# Robots for Urban Search and Rescue

## Performance Metrics and Standards

# ASTM
# E54.08.01

January 29, 2007



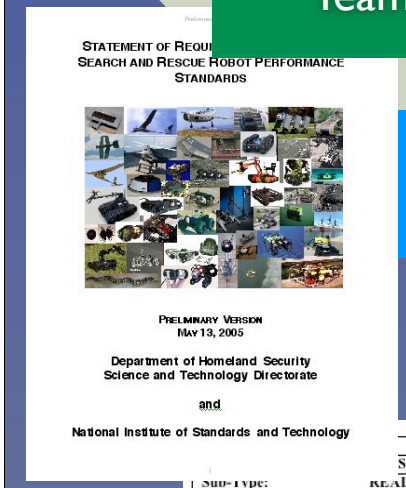
# Scope Statement

- The scope of the task group is to specify a set of performance requirements, test methods, and associated standards for robot systems used in urban search and rescue applications. Emergency responders, pertinent technology developers, and interested government officials have defined these standards to provide an objective measure of robot performance for representative urban search and rescue applications. Results from such performance tests can be considered against specific purchaser/user performance objectives for envisioned applications.
  - These standards specify a variety of performance criteria and associated test methods for urban search and rescue robots. Several representative applications of robots used in urban search and rescue have been considered in defining these test methods. These representative applications, although comprehensive, are certainly not complete.
  - The standards developed by this task group will provide a means to ensure that a robot meets the performance requirements stated. Successful completion of the tests should not be construed as an ability to successfully operate in environments other than those specifically identified in the test methods.
  - These standards do not address special applications outside the stated requirements, such as certain extreme weather conditions for example. To ensure performance for such applications, additional requirements need to be established along with associated standards.

# US&R Robot Standards: The Big Picture

Requirements from FEMA Teams → Standard Test Methods → "Consumer's Guide"

Responders Meet Robots Exercises

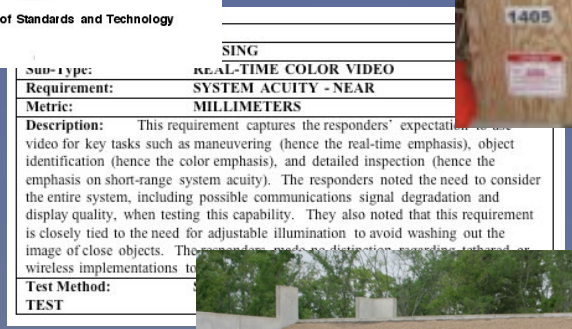

STATEMENT OF REQUI
SEARCH AND RESCUE ROBOT PERFORMANCE STANDARDS

PRELIMINARY VERSION
MAY 13, 2005

Department of Homeland Security
Science and Technology Directorate

and

National Institute of Standards and Technology


| | |
|---|---|
| | SING |
| Sub-Type: | REAL-TIME COLOR VIDEO |
| Requirement: | SYSTEM ACUITY - NEAR |
| Metric: | MILLIMETERS |
| Description: | This requirement captures the responders' expectati… video for key tasks such as maneuvering (hence the real-time emphasis), object identification (hence the color emphasis), and detailed inspection (hence the emphasis on short-range system acuity). The responders noted the need to consider the entire system, including possible communications signal degradation and display quality, when testing this capability. They also noted that this requirement is closely tied to the need for adjustable illumination to avoid washing out the image of close objects. The … wireless implementations … |
| Test Method: | … |
| TEST | |


# Requirements Categories

| Requirements Category | Number of Individual Requirements | Category Definition |
|---|---|---|
| Human-System Interaction | 23 | Pertaining to the human interaction and operator(s) control of the robot |
| Logistics | 10 | Related to the overall deployment procedures and constraints in place for disaster response |
| Operating Environment | 6 | Surroundings and conditions in which the operator and robot will have to operate |
| System | | The main body of the robot, upon which additional components and capabilities may be added. This is the minimum set of capabilities (base platform) |
| Chassis | 4 | The main body of the robot, upon which additional components and capabilities may be added. |
| Communications | 5 | Pertaining to the support for transmission of information to and from the robot, including commands for motion or control of payload, sensors, or other components, as well as underlying support for transmission of sensor and other data streams back to operator |
| Mobility | 12 | The ability of the robot to negotiate and move around the environment |
| Payload | 7 | Any additional hardware that the robot carries and may either deploy or utilize in the course of the mission |
| Power | 5 | Energy source(s) for the chassis and all other components on board the robot |
| Sensing | 32 | Hardware and supporting software which sense the environment |
| Safety | 1 | Pertaining to safety of humans and potentially property in the vicinity of robots |

# Deployment Situations

| Robot Category | Ground: Peek Robots | Ground: Collapsed Structure--Stair/Floor climbing, map, spray, breach bots | Grou collap Struc Wide surve | atic: able th Sub s | Aquatic: Bottom Crawler Bot | Aquatic: Swift Water Surface Swimmer |
|---|---|---|---|---|---|---|
| **Employment Role(s)** | Provide rapid audio visual situational awareness; provide rapid HAZMAT detection; data logging for subsequent team work | Stairway & upper floor situational awareness; mitigation activities; stay behind monitoring | human stairwa upper situatio awaren contan area s site assess victim identifi mitigat activiti behind monito | ctural ection; leak ization/miti n; object ) recovery | Water traverse; rapid current station keeping; object recovery | Upstream access and station keeping; payload delivery; object recovery |
| **Deployment Method(s)** | Tossed, chucked, thrown pneumatically, w/surgical tubing; marsupially deployed | Backpacked; self driven; marsupially deployed | Backpa self dri marsup deploy | pped into r; lowered ether | Driven across w | Dropped into water; marsupially deployed |
| **Tradeoffs** | Trade mobility, duration, sensing for increased expendability | form factor for increased mobility, sensing, manipulation; mapping variant; spraying variant; breaching variant | form fa increas mobilit sensin manipu mappin variant sprayin variant breach variant | e ground ility for sub ace access e swim city | pursue amphibious mobility at cost of other performance | pursue swift water capacity at cost of other performance |

| Robot Category | Ground: Peek Robots |
|---|---|
| Employment Roles(s) | Provide rapid audio visual situational awareness; provide rapid HAZMAT detection; data logging for subsequent team work |
| Deployment Method(s) | Tossed, chucked, thrown pneumatically, w/surgical tubing; marsupially deployed |
| Tradeoffs | Trade mobility, duration, sensing for increased expendability |

# Deployment Situations

| Robot Category | Ground: Non-Collapsed Structure –Wide Area Survey |
|---|---|
| Employment Roles(s) | Long range, human access stairway & upper floor situational awareness; contaminated area survey; site assessment; victim identification; mitigation activities; stay behind monitoring |
| Deployment Method(s) | Backpacked; self driven; marsupially deployed |
| Tradeoffs | Experience form factor for increased mobility, sensing, manipulation; mapping variant; spraying variant; breaching variant |

| Robot Category | Ground: Peek Robots | Ground: Collapsed Structure--Stair/Floor climbing, map, spray, breach bots | Grou collap Struc Wide surve | ub | Aquatic: Bottom Crawler Bot | Aquatic: Swift Water Surface Swimmer |
|---|---|---|---|---|---|---|
| Employment Role(s) | Provide rapid audio visual situational awareness; provide rapid HAZMAT detection; data logging for subsequent team work | Stairway & upper floor situational awareness; mitigation activities; stay behind monitoring | human stairwa upper situatio awaren contan area s site assess victim identifi mitigat activiti behind monito | leak w/miti ect overy | Water traverse; rapid current station keeping; object recovery | Upstream access and station keeping; payload delivery; object recovery |
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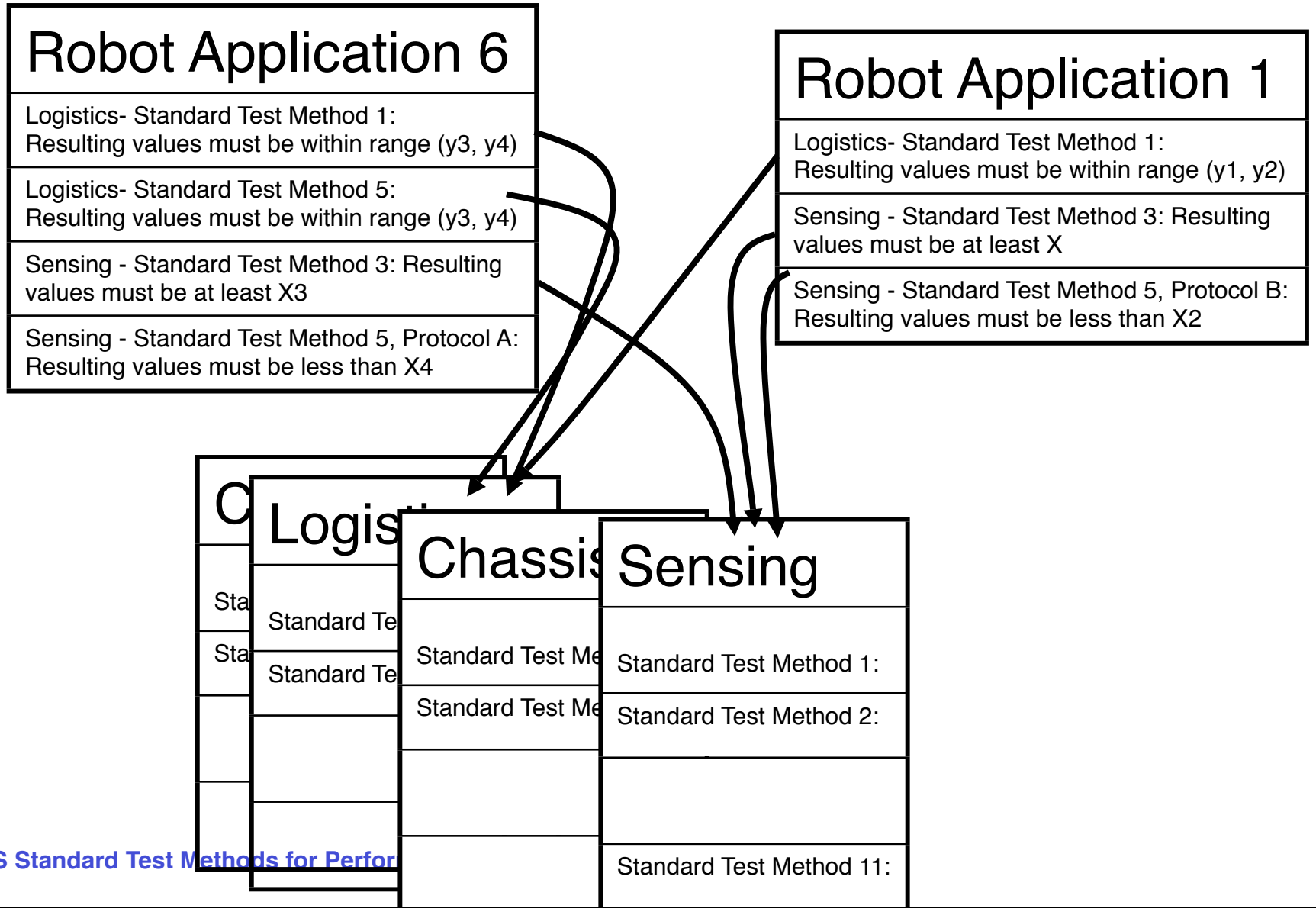
DHS Standard Test Method

# Example Requirements

| | | | |
|---|---|---|---|
| Logistics | | Cache packaging--Setup Time | Time from on-site delivery to operation. |
| Logistics | | Cache packaging--Volume | Scale defined: 1=Pelican 1650 box; 3=Hardigg box checkable on commercial aircraft; 5=Ropack model 4048, 4039 with drop door |
| Logistics | | MTBF | Operating hours. |
| Logistics | **Field Maintenance:** | Spares and Supplies | Self sustaining for 72 hours. |
| Logistics | **Field Maintenance:** | Tools | Scale Defined: 1=Requires special tools, 3=Simple tools (e.g., screw driver), 5= No tools required |
| Logistics | **Field Maintenance:** | Intervals | Mean time between routine maintenance. |
| Power | **Power:** | Working Time | Must have sufficient power to operate for specified number of hours. Assumes one power charge. One out and back mission. |
| Power | **Power:** | Runtime Indicator | Must be able to inform operator of remaining power level (percent). |
| Power | **Power:** | Sustainment | Amount of time system must be able to operate in field before re-supply is needed. |
| Sensing | **Video:** | Real time remote video system (Far) | Resolution of the image will be tested using visual acuity tests at given range. Limiting case could be assessment of structural integrity of the building. Image should be in color and resolution. Operator must read eye chart through entire imaging system |

# Integrating the Two Views




DHS Standard Test Methods for Perfor

# Working Groups within E54.08.01

- Logistics - Bob McKee, FEMA TF-1
- Operating Environment - Glen Keller, Allentown Fire Department
- Communications - Kate Remley, NIST
- Human-System Interaction - Sal Schipani, NIST
- Sensing - John Evans, John Evans LLC
- Mobility - Bill McBride, SwRI
- Safety - Mark Micire, UML and American Standard Robotics
- Power - TBD
- Terminology - Hui-Min Huang, NIST

# Status

- 5 Work Items introduced; 2 balloted
  - ✓ Visual Acuity and Field of View
  - ✓ Terminology
  - – Human-System Interaction: Usability
  - – Logistics, Cache Packaging
  - – Communications: Line of sight and Non-line of sight wireless
- Additional ones in queue
  - – Mobility
  - – Safety

# Status

- 11 test methods (some covering multiple requirements) have been piloted at least once
- Today, we will have more in-depth discussions regarding
  - Sensing, Visual Acuity and Field of View
  - Communications, Wireless LOS and NLOS

# Requirements Addressed in Wave 1

| Requirement #‡ | Requirement |
|---|---|
| | |
| 38 | Logistics-Cache Packaging-Volume |
| 34 | Logistics-Cache Packaging-Weight |
| 36 | Logistics-Cache Packaging-Setup Time |
| 96 | Sensing-Vision System-Acuity, Near |
| 99 | Sensing-Vision System-Acuity, Far |
| 101 | Sensing-Vision System-Field of View |
| 14 | Human-System Interaction - Acceptable Usability |
| 3 | Chassis - Adjustable Illumination |
| 6 | Communications-Range NLOS |
| 8 | Communications-Range LOS |

‡ References original requirements in Preliminary Report. See http://www.isd.mel.nist.gov/US&R_Robot_Standards

# Requirements Addressed in Wave 1

| Requirement # ‡ | Requirement |
|---|---|
| | |
| 59 | Payload-Manipulation |
| 65 | Payload-Retrieval |
| 60 | Payload-Manipulation-Sensor Manipulation |
| 45-47 | Mobility-Locomotion-sustained speed |
| 44 | Mobility-Aerial-Stationkeeping |
| new | *Mobility-Vertical Climbing* |
| new | *Mobility-Locomotion-Random Step Fields* |
| new | *Mobility-Stair Climbing* |
| new | *Mobility-Ramps* |
| new | *Mobility-Confined Space Access* |
| new | *Sensing-Vision System-Acuity, Aerial* |

‡ References original requirements in Preliminary Report. See http://www.isd.mel.nist.gov/US&R_Robot_Standards

# Responders Meet Robots Exercises

## Refining Requirements

## Understanding Operational Scenarios

## Encouraging Information Flow: Manufacturers & End Users

## Evaluating Draft Test Methods and Artifacts

1. FEMA Nevada TF1 Training Facility August 5-9, 2005
   - Diverse set of robots: ground, aerial, underwater, and amphibious brought by manufacturers and researchers
   - Responders operated robots in scenarios within rubble pile, freeway collapse, and using NIST test artifacts (simulated victims, mobility, vision, and other tests)
   - Responders and vendors critiqued draft test methods, artifacts
2. FEMA Texas TF1 Training Facility April 4-7, 2006
   - Disaster City - a 52 acre facility with diverse and rich training scenarios
   - Numerous small aerial vehicles participated
   - Initial piloting of Wave 1 test methods
3. FEMA Maryland TF1 Training Facility August 19-21, 2006
   - Piloting of test methods prior to submission to standards organization
   - Initial integration of radiation sensors and other hazmat sensors in test methods and operational scenarios
   - Leveraging NIST-organized conferences: Performance Metrics for Intelligent Systems and IEEE Safety, Security, and Rescue Robots

# Participating Robots (thus far)

**GROUND**

- Remington EyeBall (throwable, panning camera)
- Omnitech Toughbot (throwable, maneuverable)
- Inuktun VGTV (shape shifter), VGTV Extreme
- M-Bots Sneaky (low profile search)
- ARA LRV (stair climbing)
- Automatika DragonRunner (wheeled)
- WVHTC Bombot (wheeled)
- Exponent Marcbot (wheeled)
- Robotic FX Negotiator (flipper, tracks)
- Toin University Iris
- Toin University Hibiscus
- Toin University Cphea
- International Rescue Systems Soryu
- University Electro Communications Shinobi
- ASI Chaos (four flipper)
- Packbot Explorer (with infrared)
- Packbot Scout
- Packbot EOD (with manipulator)
- Mesa Robotics Marv (double track)
- Mesa Robotics Matilda
- Mesa Robotics Matilda EOD (with manipulator)

**GROUND**

- INL ATRV-mini
- Foster-Miller Talon (with manipulator)
- Remotec Andros F6A (with manipulator)
- Remotec Andros Minim (with manipulator)
- Boz Robots Boz I

**WALL CLIMBERS**

- Vortex (suction)
- Nanomag (magnetic)

**AERIAL**

- Aerovironment Wasp
- ARA Nighthawk
- Aerovironment Raven
- BAI/L-3 Evolution
- Cyberdefense Cyberbug
- UAH Flying Bassett Helicopter
- AirRobot Helicopter
- ARACAR Tethered Blimp

**WATER**

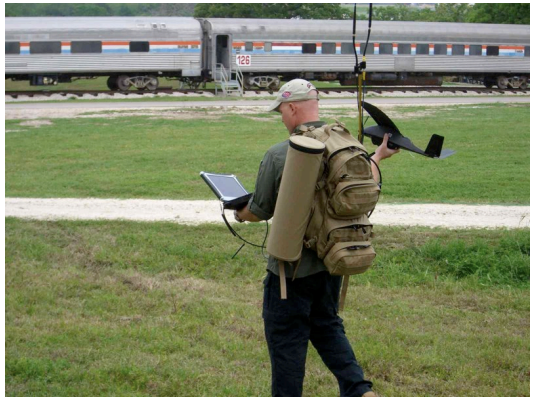
- VideoRay Sea Sprite
- Video Ray Pro III

**ROBOT SIMULATORS/ VISUALIZERS**

- Acroname Symonym
- USARSim

# Participating FEMA Task Forces (thus far)


Arizona TF1
California TF1
California TF2
California TF3
California TF6
California TF7
California TF8
Colorado TF1
Indiana TF1
Massachusetts TF1
Maryland TF1
Missouri TF1
Nebraska TF1
Nevada TF1
New York TF1
Ohio TF1
Pennsylvania TF1
Tennessee TF1
Texas TF1
Utah F1
Virginia TF1
Virginia TF2
Washington TF1



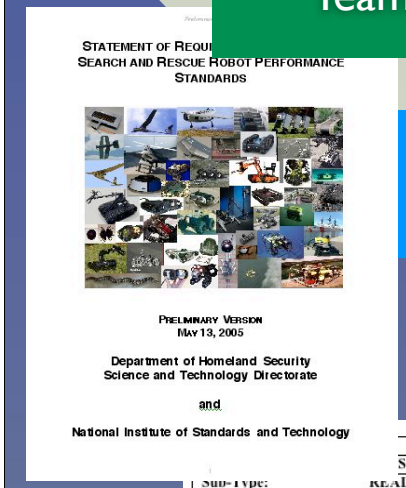

# Responder-Driven Scenarios


**DHS Standard Test Methods for Performance and Use of US&R Robots**

# US&R Robot Standards: The Big Picture

Requirements from FEMA Teams → Standard Test Methods → "Consumer's Guide"

Responders Meet Robots Exercises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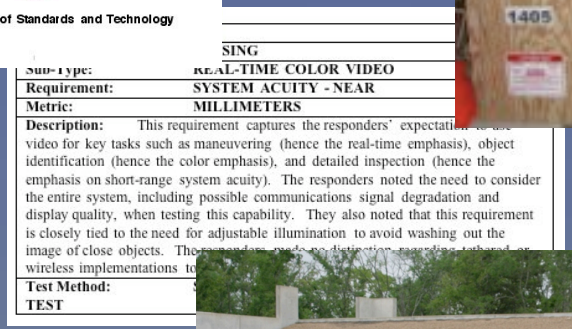
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# Example

Logistics – Cache Packaging;

Logistics - Field Maintenance - Tools

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Developing

## Standard Test Methods For Response Robots

### Logistics - Cache Packaging

ROBOT: _____ ☐ TETHER ☐ RF

OPERATOR: _____ ORG: _____

SKILL LEVEL: ☐ Novice ☐ Intermediate ☐ Expert

INSTRUCTIONS: 1) Note the number and weight of each packaging container necessary for robot to deploy for 10 days, without re-supply for the first 72 hours. 2) Time the setup process until ready to go downrange. 3) Note the tools needed to perform setup and repair. 4) Weigh the deployable robot and operator control unit.

Planning for a 10 day deployment, without resupply for the first 72 hours

Number of packages:

_____ Pelicans _____ kg or _____ lb

_____ Hardiggs _____ kg or _____ lb

_____ Ropacks _____ kg or _____ lb

_____ Pallets _____ kg or _____ lb

Total Weight: _____ kg or _____ lb

---

Measure the length of time to unpackage the robot system and fully prepare it for deployment.

Setup Time:

Start Time: _____

End Time: _____

Elapsed: _____ minutes

---

Setup and Reparis can be performed at the base of operation

Tools Needed:

☐ None

☐ Typical Toolbox: Metric or English (circle one)

☐ Any Specialized Tools: Describe: _____

Describe: _____

Describe: _____

---

Down-Range Weight:

Robot: _____ kg Operator Control Unit: _____ kg Total: _____ kg

Robot: _____ lbs Operator Control Unit: _____ lbs Total: _____ lbs

TEST LEADER DATE NOTES

**DHS Standard Test Methods for Performance and Use of US&R Robots**

# Example

Payload – Manipulation - Sensor Manipulation

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Developing
## Standard Test Methods For Response Robots

### DIRECTED PERCEPTION

Robot: _____

Operator: _____

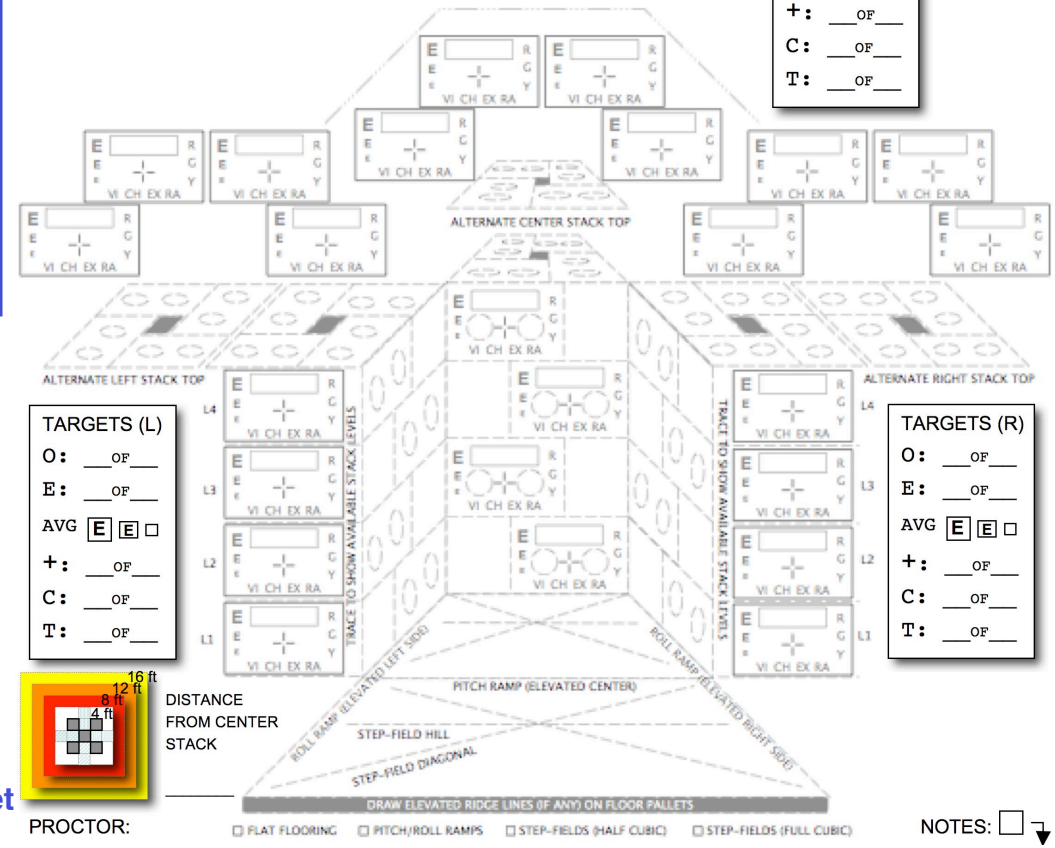
Skill Level: ☐ NOVICE ☐ INTERMEDIATE ☐ EXPERT

Start Time: _____

End Time: _____

Elapsed: _____

TARGETS (C)
O: ___OF___
E: ___OF___
AVG [E] [E] ☐
+: ___OF___
C: ___OF___
T: ___OF___




TARGETS (L)
O: ___OF___
E: ___OF___
AVG [E] [E] ☐
+: ___OF___
C: ___OF___
T: ___OF___

TARGETS (R)
O: ___OF___
E: ___OF___
AVG [E] [E] ☐
+: ___OF___
C: ___OF___
T: ___OF___




DISTANCE FROM CENTER STACK _____

PROCTOR:

☐ FLAT FLOORING ☐ PITCH/ROLL RAMPS ☐ STEP-FIELDS (HALF CUBIC) ☐ STEP-FIELDS (FULL CUBIC)

NOTES: ☐

DHS Standard Test Met

# Example Movie of Robot Performing Directed Perception Test Method

# Partnering

- Within ASTM
  - F32 - Search and Rescue
  - F38 - Unmanned Aerial Systems
  - F41 - Unmanned Underwater Vehicles
  - E54.01 - CBRNE
  - E54.92 - Terminology
- With Other SDO's
  - Leverage wherever possible
  - SAE AS4 Joint Architecture for Unmanned Systems (JAUS): interoperability
  - IEEE communications standards