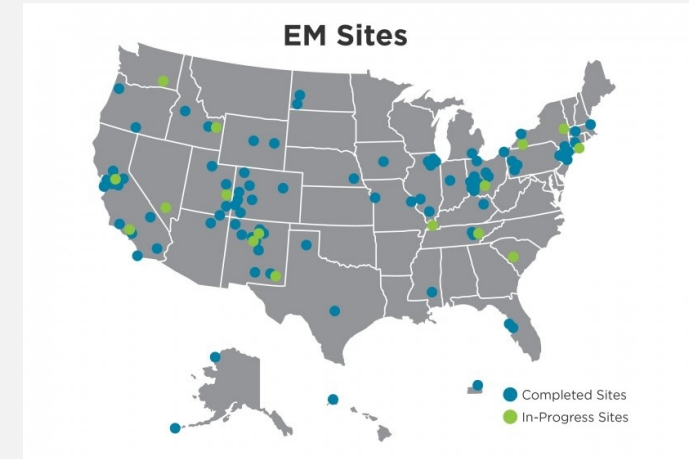
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Jason Wheeler, Distinguished R&D Staff, Advanced Field Operations & Robotics

[jwwheel@sandia.gov](mailto:jwwheel@sandia.gov)

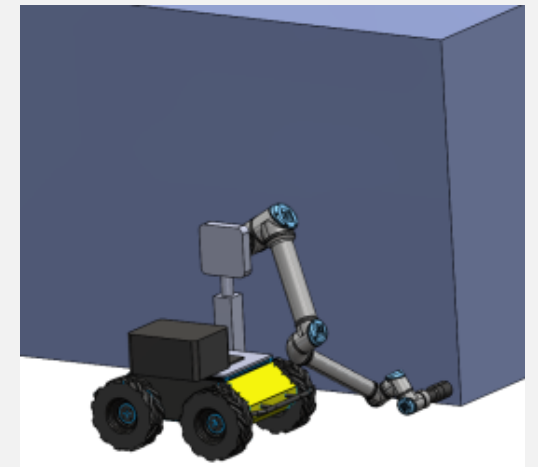
# US DOE Office of Environmental Management

- DOE-EM is responsible for managing and remediating the US nuclear waste legacy, including
  - Processing and storing waste
  - Mitigating environmental impacts
  - Decommissioning of obsolete facilities
- Sites are scattered across the country and have unique challenges
- Much of the simple work is complete, the most challenging work remains
- Workers perform many dull, dirty, or dangerous tasks
- The workforce is rapidly aging



# Sandia Labs Robotics for DOE-EM

- Wearable robotics for worker safety
- Robotic tools for small pipe inspection at Hanford
- Automated NDA of waste containers
- Data modernization or rock bolt monitoring at WIPP
- Robotic site characterization and mapping at Oak Ridge and WIPP



# DOE-EM Wearables Activity Highlights

Field Eval/  
Deployed COTS  
(TRL 7-8)

Lab Eval & Device  
Customization  
(TRL 4-7)

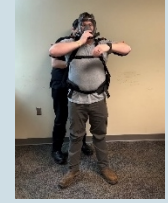
Novel Tech  
Dev/Biomechanics  
(TRL 2-4)



Field testing of COTS exos



Routine use of back/shoulder exos



Field testing of COTS for D&D



Device user surveys



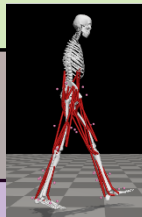
Hanford shoveling and tank farm studies



Glovebox exo testing



Biomechanical testing of exos



Developing insole for testing



Developing glovebox exo



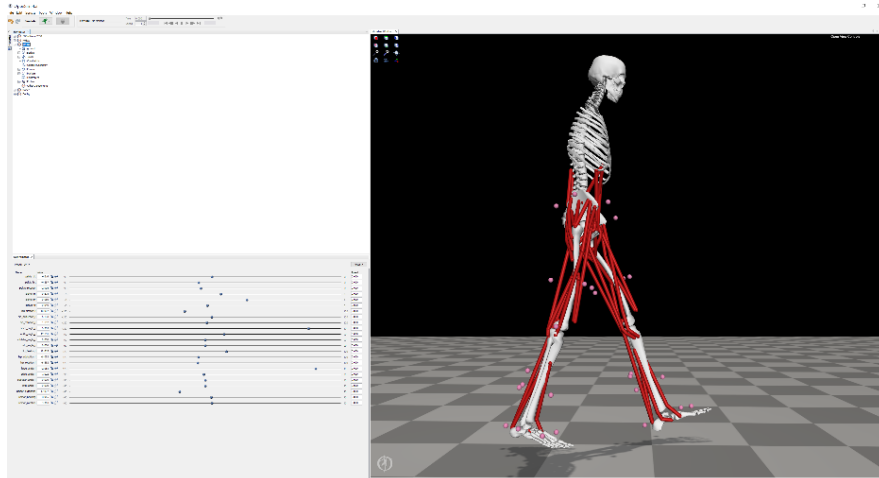
Developing powered lower-body exo





# 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
- Two studies completed for Hanford



# Work Planning for Decommissioning

- Deactivation and decommissioning (D&D) operations at DOE-EM sites requires careful planning
- Facilities are often unsafe for personnel to enter
  - Some prohibited, others require extensive PPE which results in risks and high costs
- If a facility can be realistically mapped, work planning can potentially be done virtually in a safe environment



# Imaging Tools for Facility Mapping

- Several nascent commercial tools are available that can map the imagery and/or geometry of facilities
- 3D imaging tools are widely available
- LiDAR system can overlay geometric information with RGB imagery
  - Stationary sensors for high resolution in smaller areas
  - Mobile sensors running SLAM for large areas



Leica BLK360



Exyn Nexys

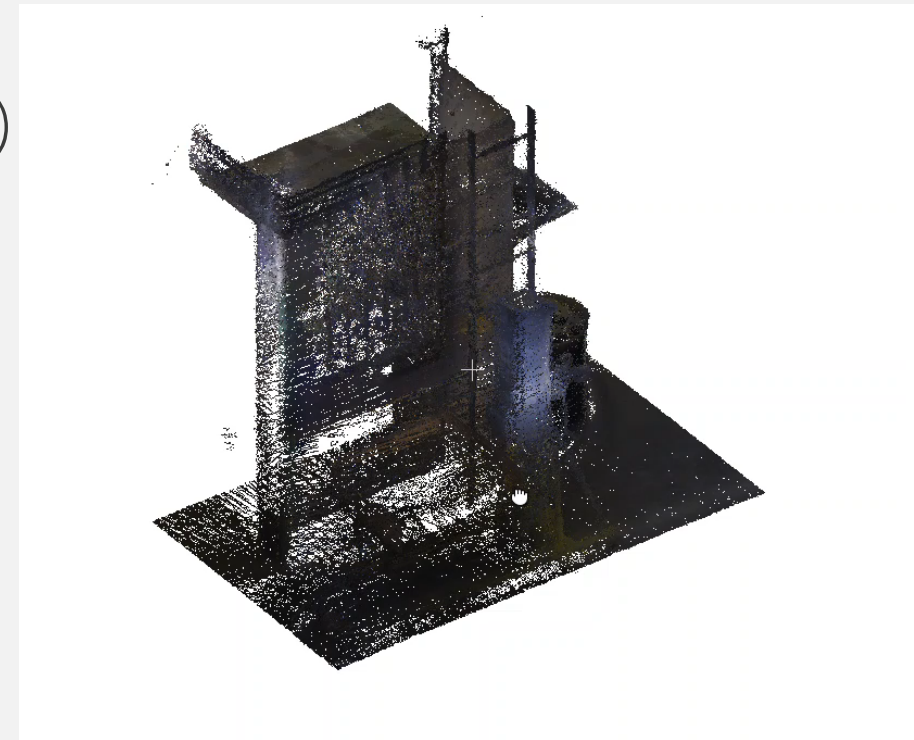
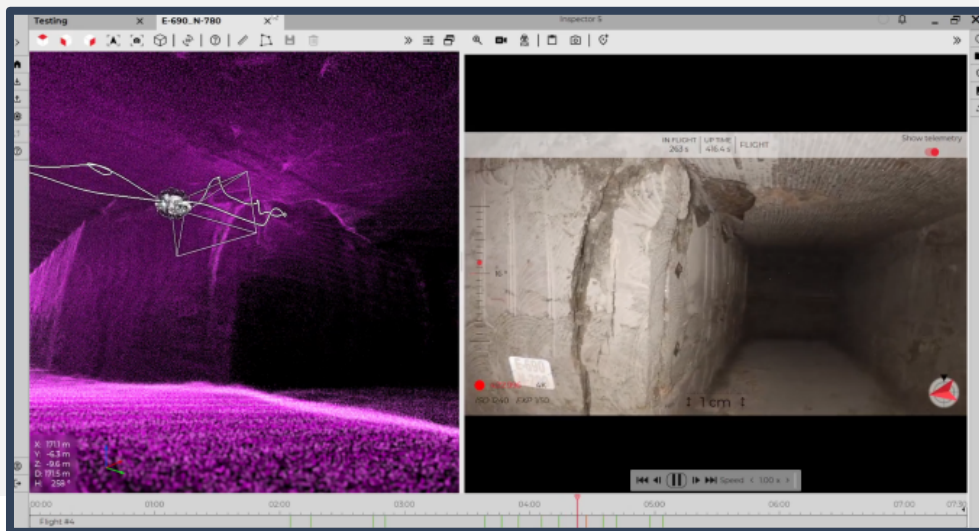
# Mobile LiDAR Scanning of Large Facilities

- Nuclear facilities scheduled for D&D often have unique characteristics
  - Environmental hazards
  - Large area with many rooms
  - Industrial and/or office equipment
  - May have standing water and or structural damage
- Due to the challenges in entering these facilities, robotic and/or human carried LiDAR scanners running SLAM offer a compelling opportunity to create a digital twin of the building
- This digital twin can be navigated virtually using conventional displays and/or XR
- Work planning and other assessments can be done using this digital twin



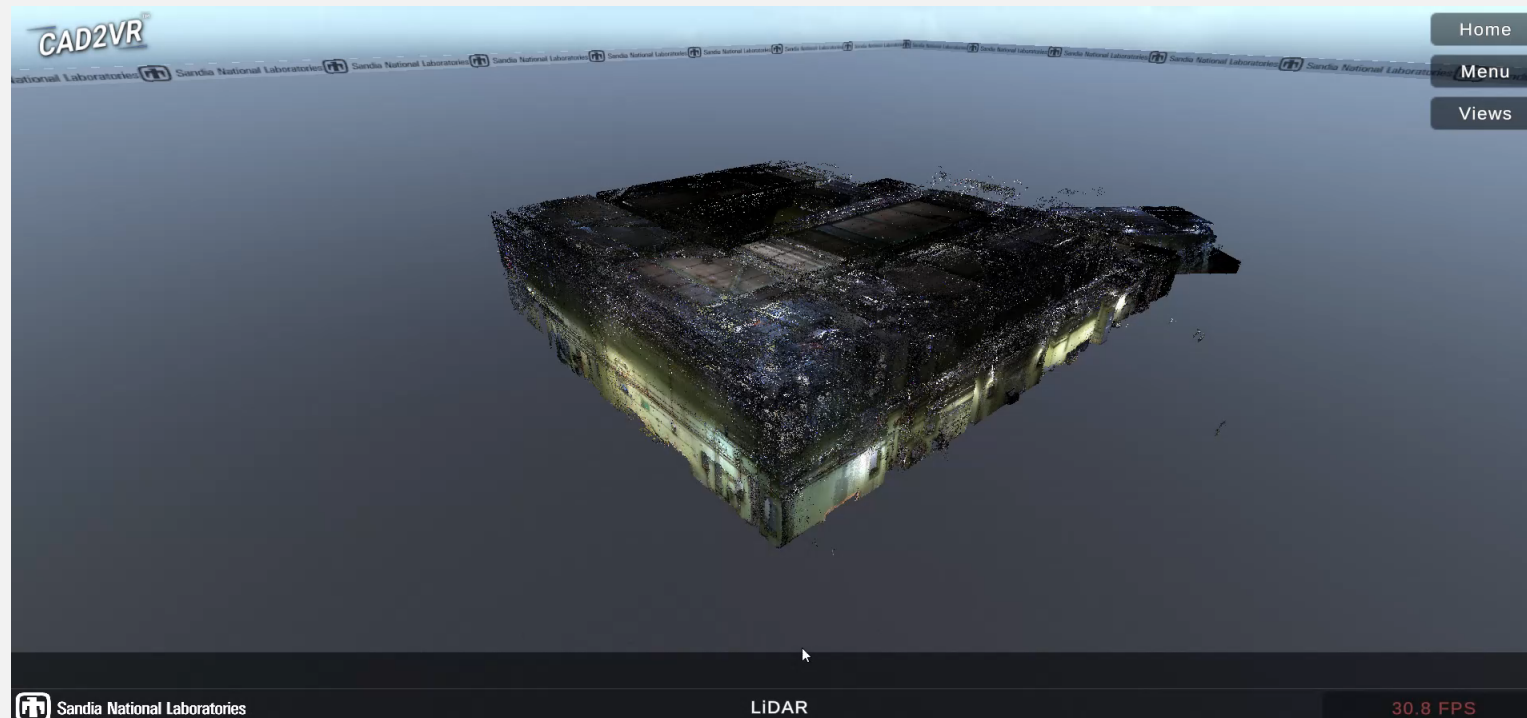
# DOE-EM LiDAR Scans to Date

- ORNL basement industrial and storage facility (handheld)
- Outdoor area at Oak Ridge to assess volume of soil removed (handheld)
- Contaminated area at Oak Ridge for work planning (handheld)
- WIPP above ground and salt pile (UAV)
- WIPP underground areas (handheld, UAV, and UGV)
- Prohibited area in WIPP underground (UAV)



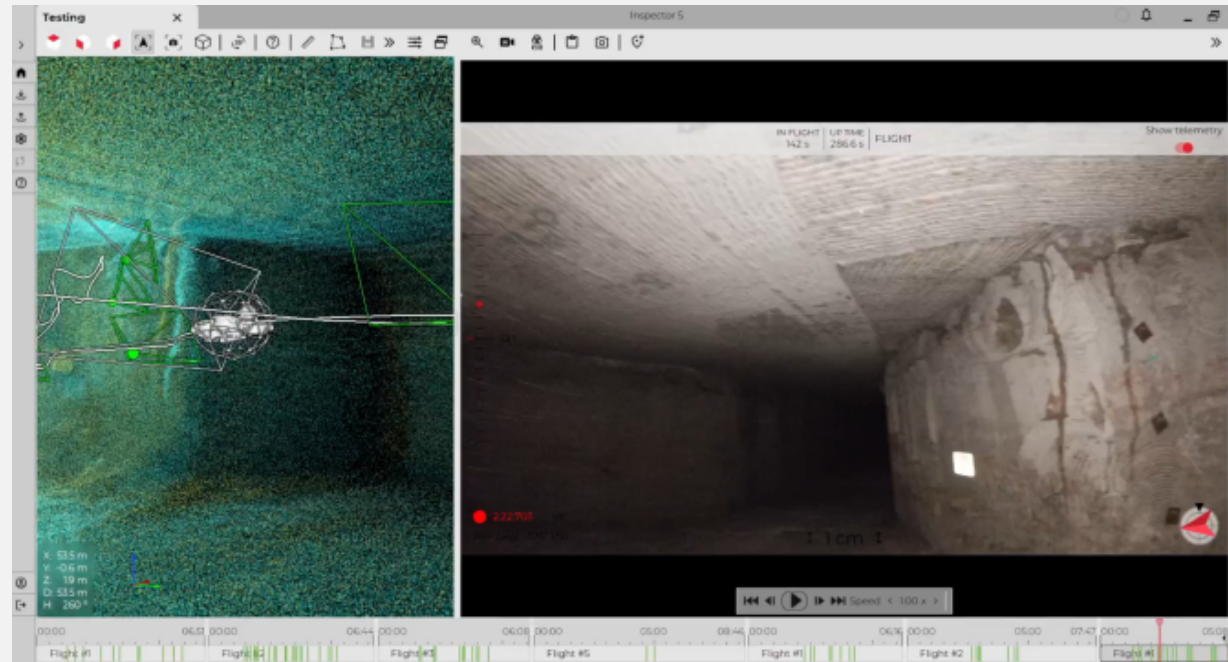
# ORNL Basement Facility

- Collected with handheld LiDAR running SLAM (Exyn) in 2023
- Sample facility for D&D, with comparable features to many similar Oak Ridge facilities



# WIPP Prohibited Area

- WIPP managers requested a survey of an area prohibited to personnel due to concerns about structural integrity
- Area had not been accessed for many years
- UAV with cameras and LiDAR collected several scans which were stitched together



# Conclusions and Future Work

- Building a digital model of a facility can improve worker safety and the efficiency of work planning for D&D and other operations
- In prohibited areas, robotic vehicles can be used to collect data
- Currently seeking approval to use robots in more secure areas
- Exploring point cloud visualization and manipulation tools to facilitate more efficient use of these data sets
- Long term, machine learning may enable point cloud segmentation and semantic labeling of objects

