Things to Consider for Robotic Deployments in Radioactive Environments

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Typical Constraints and Requirements

- 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

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
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
### Pu Glovebox Robot Simplified Seismic Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>PC-1 Event</th>
<th>PC-2 Event</th>
<th>PC-3 Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remain attached to mounting</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Retain gripper and payload</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Prevent glovebox window contact including gripper and payload</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Retain manual movement capability</td>
<td>Yes</td>
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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

• **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

• 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

• 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
Requirements for Sensitive Data

• 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

• 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

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

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

- **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

**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/](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**