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

Stimulating Robotic Technology Development for First Responder Applications

Elena Messina
Intelligent Systems Division
National Institute of Standards and Technology
Gaithersburg, MD 20899

http://www.isd.mel.nist.gov/US&R_Robot_Standards/

usar.robots@nist.gov

October 23, 2008

National Institute of Standards and Technology

NIST strengthens the U.S. economy and improves the quality of life by working with industry to develop and apply technology, measurements, and standards

NIST carries out its mission through a portfolio of four programs:

Measurements and Standards

Technology Innovation

Manufacturing Extension Partnership

Baldrige National Quality

What Must Response Robots Do?

(mobility, power, sensors, communications, operator interfaces)

Building Confidence that new Technology is up to the Challenge

What are the requirements?

How can we quantify robot performance in specific areas?

How can we abstract domain challenges?

How can we make them reproducible, repeatable?

Toward Performance Standards for Homeland Security Robots

Requirements from FEMA Teams & Bomb Squads

Standard Test Methods

"Consumer's Guide"

Response Robots Exercises

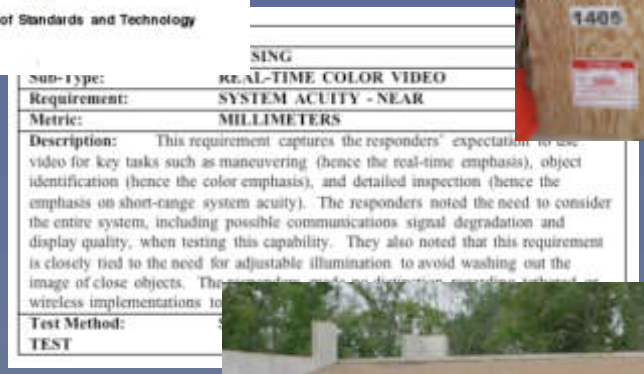

STATEMENT OF REQUI
SEARCH AND RESCUE ROBOT PERFORMANCE STANDARDS

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' expectation [illegible] 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 [illegible] wireless implementations to
Test Method:	TEST

Homeland Security

Responder Requirements

Results from 3 FEMA US&R TF Workshops

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

Example Responder-Defined Requirements

Sensing	Real-time Video	Resolution of the image will be tested using visual acuity tests at given range. Image should be in color. Quality is evaluated through entire system (i. e., not standalone).
Logistics	Field Maintenance: Tools	Scale Defined: 1= Requires Special Tools; 3=Simple Tools (e.g., screw driver); 5=No Tools Required
Power (Energy)	Working Time	System working time beyond mobility requirements. Assumes one power charge; one out and back mission. Scale defined: 1=1hr; 3=4hrs; 5=12hrs.

Robot Deployment Categories

Ground: Peek Robots
Ground: Collapsed Structure--Stair/Floor climbing, map, spray, breach Robots
Ground: Non-collapsed Structure--Wide area Survey Robot
Ground: Wall Climbing Deliver Robots
Ground: Confined Space, Temporary Shore Robots
Ground: Confined Space Shape Shifters
Ground: Confined Space Retrieval Robots
Aerial:High Altitude Loiter Robots
Aerial: Rooftop Payload Drop Robots
Aerial: Ledge Access Robot
Aquatic: Variable Depth Sub Robot
Aquatic: Bottom Crawler Robot
Aquatic: Swift Water Surface Swimmer

Example Deployment Categories for Robots

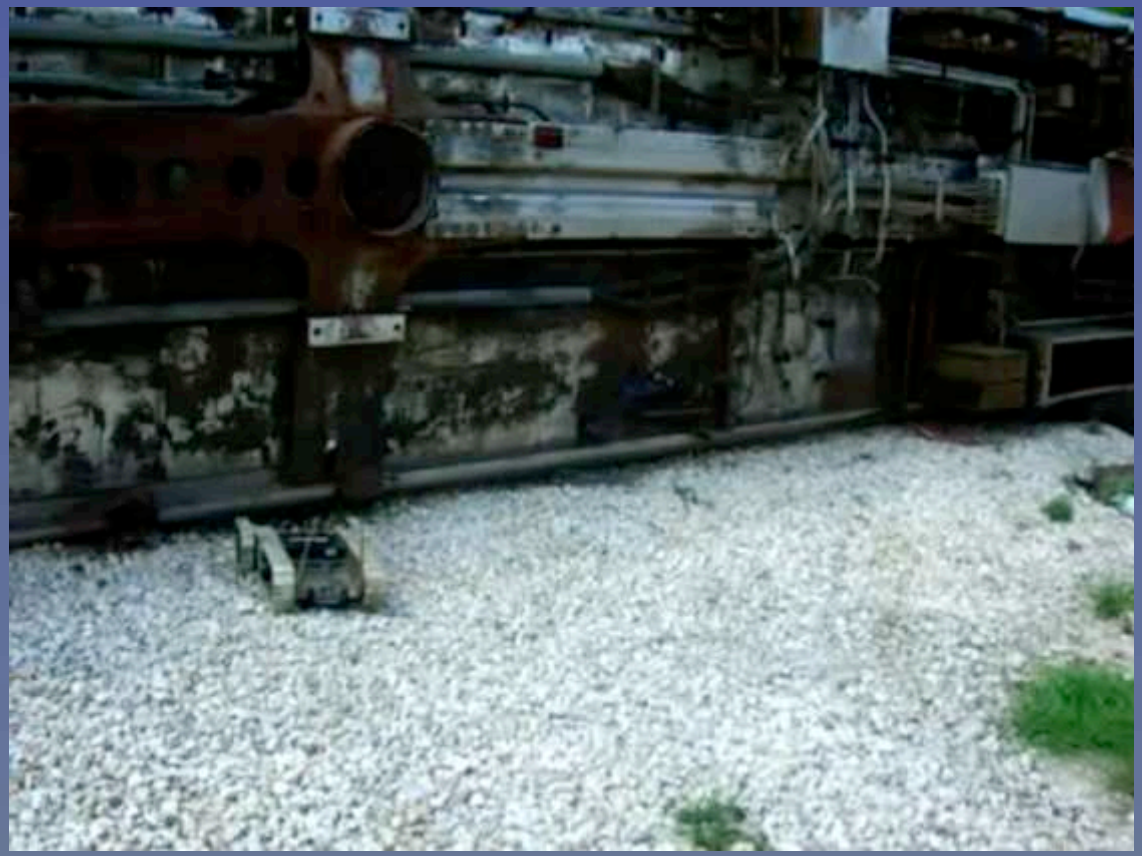
Robot Category	Ground: Peek Robots
Employment Roles(s)	Provide rapid audio visual situational awareness; provide rapid HAZMAT detection; data logging for subsequent team work
Deployment Method(s)	Tossed, chucked, thrown pneumatically, w/ surgical tubing; marsupially deployed
Tradeoffs	Trade mobility,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

Omnitech Toughbot

Some commercial products are shown for illustration purposes. This does not imply endorsement by NIST.

Example Deployment Categories for Robots

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



iRobot Packbot

Example Deployment Categories for Robots

Robot Category	Aerial –Wide Area Survey (& Loiter)
Employment Roles(s)	Provide overhead perspective & sit. Awareness; provide HAZMAT plume detection; provide comm repeater coverage
Deployment Method(s)	Released; balloon or F/W; tethered; launched; VTOL
Tradeoffs	Trade penetration capacity for vertical perspective (in some cases); trade simplicity for greater sit. Awareness.

ASTM E54.08.01 Working Groups

Homeland Security Applications, Operational Equipment, US&R Robot Performance Standards

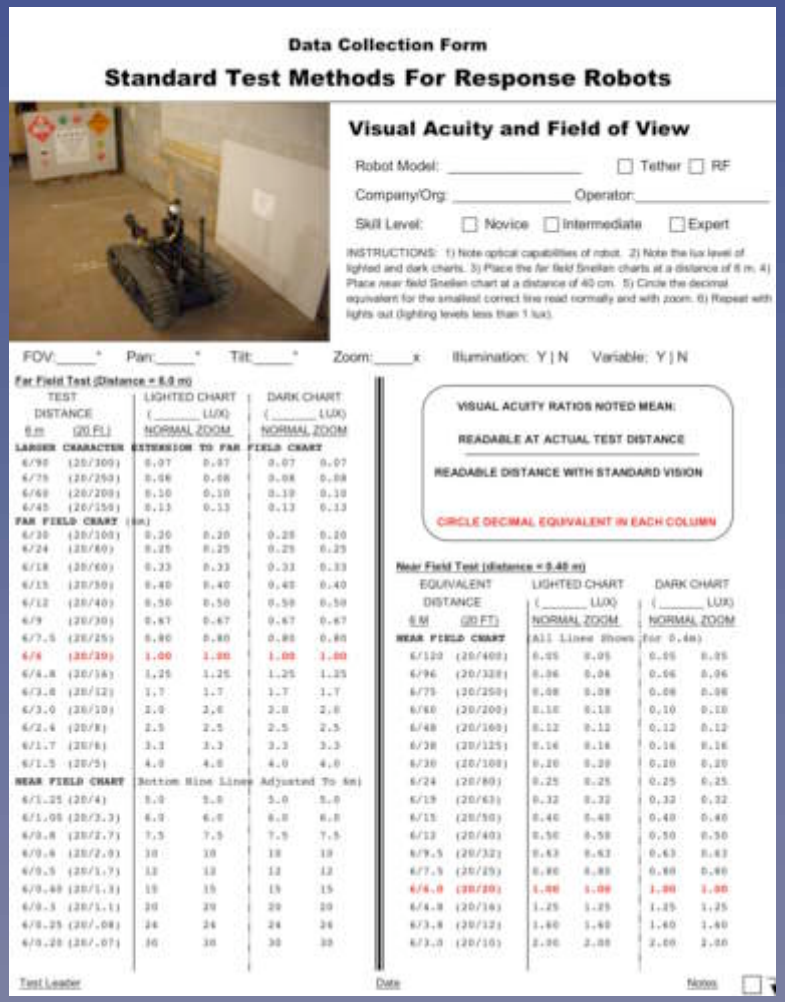
- Terminology
- Logistics
- Safety and Operating Environment
- Communications
- Human-System Interaction
- Sensing
- Mobility
- Power (renamed Energy)

ASTM E54.08.01 Working Groups

- 6 Work Items introduced; 3 balloted
  - Visual Acuity and Field of View (E 2566)
  - Terminology (E2521-07a)
  - Logistics, Cache Packaging (E2592-07)
  - Communications: Line of sight and Non-line of sight wireless
  - Human-System Interaction: Usability
  - Mobility
- Additional ones in queue
  - Safety
  - Power

Example: Visual Acuity & FOV Test Method

Requirements	
Illumination	Adjustable
Video	Real-time remote video system (near)
Video	Real-time remote video system (far)
Video	Field of View
Video	Pan
Video	Tilt



Data Collection Form

Standard Test Methods For Response Robots

Visual Acuity and Field of View

Robot Model: ☐ Tether ☐ RF

Company/Org: Operator:

Skill Level: ☐ Novice ☐ Intermediate ☐ Expert

INSTRUCTIONS: 1) Note optical capabilities of robot. 2) Note the lux level of lighted and dark charts. 3) Place the far field Snellen charts at a distance of 6 m. 4) Place near field Snellen chart at a distance of 40 cm. 5) Circle the decimal equivalent for the smallest correct line read normally and with zoom. 6) Repeat with lights out (lighting levels less than 1 lux).

FOV:____° Pan:____° Tilt:____° Zoom:____x Illumination: Y | N Variable: Y | N

Far Field Test (Distance = 6.0 m)

TEST DISTANCE 6 m	(20 Ft.)	LIGHTED CHART (_____ LUX) NORMAL	ZOOM	DARK CHART (_____ LUX) NORMAL	ZOOM
LARGER CHARACTER EXTENSION TO FAR FIELD CHART					
6/90	(20/300)	0.07	0.07	0.07	0.07
6/75	(20/250)	0.08	0.08	0.08	0.08
6/60	(20/200)	0.10	0.10	0.10	0.10
6/45	(20/150)	0.13	0.13	0.13	0.13
FAR FIELD CHART (m)					
6/30	(20/100)	0.20	0.20	0.20	0.20
6/24	(20/80)	0.25	0.25	0.25	0.25
6/18	(20/60)	0.33	0.33	0.33	0.33
6/15	(20/50)	0.40	0.40	0.40	0.40
6/12	(20/40)	0.50	0.50	0.50	0.50
6/9	(20/30)	0.67	0.67	0.67	0.67
6/7.5	(20/25)	0.80	0.80	0.80	0.80
6/6	(20/20)	1.00	1.00	1.00	1.00
6/4.8	(20/16)	1.25	1.25	1.25	1.25
6/3.8	(20/12)	1.7	1.7	1.7	1.7
6/3.0	(20/10)	2.0	2.0	2.0	2.0
6/2.4	(20/8)	2.5	2.5	2.5	2.5
6/1.7	(20/6)	3.3	3.3	3.3	3.3
6/1.5	(20/5)	4.0	4.0	4.0	4.0
NEAR FIELD CHART		Bottom Nine Lines Adjusted To 4m			
6/1.25	(20/4)	5.0	5.0	5.0	5.0
6/1.05	(20/3.3)	6.0	6.0	6.0	6.0
6/0.8	(20/2.7)	7.5	7.5	7.5	7.5
6/0.6	(20/2.0)	10	10	10	10
6/0.5	(20/1.7)	12	12	12	12
6/0.40	(20/1.3)	15	15	15	15
6/0.3	(20/1.1)	20	20	20	20
6/0.25	(20/.08)	24	24	24	24
6/0.20	(20/.07)	30	30	30	30

VISUAL ACUITY RATIOS NOTED MEAN:

READABLE AT ACTUAL TEST DISTANCE

READABLE DISTANCE WITH STANDARD VISION

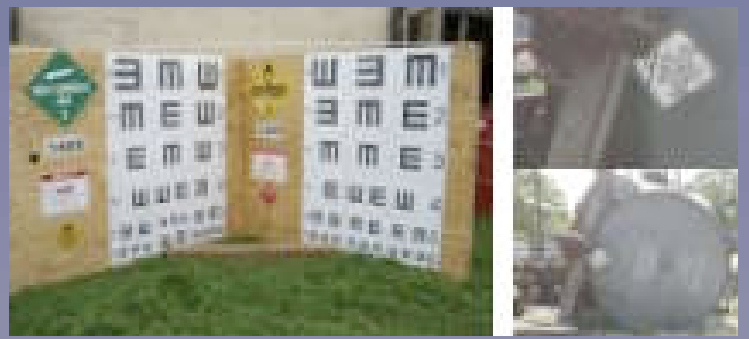
CIRCLE DECIMAL EQUIVALENT IN EACH COLUMN

Near Field Test (distance = 0.40 m)

EQUIVALENT DISTANCE 6 M	(20 FT)	LIGHTED CHART (_____ LUX) NORMAL	ZOOM	DARK CHART (_____ LUX) NORMAL	ZOOM
NEAR FIELD CHART		All Lines Shown for 0.4m			
6/120	(20/400)	0.05	0.05	0.05	0.05
6/96	(20/320)	0.06	0.06	0.06	0.06
6/75	(20/250)	0.08	0.08	0.08	0.08
6/60	(20/200)	0.10	0.10	0.10	0.10
6/48	(20/160)	0.12	0.12	0.12	0.12
6/38	(20/125)	0.16	0.16	0.16	0.16
6/30	(20/100)	0.20	0.20	0.20	0.20
6/24	(20/80)	0.25	0.25	0.25	0.25
6/19	(20/63)	0.32	0.32	0.32	0.32
6/15	(20/50)	0.40	0.40	0.40	0.40
6/12	(20/40)	0.50	0.50	0.50	0.50
6/9.5	(20/32)	0.63	0.63	0.63	0.63
6/7.5	(20/25)	0.80	0.80	0.80	0.80
6/6.0	(20/20)	1.00	1.00	1.00	1.00
6/4.8	(20/16)	1.25	1.25	1.25	1.25
6/3.8	(20/12)	1.60	1.60	1.60	1.60
6/3.0	(20/10)	2.00	2.00	2.00	2.00

Test Leader Date Notes ☐

Snellen Eye chart correlated to Relevant Visual Targets



Example: Wireless Communications Range

Requirements Addressed	
Communications	Range - Line of Sight
Communications	Range - Beyond Line of Sight

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

Developing

Standard Test Methods For Response Robots

Version: 2007.4

RADIO COMMS (LINE-OF-SIGHT)

ROBOT: _____ ☐TETHER ☐RADIO

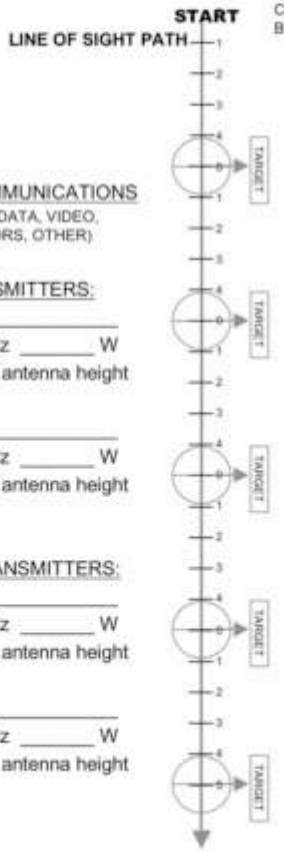
OPERATOR: _____ ORG: _____

TRAINING TIME: ☐ 0-24 HRS ☐ 24-100 HRS ☐ > 100 HRS

INSTRUCTIONS: WHILE TRAVERSING THE PATH SHOWN, STOP AND READ THE SMALLEST COMPLETE LINE ON THE VISUAL ACUITY TARGETS UNTIL PERFORMANCE DEGRADES TO UNUSABLE. THEN RETURN READING ALL THE SAME TARGETS IN REVERSE ORDER. ANTENNA HEIGHT < 2 METERS.

ADMINISTRATOR: 1) NOTE ALL RADIO INFORMATION. 2) NOTE THE DISTANCES FROM THE START POINT TO EACH EQUALLY SPACED TARGET. 3) NOTE THE TIME ON TARGET TO POINT TO AND READ THE SMALLEST CORRECT LINE. 4) CIRCLE LAST LINE MARKER IF FARTHEST RANGE IS BETWEEN TARGETS.

START TIME: _____



RADIO COMMUNICATIONS
(COMMANDS, DATA, VIDEO, AUDIO, SENSORS, OTHER)

OCU TRANSMITTERS:
Content: _____
_____ MHz _____ W
_____ cm antenna height

Content: _____
_____ MHz _____ W
_____ cm antenna height

ROBOT TRANSMITTERS:
Content: _____
_____ MHz _____ W
_____ cm antenna height

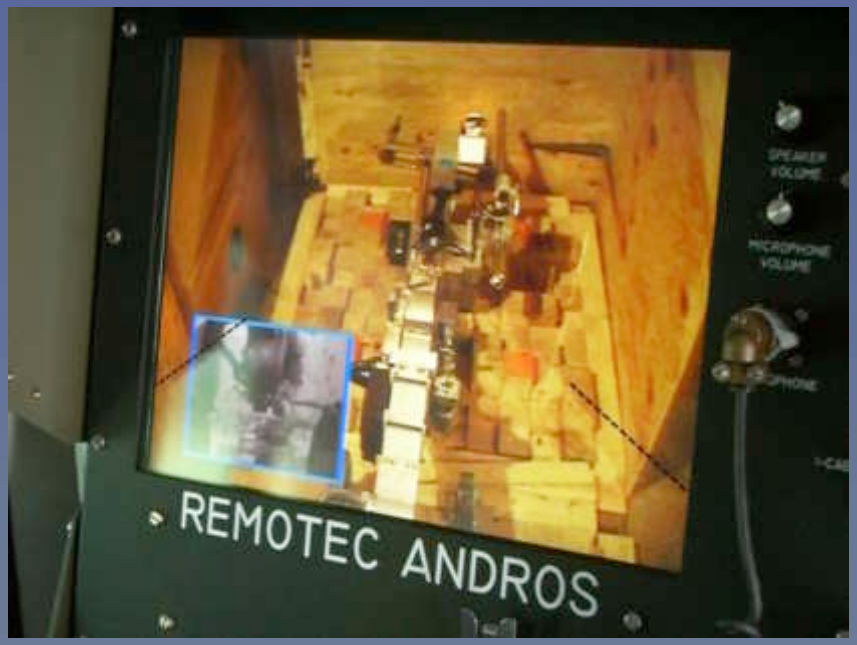
Content: _____
_____ MHz _____ W
_____ cm antenna height

	OUTBOUND	INBOUND
1ST TARGET:	_____ meters	
ARRIVAL TIME:	_____	_____ m:s
TIME ON TARGET:	_____	_____ m:s
SMALLEST ACUITY:	_____	_____ (decimal)
2ND TARGET:	_____ meters	
ARRIVAL TIME:	_____	_____ m:s
TIME ON TARGET:	_____	_____ m:s
SMALLEST ACUITY:	_____	_____ (decimal)
3RD TARGET:	_____ meters	
ARRIVAL TIME:	_____	_____ m:s
TIME ON TARGET:	_____	_____ m:s
SMALLEST ACUITY:	_____	_____ (decimal)
4TH TARGET:	_____ meters	
ARRIVAL TIME:	_____	_____ m:s
TIME ON TARGET:	_____	_____ m:s
SMALLEST ACUITY:	_____	_____ (decimal)
5TH TARGET:	_____ meters	
ARRIVAL TIME:	_____	_____ m:s
TIME ON TARGET:	_____	_____ m:s
SMALLEST ACUITY:	_____	_____ (decimal)

TEST LEADER DATE NOTES

Example: Directed Perception Test Method

(eye charts, hazmat labels, thermal, chemical, radiological, explosive)




Cache Packaging


Confined Space


Human Factors

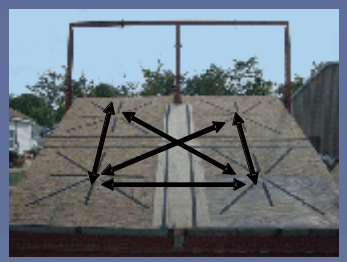
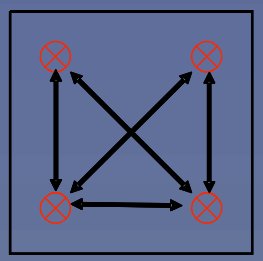

Stairs


Visual Acuity


Mobility/Endurance


Radio Comms


Remote Situational Awareness

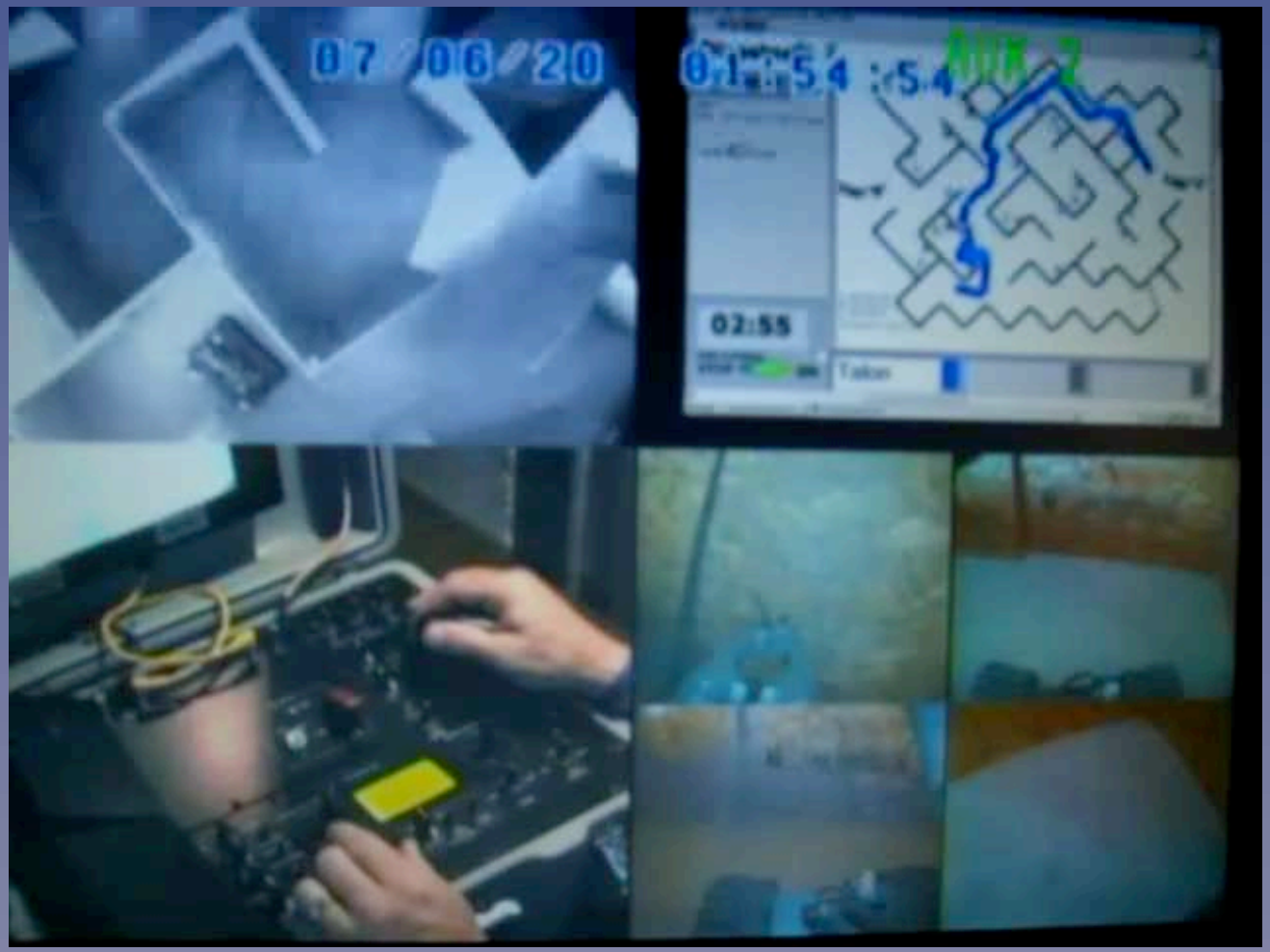
Inclined Plane


Directed Perception


Random Stepfields


Grasping Dexterity

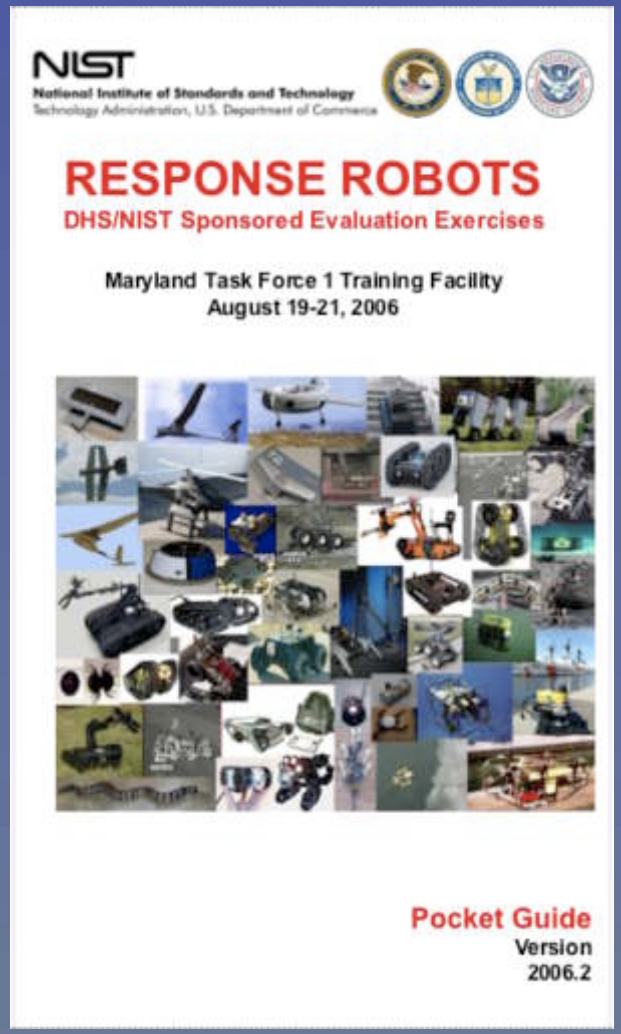
Common Underlying Artifacts & Measurement Infrastructure



Quad Screen, Time-tagged video capture of tests, including ultra wide band tracking of robot position within test areas

Pocket Guide - Per Event

http://www.isd.mel.nist.gov/US&R_Robot_Standards/



- Program Overview
- Event Introduction
- Site Overview
- Safety
- Test Methods and Artifacts
- Participating Robots
  - Ground
  - Wall Climbers
  - Aerial
  - Aquatic
- Sensors
- Index

Response Robot Exercises: Validating the Tests; Characterizing the Application

- Held at FEMA US&R Training Facilities
  - *Nevada (8/05)*
  - *Texas (4/06, 6/07, 11/08)*
  - *Maryland (8/06)*
- 23 FEMA Task Forces have Participated
- 34 organizations have brought 46 robots (aerial, ground, aquatic)

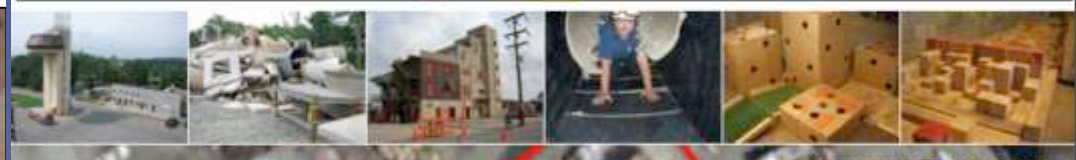
Response Robot Evaluation Exercise

TX-TF1 Training Facility - Disaster City
College Station, TX
April 4-6, 2006
(with a standards meeting April 7, 2006)
www.isd.mel.nist.gov/us&r_robot_standards
usar.robots@nist.gov

Response Robot Evaluation Exercise

MD-TF1 Training Academy
Rockville, MD
August 19-21, 2006
(with a standards meeting August 21, 2006)

www.isd.mel.nist.gov/us&r_robot_standards usar.robots@nist.gov



Marsupial Deployment of
Omnitech Toughbot by Talon

Foster-Miller Talon Finding
Simulated Victim

Bomb Squads Robots - Updating Requirements, Testing the Tests: MetroTech Meeting at NIST

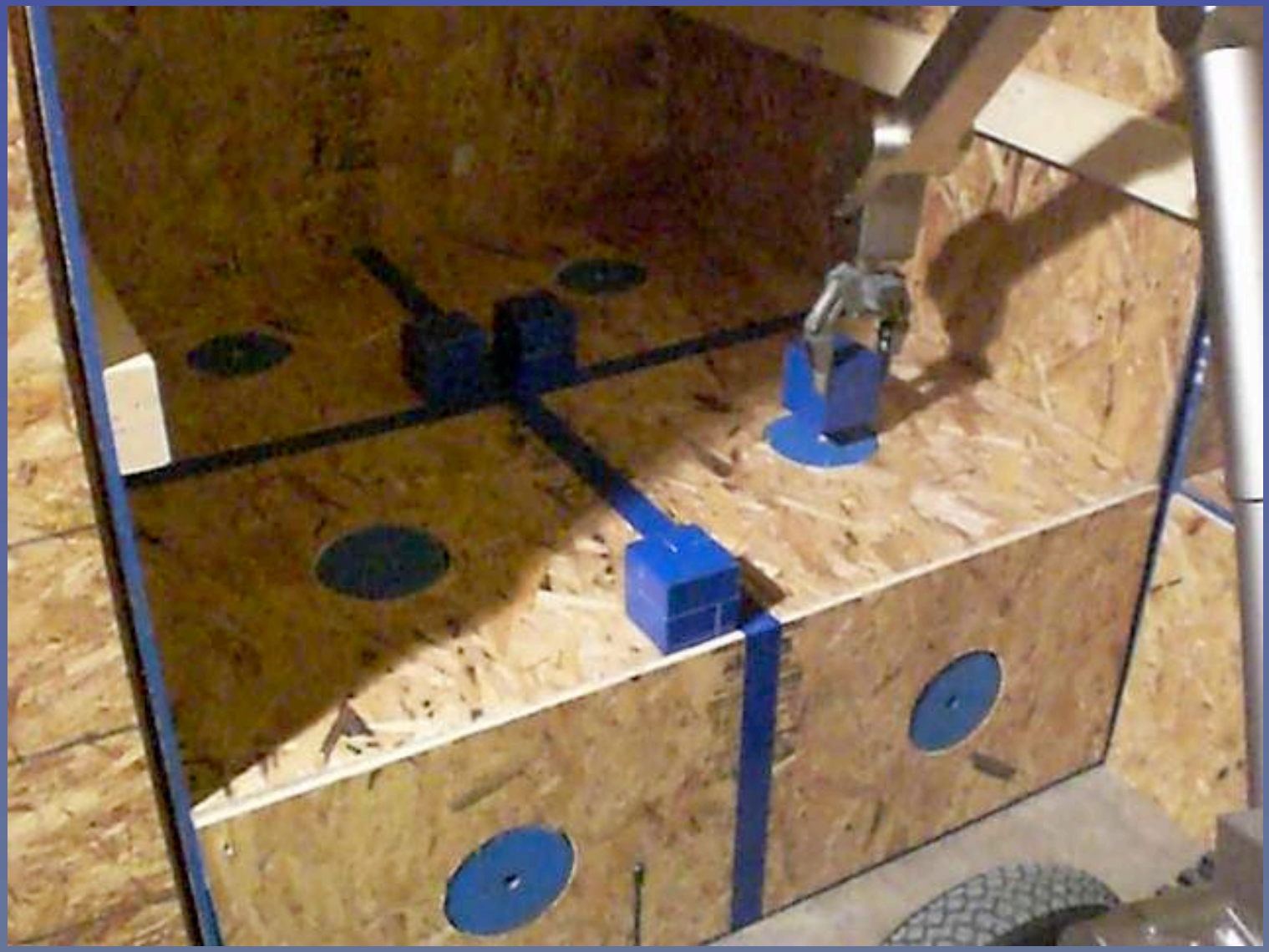
Mobile Manipulation: Directed Perception

Example of an Abstract Test Method

Apparatus: Shelves with face/top holes (up to 4 levels) and terrains: flat, roll, stepfields
Method: Identify targets inside holes (visual, CBRNE) with three constraints: open, over, under
Measure: Number targets identified at each level with each constraint, time

Mobile Manipulation: Grasping Dexterity

Example of an Abstract Test Method



Apparatus: Shelves with top holes (up to 4 levels) and terrains: flat, roll, stepfields
Method: Place blocks into holes with three constraints: open, over, under
Measure: Number of blocks placed at each level with each constraint, time

Summary

Robotics and associated technologies provide a diverse and evolving set of capabilities for emergency response.

To get these advanced tools into the hands of emergency responders, we are:

- Measuring performance of robots in reproducible, repeatable ways that can correlate to use in the field
- Developing concepts of operation and match the right characteristics to different deployment needs
- Moving toward statistically significant repetitions to capture performance and reliability
- Standardizing performance test methods through ASTM International

Summary

Robotics and associated technologies provide a diverse and evolving set of capabilities for emergency response.

To get these advanced tools into the hands of responders, we are:

- Measuring performance of robots in reproducible, repeatable ways that can correlate to use in the field
- Developing concepts of operation and match the right characteristics to different deployment needs
- Moving toward statistically significant repetitions to capture performance and reliability
- Standardizing performance test methods through ASTM International

Acknowledgments

This work would not be possible without the contributions of:

- The FEMA USAR Task Force members, representing 23 Task Forces, who ably advise us throughout the process
- The Metrotech and Michigan bomb squads, the National Bomb Squad Commander's Advisory Board, the Hazardous Devices School instructors, TSWG, and others who have defined the requirements for bomb disposal robots
- All the manufacturers and researchers who have voluntarily participated in the exercises and subjected their robots to testing
- The Department of Homeland Security, Science and Technology Directorate, Standards Office
- The National Institute of Justice Office of Science and Technology
- The Standards Working Groups and Support Team (at NIST and elsewhere) including, but not limited to: Adam Jacoff, Brian Antonishek, Stephen Balakirsky, Tony Downs, John Evans, Hui-Min Huang, Galen Koepke, Alan Lytle, Philip Mattson, Bill McBride, Mark Micire, Kate Remley, Debra Russell, Jeanenne Salvermoser, Salvatore Schipani, Craig Schlenoff, Jean Scholtz, Chris Scrapper, Ann Virts, and Brian Weiss

Thank You!

For more information about

Performance Standards
for
Response Robots:

http://www.isd.mel.nist.gov/US&R_Robot_Standards/

usar.robots@nist.gov