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# Things to Consider for Robotic Deployments in Radioactive Environments

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*DOE Office of Environmental Management Robotics Team SRS Tour  
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## Typical Constraints and Requirements

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- Budget
- Time - meet schedules and deadlines
- Limited physical access
- Unplanned obstacles
- Chemical, temperature, and pressure compatibility
- Work with specified radiation types and levels
- Weight limit
- Power limitations due to existing cables, penetration connectors, etc.
- Lights
- Cameras
- Remotely maintainable or replaceable



### 2015 H-Canyon Recovery Crawler

- 4 days during Canyon outage
- 30" diameter access port
- 58" clearance hook to access port
- Acid vapors, 25 mph wind
- Beta and Gamma radiation
- No lights in tunnel

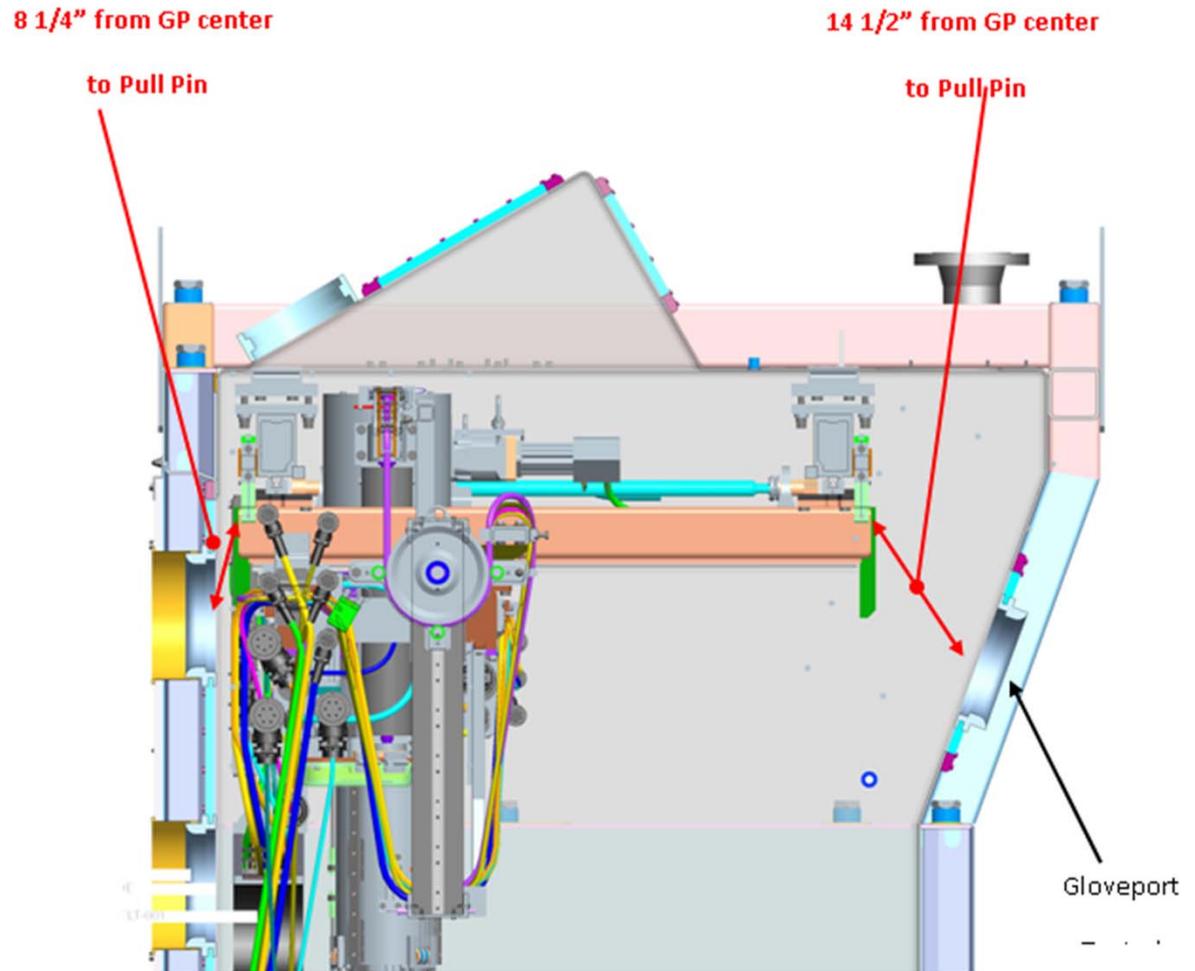


## Remote Maintenance Example

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### Pu Glovebox Robot

- Windows and gloveport added to ceiling for robot maintenance
- Show all components are reachable from gloveports
- Ensure people can handle each part during maintenance activities
- Include equipment to handle large or heavy parts



Glovebox Cross Section

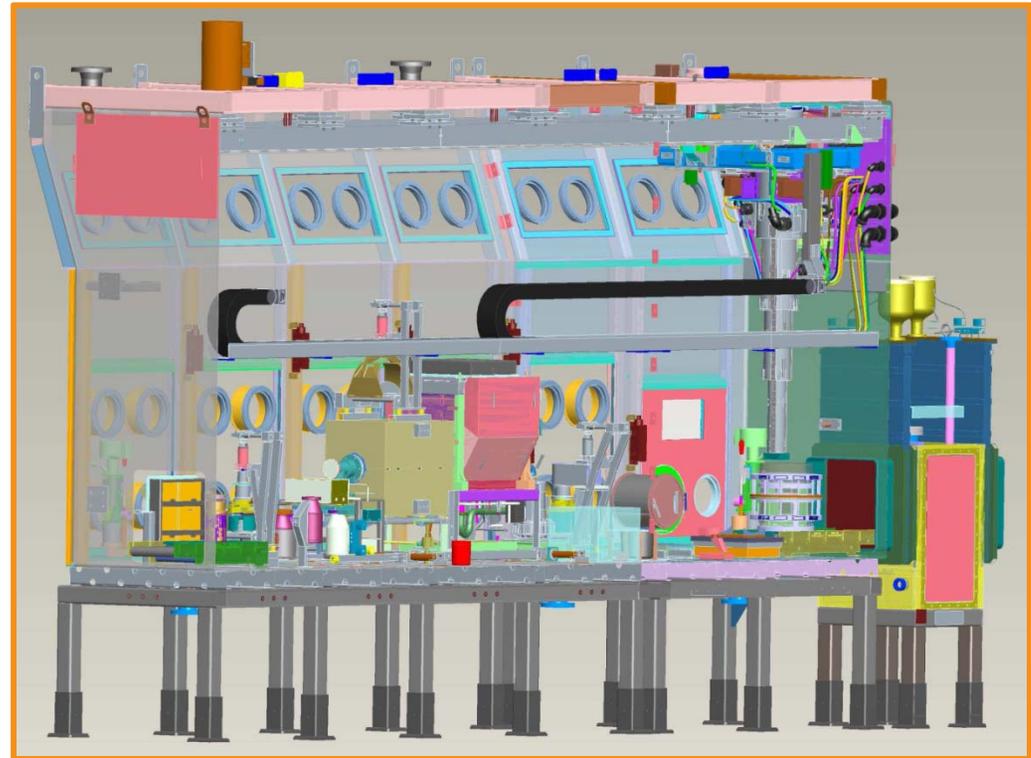


## Codes and Standards – Quality Assurance, DOE Order 414.1C, ASME NQA-1

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### Pu Glovebox Robots

- 23 Robots, > \$23M
- Spec 125 pages, 175 drawings
- Sent RFP to > 20 suppliers
- 15 attended information meeting
- 5 bids submitted
- 2 complete and viable bids
- 1 passed NQA-1 screening
- Supplier passed NQA-1 audit before placing order
  - > 95 items addressed in QA program
  - Procedure for each item
  - Documented examples for each item
- Supplier's QA program was the deciding factor



# Codes and Standards - ASCE 4, Seismic Analysis of Safety-Related Nuclear Structures

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## Pu Glovebox Robot Simplified Seismic Requirements

Requirement	PC-1 Event	PC-2 Event	PC-3 Event
Remain attached to mounting	Yes	Yes	Yes
Retain gripper and payload	Yes	Yes	
Prevent glovebox window contact including gripper and payload	Yes	Yes	
Retain manual movement capability	Yes		

From DOE-STD-1021-93 - Performance Category (PC) Guidelines

PC-1 = Failure may cause fatality or serious injuries to workers in facility

PC-2 = Classified as safety-significant

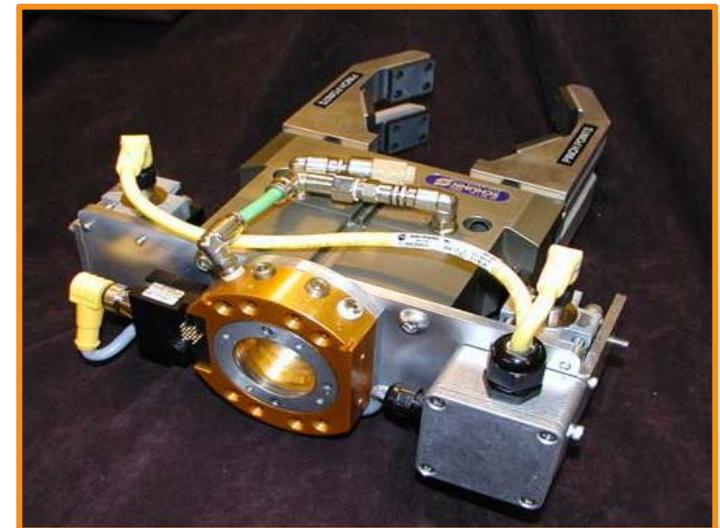
PC-3 = Failure has adverse release consequences greater than safety-class, but not enough to place it in PC-4



## Codes and Standards – DOE Order 420.1C, Facility Safety

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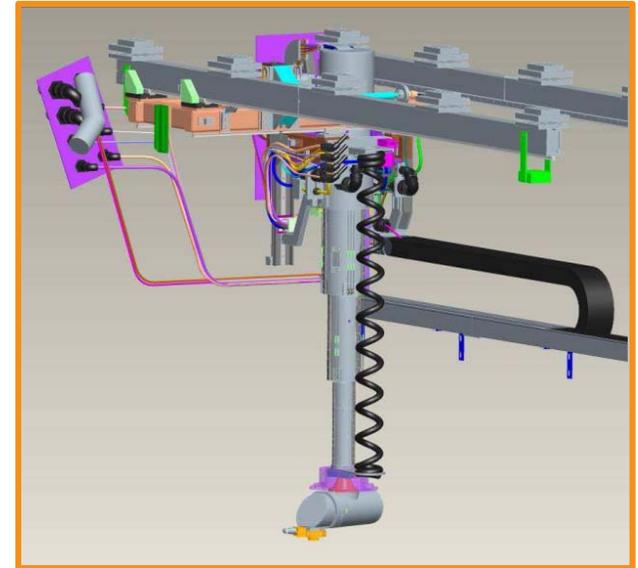
- Requirements for Contractor's Nuclear Criticality Safety Program
- Criticality Requirement for Pu Robot, ensure can location
  - Can't have 3 cans near each other
  - Grippers shall carry one can at a time
  - Interlocks shall prevent the release of a can except in designated process locations
- Proximity sensors are used to provide the interlock feature
- Relay logic, no software used



## Codes and Standards – DOE-STD-1189, Integration of Safety into the Design Process

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- Safety Significant items defined in SRS E7 2.25
- Failure of an SS item results in;
  - Significant worker radiological or chemical exposure
  - A prompt worker fatality
  - Permanently disabling worker injuries
- Pu Glovebox was SS Item
- SS Requirements for Pu Robot
  - Component location including exact feature location and tolerances
  - Calculation of design attribute, e.g. strength, spring rate, or other
  - Comparison of tolerance “stack up” to ensure feature functionality as designed
  - Analysis of potential component wear and verification of feature functionality as the components wear
  - Certified Material Test Report (CMTR)
  - Weld inspection report when welding is used
  - Installation verification (e.g. torque verified) when bolts or fasteners are used.
  - ANSI/ISA 84.00.01 Safety Interlock (SIL) Level 2 calculations for electrical components.



## Codes and Standards – Safety Significant Example

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- Pu Can Handling Robot
- SS requirement, ensure can integrity
  - Must not raise can higher than 6'
  - Limit robot velocity
- First concept, floor mounted robot
  - Commercial robots with payload exceeded 6' limit
  - Software used to limit velocity, not feasible to implement
- Final concept, gantry robot
  - Mechanical design kept can under 6' elevation
  - Motor and gearbox selection limited velocity



Convenience Can  
Inner Can  
Outer Can



## Requirements for Sensitive Data

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- Pu Glovebox Robots would handle classified items
- Robot position data was sensitive
- Pu Glovebox supplier required to use U.S. citizens for software development
- Cables carrying sensitive data required separation from other cables
- Sensitive data cables include;
  - Process Control System to each robot control cabinet
  - Teach pendant
  - Monitor, keyboard, and mouse
  - Robot control computer



## Requirements for Non Listed Devices

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- OSHA requires electrical devices in the workplace be free from hazards that can seriously harm employees
- SRS requires all electrical equipment be listed by a Nationally Recognized Testing Lab (NRTL) or evaluated
- Underwriters Lab, Canadian Standards Association, and Factory Mutual are NRTLs
- Most custom robots are not NRTL listed
- OSHA 29 CFR Part 1910.303 requires a safety evaluation for non listed devices before use
- WSRC-IM-95-58 Guide 16980-G outlines the inspection, documentation, and marking required for the safety evaluation



## Codes and Standards

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### ANS Design Guide for Radioactive Material Handling Facilities & Equipment

- **Well suited for SRS/DOE projects**
  - Operations, maintenance, and D&D of radioactive facilities
  - Shielding and wall penetrations
  - Shielded windows
  - Doors and transfer devices
  - Lighting and cameras
- **Last updated in 1988**
- **Outdated or missing information**
  - Robotics
  - Automation
  - Computer controlled systems

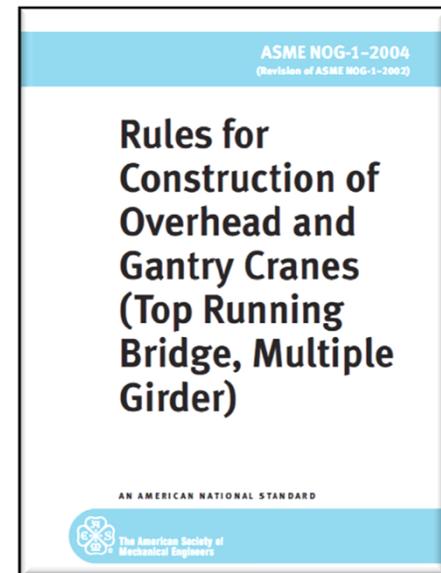
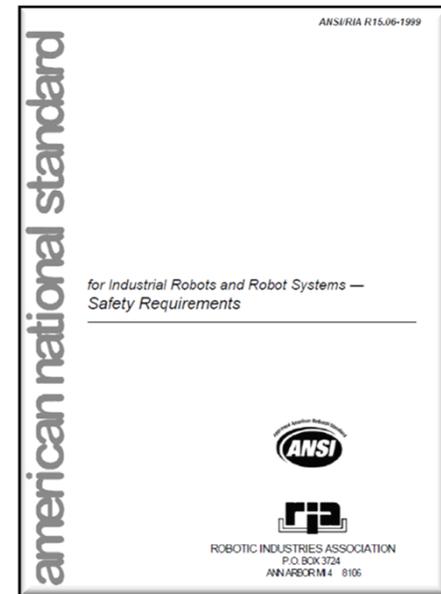


## Codes and Standards

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The following can apply to robotic projects;

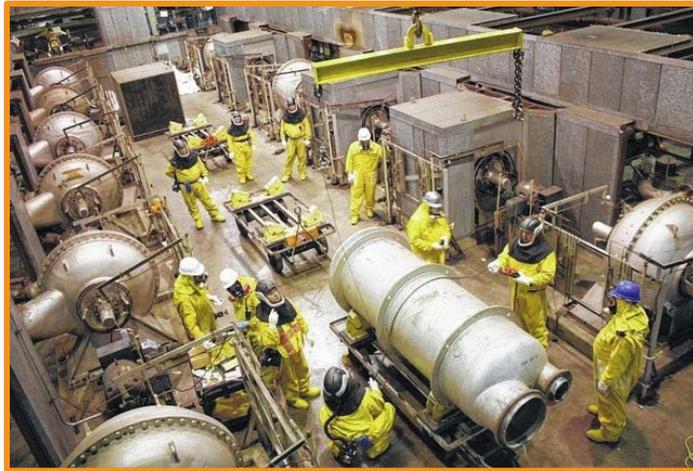
- ANSI/RIA R15.06, Industrial Robot Safety Requirements
- ANSI/RIA R15.05-3, Industrial Robot Acceptance Testing
- NEMA MG1, Motors and Generators
- NEMA 250, Enclosures for Electrical Equipment
- NFPA 70, National Electric Code
- NFPA 79, Electrical Standard for Industrial Machinery
- IEEE 383, Class 1E Electric Cables
- ASME NOG-1, Rules for Construction of Overhead Cranes
- AWS D1.6, Structural Welding Code



## D&D Projects

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- Looking for equipment that is;
  - Low cost
  - Reliable
  - Low risk
  - Quick to deploy
- Typical priority of options
  - People in PPE
  - Commercially available equipment
  - Custom equipment



## Needs and Gaps

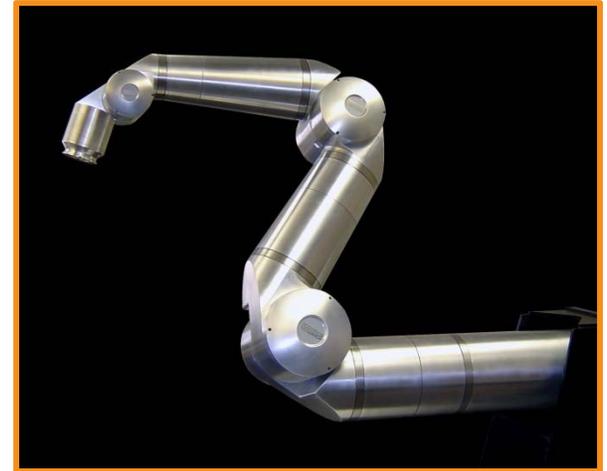
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### D&D Robotics

- Low cost, readily available, reliable, modular components
- Integration system for modular components, software, sensors, etc.
  - Robot Operating System, Industrial (ROS-I)  
<http://rosindustrial.org/>
  - Joint Architecture for Unmanned Systems (JAUS)
  - Manufacturer's liability makes it hard to adopt open source software

### New or Existing Facility Robotics

- Pre-qualified and tested computer hardware and software
  - Safety Significant
  - Classified / Sensitive
  - Wireless communications
- Pre-qualified suppliers, Quality Assurance



Robotics Research Corp.



Modular Motion Systems

