Overview of the Challenges and Opportunities for the Testing and Use of Robotic Technologies at Nuclear Facilities

Kamel S. Saidi, Ph.D.
Intelligent Systems Division
National Institute of Standards and Technology
U.S. Department of Commerce

Prepared for the
U.S. NRC’s 28th Annual Regulatory Information Conference
Session T9 - Deployment of Robotic Technologies at Nuclear Facilities

Standard Test Methods for Evaluating, Purchasing, and Training with Response Robots

Test Director:
Adam Jacoff
Intelligent Systems Division
National Institute of Standards and Technology
Department of Commerce

Sponsor:
Phil Mattson
Office of Standards
Science and Technology Directorate
Department of Homeland Security

Definition of a Response Robot

“A remotely deployed device intended to perform operational tasks at operational tempos.” ASTM E2854

- A response robot should serve as an extension of the operator to improve remote situational awareness, provide means to project operator intent through the equipped capabilities, and reduce risk to the operator while improving effectiveness and efficiency of the mission.
Challenges for the Use of Robots…

• …at Nuclear Facilities
  – Radiation / HAZMAT / fire / water / collapsed structures
  – Confined spaces
  – Indoor/outdoor, underwater, in air
  – Communications
  – No room for errors
  – Relatively well-known environments (except during accidents)

• …for Emergency Response
  – Explosives / HAZMAT / fire / water / collapsed structures
  – Confined spaces
  – Indoor/outdoor, underwater, in air
  – Communications
  – No room for errors
  – Unknown environments

Challenges for the Use of Robots

• The challenges are not technological, but technical.

• In most cases, the technologies needed to solve a particular problem robotically probably already exist.

• Robotic implementations are often not sufficiently technically developed or evaluated.
“Standard Test Methods”
A consensus-based process for determining the performance of a product.

- **Apparatus**: A repeatable, reproducible, and inexpensive representation of a task you expect the robot to perform.
- **Procedure**: A script for a user to follow.
- **Metric**: A quantitative measure of performance.

A Comprehensive Suite of 50 Test Methods for Ground, Aerial, and Aquatic Systems

- Mobility
- Dexterity
- Endurance
- Sensors
- Radio Comms
- Durability
- Logistics
- Safety
- Autonomy
- Proficiency

Apparatuses Scale to Intended Environments
Increasing Complexity with Same Procedure and Metric
Apparatuses Scale to Intended Environments
Increasing Complexity with Same Procedure and Metric

Example of Apparatuses

- Mini Arena Scale: 30cm (12 in) Lateral Clearance
- Gravel
- Sand
- Crossing Ramps
- Symmetric Stepfields

Examples of Aquatic Test Methods
Baseline Capabilities in a Water Tank Before Adding Variables

Examples of Aerial Test Methods
Baseline Capabilities for Small UAS (<5kg)
Quantitative Comparison of Capabilities
Works for Robots and/or Operators on a Given Robot

Average Rate of Advance on Terrain (at least 500/10 repetitions)

<table>
<thead>
<tr>
<th>ROBOT A</th>
<th>ROBOT B</th>
<th>ROBOT C</th>
<th>ROBOT D</th>
<th>ROBOT E</th>
<th>ROBOT F</th>
<th>ROBOT G</th>
<th>ROBOT H</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>

Standard Test Methods Help Different Stakeholders

Help Robot Developers to:
- Better understand missions
- Practise and refine robot designs, and make trade-off decisions
- Highlight their “Best-In-Class” capabilities

Help Robot Users to:
- Compare robots with objective data, not marketing
- Specify purchases based on existing measured capabilities
- Align expectations with deployment decisions

Help Program Managers to:
- Describe objectives with a collection of tangible tasks
- Challenge conventional approaches and inspire innovation
- Measure baseline capabilities and document progress

Validation Exercises for Robot Developers
Various Robot Sizes and Capabilities To Ensure Tests Scale Effectively

www.nist.gov/el/isd/ms/robottestmethods.cfm
Facilities in USA

110 Requests from Bomb Squads
(of 466 nationwide)

Existing Facilities
Validated/Trained
FY16 Plan

Fifty States:
- Washington
- Oregon
- California
- Nevada
- Idaho
- Montana
- Utah
- Arizona
- New Mexico
- Colorado
- Wyoming
- North Dakota
- South Dakota
- Nebraska
- Kansas
- Oklahoma
- Texas
- Minnesota
- Iowa
- Missouri
- Wisconsin
- Illinois
- Indiana
- Michigan
- Ohio
- Arkansas
- Louisiana
- Kentucky
- Tennessee
- Mississippi
- Alabama
- Georgia
- Florida
- South Carolina
- North Carolina
- Virginia
- West Virginia
- Pennsylvania
- New York
- New Jersey
- Maryland
- Vermont
- New Hampshire
- Massachusetts
- Maine
- Rhode Island
- Connecticut
- Delaware
- District of Columbia

New Facilities
- US State Department Anti-Terrorism Assistance
  Kabul, Afghanistan (2015)
- Korean Atomic Energy Research Institute
  Seou, South Korea (2016)
- Japanese Atomic Energy Agency
  Fukushima, Japan (2016)

Other:
- DARPA Robotics Challenge Trials, Homestead, Florida – December 2013
- DARPA Robotics Challenge Finals, Pomona, California – June 2015
- Validation of ground robot test methods, Japan Atomic Energy Agency (JAEA) and Tokyo Electric Power Company (TEPCO) Test Facility (under construction) in Naraha, Japan – Date TBD
- Validation of ground, aerial and aquatic robot test methods, Japanese Ministry of Economy, Trade and Industry (METI) Robot Testing Field and International Collaboration Facility in the Hamadori area of Fukushima Prefecture, Japan – Date TBD

www.nist.gov/el/isd/ms/robottestmethods.cfm
Simple Rules for Evaluating Robots and Measuring Proficiency

- Select all applicable tests (20+ typically apply) in scale of deployment environment.
- Freeze robot configuration for entire suite of tests to capture trade-offs.
- Operate remotely, out of sight and sound of robot as if downrange.
- Use "expert" operators to capture best possible robot capabilities and 100% level of operator proficiency for comparisons.
- Capture statistically significant repetitions (10-30 reps) to establish reliability.
- Compare quantitative scores:
  - Robot capabilities across all tests.
  - Operator proficiency relative to 100% across all tests using the same robot.

Basic Skills: Maneuvering (5)

Drive forward then reverse | 10 minute time limits | 50 minutes overall
Mission Essential Tasks: Building Access (5)

- Drive as necessary | 10 minute time limits | 50 minutes overall
- (covered with tarp for dark environment)

- Open Doors
- Remove Handle
- Assemble/Disassemble Tools
- Entangle Obstacles
- Negotiate Hallways

Standard Test Methods in a Box

“A New Approach for Operator Training and Evaluation – Worldwide!”

- Standard test methods are not intended to replace regular scenario training. They provide a rigorous method to prepare for and augment such training.

- Similar to sports examples:
  - Circuit training — 5 or 10 minute trials on each apparatus to train your entire skill set. Repeat often
  - Golf driving range — practice skills, gain muscle memory

- Quick training tasks can be performed as a group rotating through several test methods simultaneously with robots remaining in each apparatus.

- Techs can practice and train by themselves if they miss a training day.

- Now you can measure your operator proficiency as a percentage of “expert” performance on the same robot!