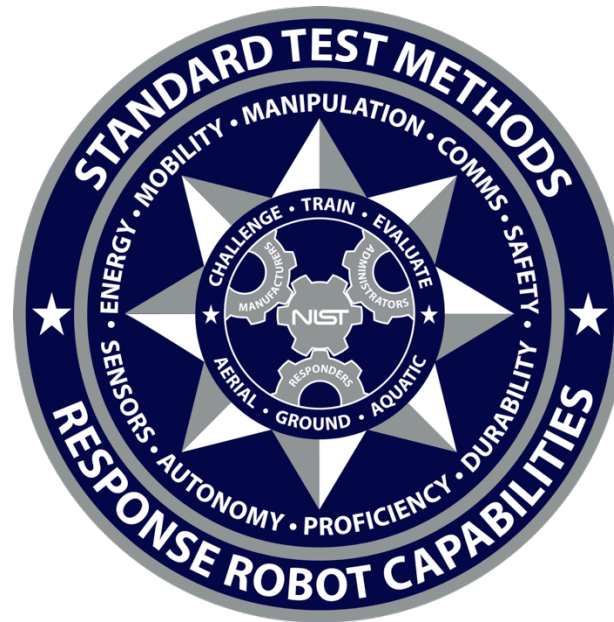


Standard Test Methods for Evaluating, Purchasing, and Training with Response Robots



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

Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



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

Mobility

Dexterity

Endurance

Sensors

Radio Comms

Durability

Logistics

Safety

Autonomy

Proficiency



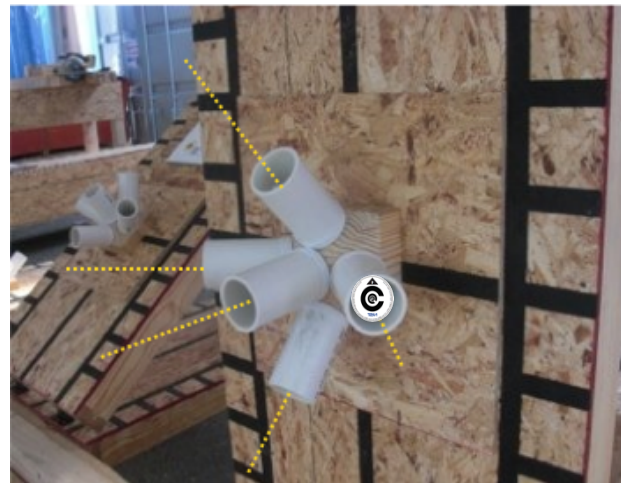
“Standard Test Methods” not “Standard Robots”

Consensus Process Produces Agreed Upon Ways to Test Robots

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



Sensor Targets for
Visual Acuity



Manipulator Dexterity Tasks



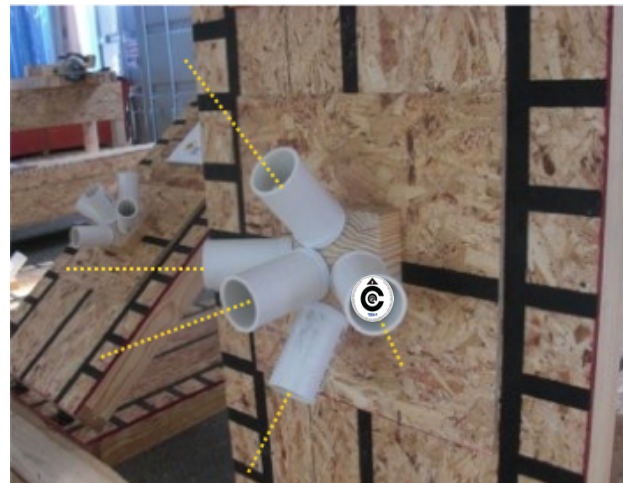
Mobility Terrains and
Obstacles

“Standard Test Methods” not “Standard Robots” Consensus Process Produces Agreed Upon Ways to Test Robots

- **Apparatus:** A repeatable, reproducible, and inexpensive representation of a task you expect the robot to perform.
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Sensor Targets for
Visual Acuity

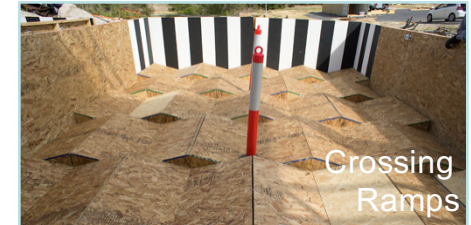


Manipulator Dexterity Tasks



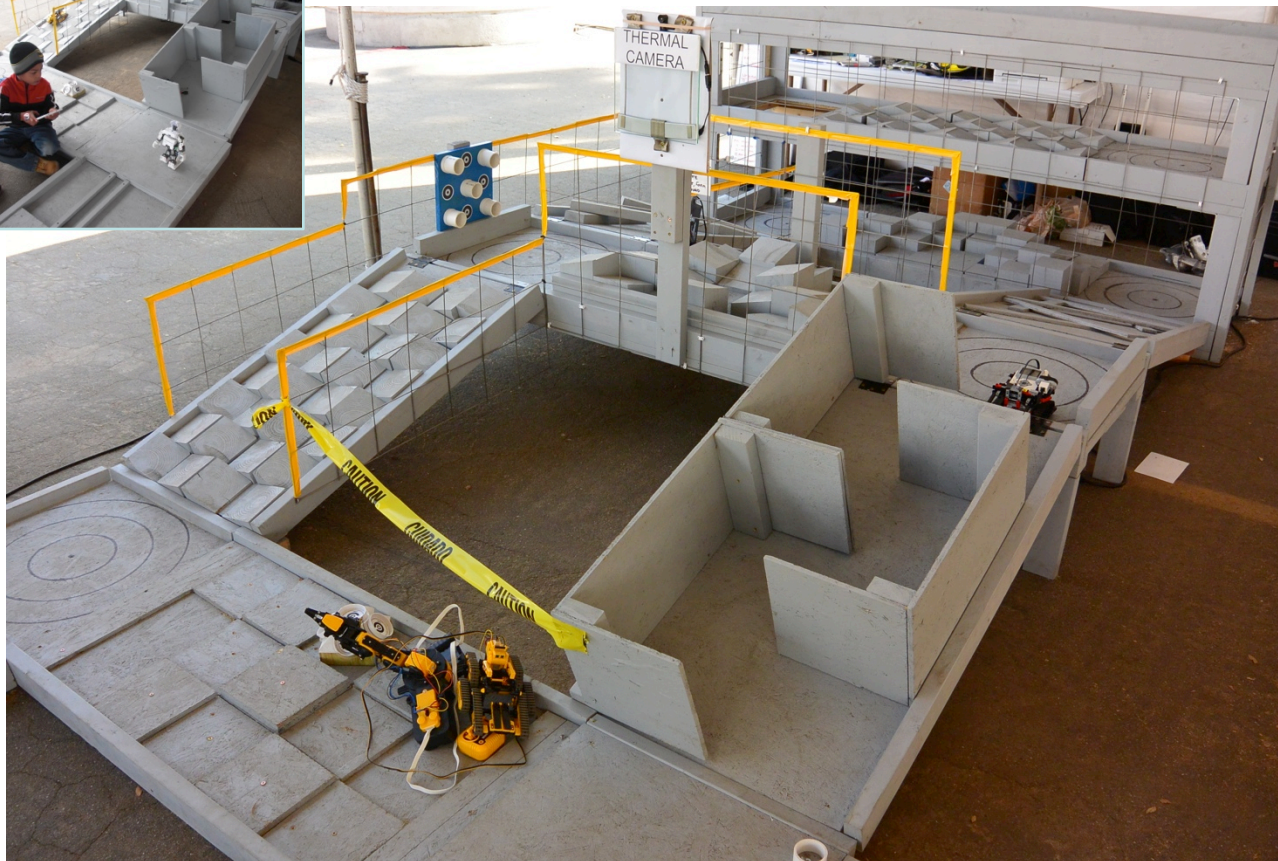
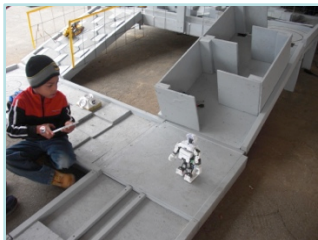
Mobility Terrains and
Obstacles

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



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

Mini Arena Scale: 30cm (12 in) Lateral Clearance)



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.



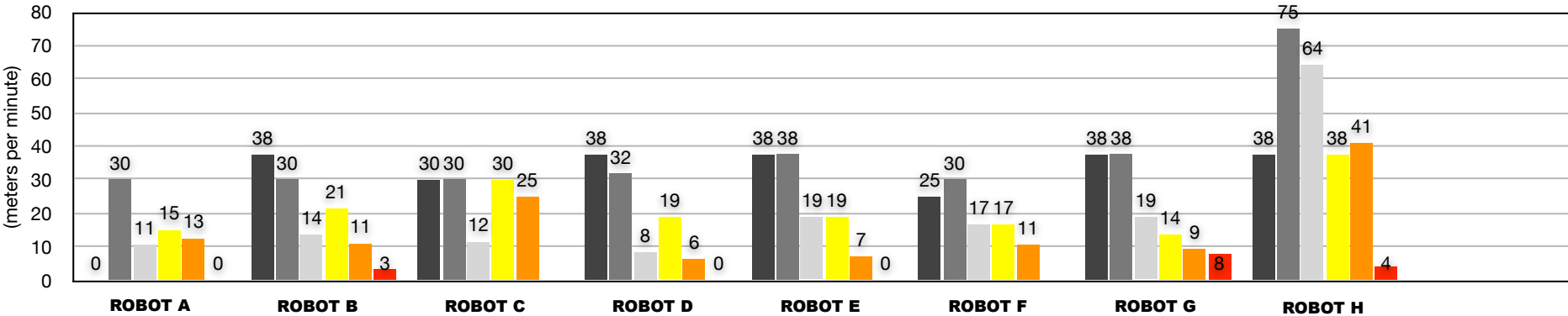
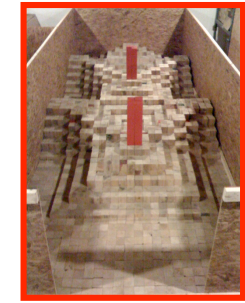
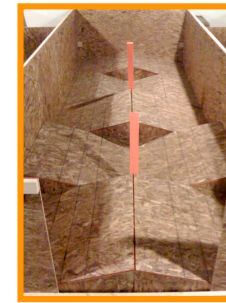
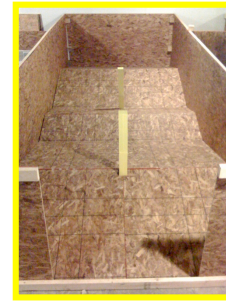
Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



Quantitative Comparison of Capabilities Works for Robots and/or Operators on a Given Robot

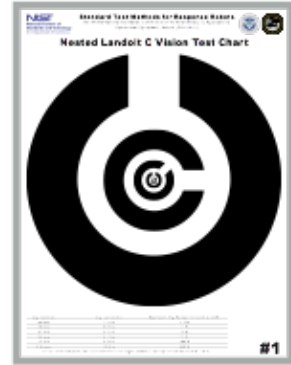
Sand
 Gravel
 Flat Line Following
 Continuous Ramps
 Crossing Ramps
 Stepfields



Average Rate of Advance on Terrain (at least 100m/10repetitions)

Basic Skills: Maneuvering (5)

Drive forward then reverse | 10 minute time limits | 50 minutes overall



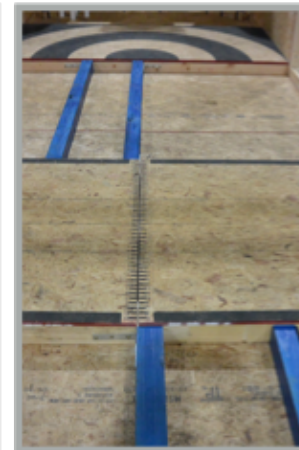
Near Field and Far Field Visual Acuity Charts



Follow Lines



Center In Alleys



Align Edges



Pitch/Roll Rails

Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



Basic Skills: Dexterity and Strength (5)

Drive as necessary | 10 minute time limits | 50 minutes overall



**Inspect
Acuity
Charts**



**Touch
Targets**



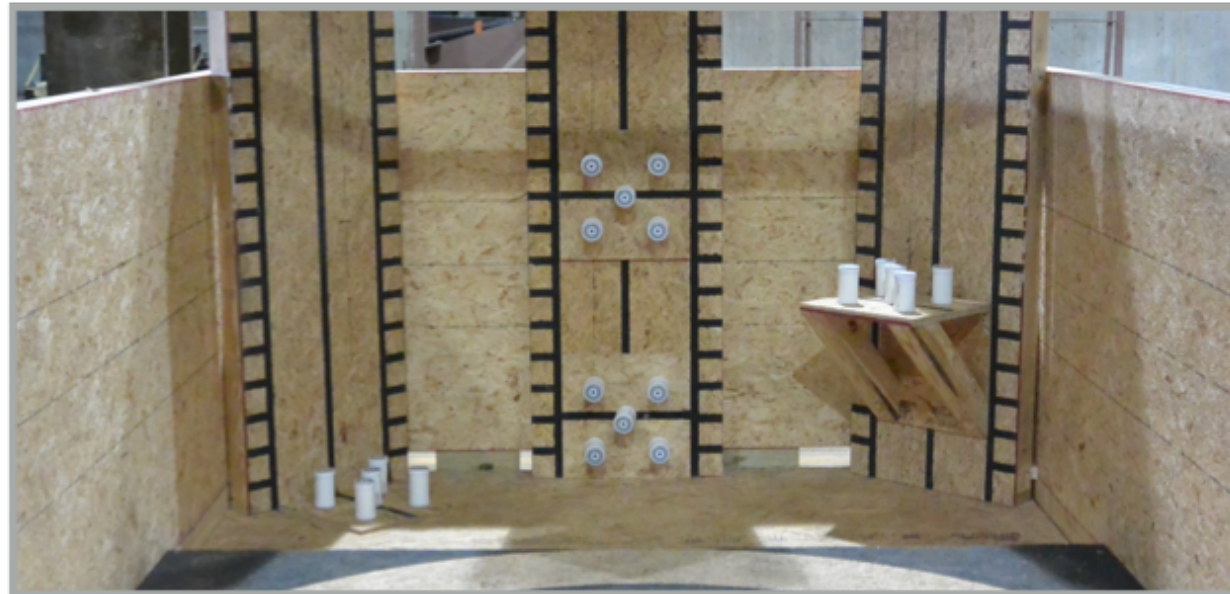
**Extract
Objects**



**Rotate
Features**



**Lift Strength
(on a slope)**



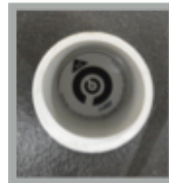
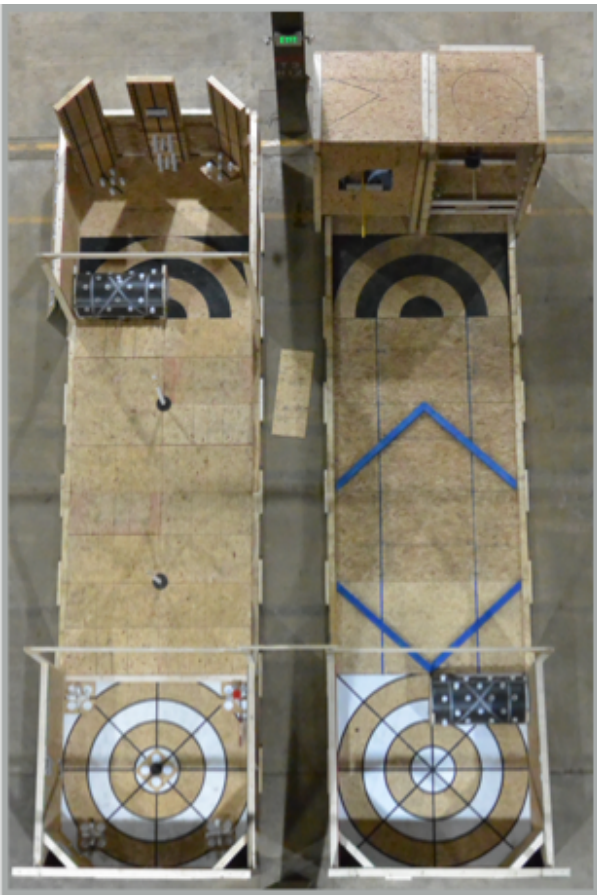
Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
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Mission Essential Tasks: Small Objects (5)

Drive as necessary | 10 minute time limits | 50 minutes overall



**Inspect
Acuity
Charts**



**Aim
Disruptors**



**Extract
Objects**



**Lift / Move
Package**

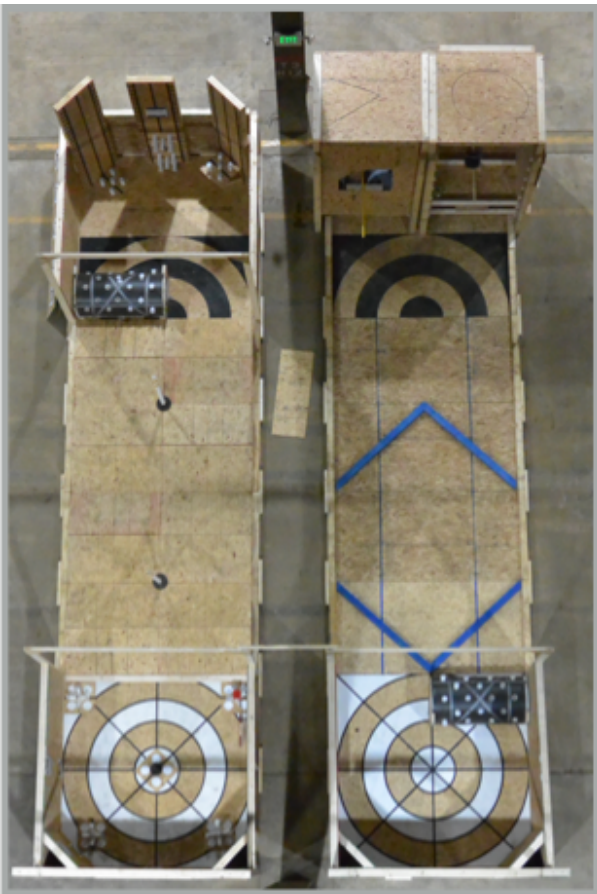


**Place Mineral
Water Bottle or
X-Ray Panel**



Mission Essential Tasks: Large Objects (5)

Drive as necessary | 10 minute time limits | 50 minutes overall



**Inspect
Acuity
Charts**



**Aim
Disruptors**



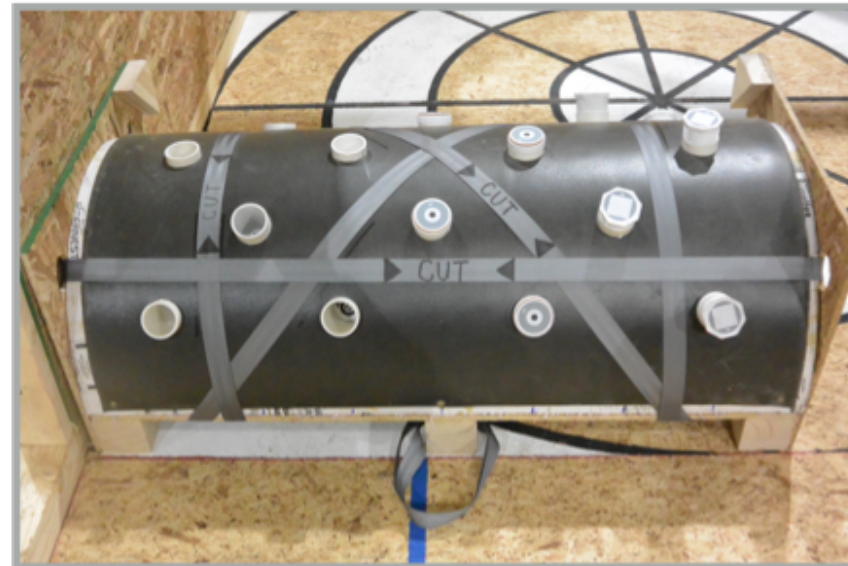
**Extract
Objects**



**Cut
Straps**



**Lift / Roll
Over**



Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



Mission Essential Tasks: Building Access (5)

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

environment)



Open Doors



Surmount Hurdle



Ascend/Descend
Stairs



Entangle Obstacles



Negotiate Hallways

Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



Mission Essential Tasks: Confined Space Access (5)



The Same Test Methods Help Different Users Facilitate Communications and Results

Robot Developers

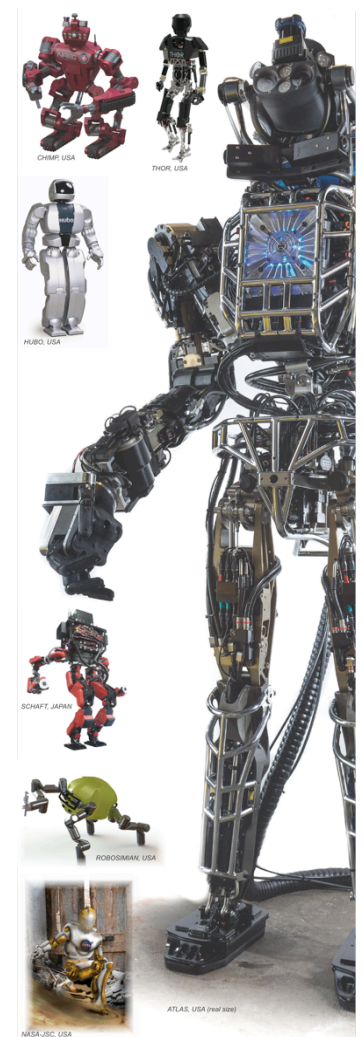
- Understand missions through tangible test apparatuses
- Practice and refine robot designs, make trade-off decisions
- Highlight “Best-In-Class” capabilities

Responders, Soldiers, and Other Users

- Compare robots with objective data, not marketing
- Specify purchases based on existing combinations of capabilities
- Align expectations with deployment decisions

Program Managers

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



Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
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Sponsors

Adopting and Developing
New Test Methods



Robot Purchases

Using Data From
Existing Test Methods

\$60M / 60B Yen



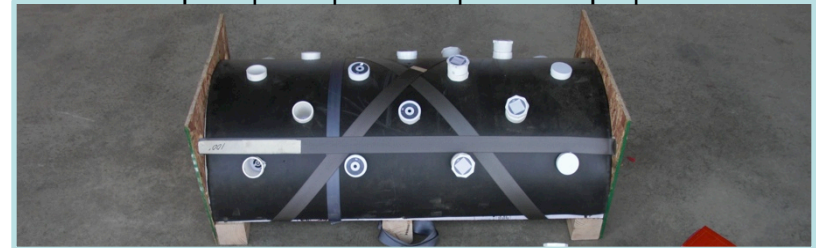
Adoption by Bomb Squad Community

- National Bomb Squad Commanders Advisory Board (NBSCAB) saw value in our approach and asked to address IED/PBIED/VBIED missions.
- Formed bomb technician working group from NBSCAB Volunteer list and generated 30 test methods to evaluate basic skills and mission essential tasks.
- Hosted a series of test method validation exercises with bomb squad commanders, robot manufacturers, and bomb technicians for training.
- Currently collecting robot capabilities data to standardize the test methods (15 so far).

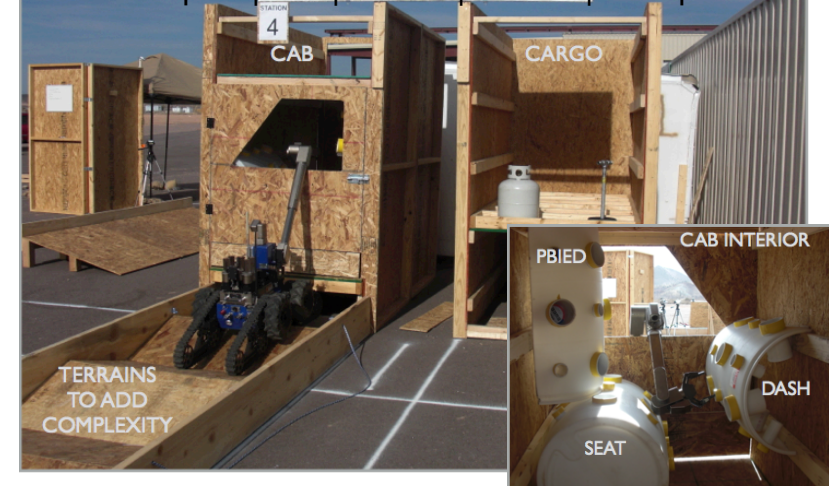
IED: Lift & Carry | Inspect | Aim | Extract | MWB/Xray



PBIED: Inspect | Aim | Extract | Cut Straps | Roll Over



VBIED: Inspect | Aim | Extract | Access | Disrupt



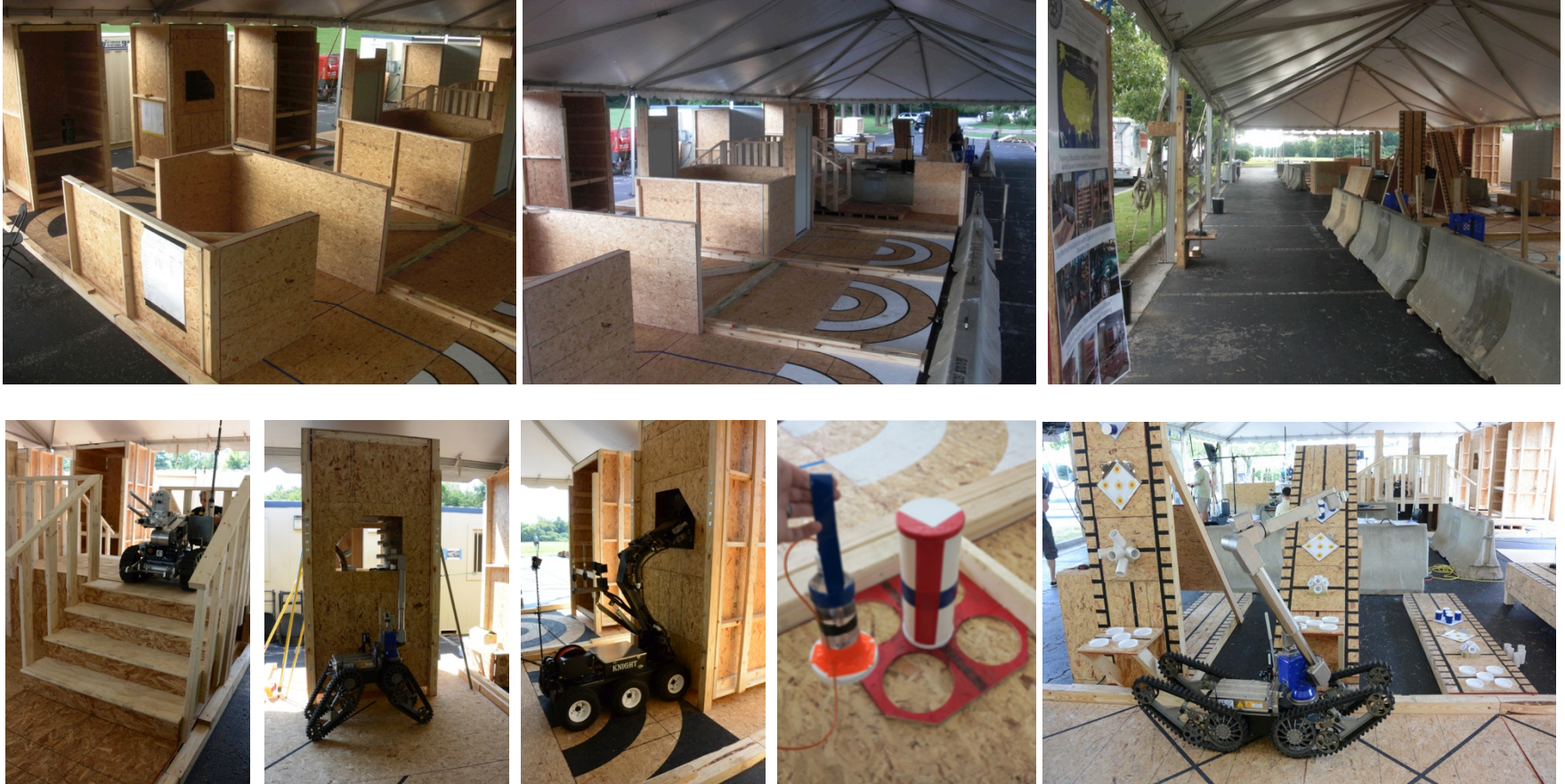
Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
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Validation Exercises for Robot Users

Mission Task Representations, Variable Settings and Complexity, Sequences



30 Test Methods: 10 Basic Skills, 15 IED/PBIED/VBIED, 5 Building Access

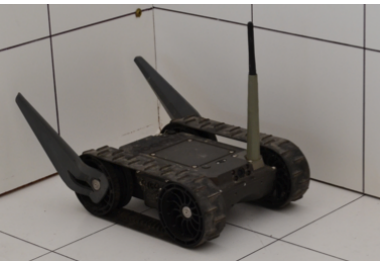
Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



Validation Exercises for Robot Developers

Various Robot Sizes and Capabilities To Ensure Tests Scale Effectively



iRobot 110 FirstLook
2.4kg (5.2lbs)



Qinetiq Dragon Runner 10
4.5kg (10lbs)



iRobot 310 SUGV
13.2kg (29lbs)



ICOR Caliber Mini
27kg (65lbs)



Remotec Titus
61kg (135lbs)



ICOR Caliber T5
64kg (140lbs)



Cobham Telemax
80kg (175lbs)



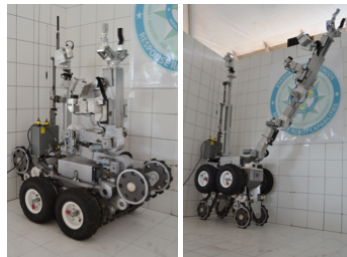
ICOR Caliber MK3
84kg (185lbs)



Remotec HD-SEL
111kg (245lb)



iRobot 710 Kobra
166.5kg (367lbs)



Remotec F6B
220kg (485lb)



WM Robotics Knight
249kg (550lbs)

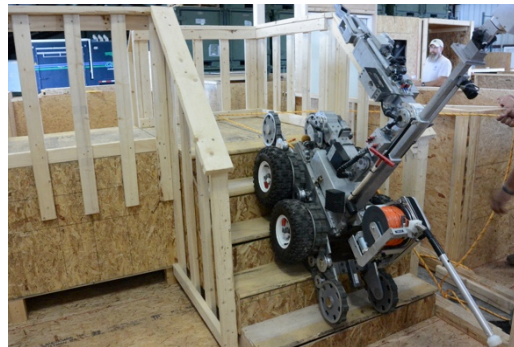
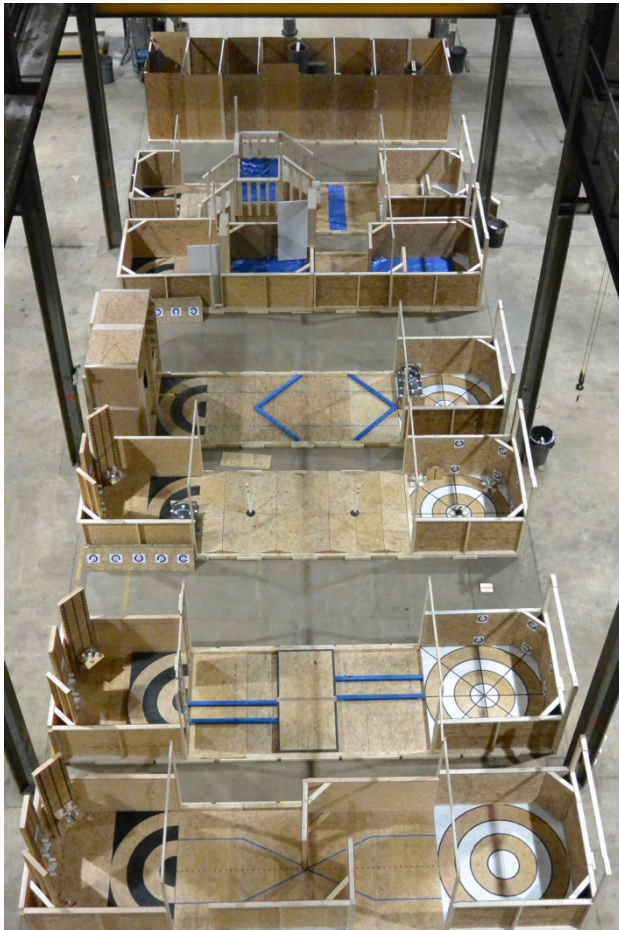


Remotec Mark 5-A 358kg (790lbs) Remotec Wolverine 367kg (810lbs)

Validation Exercises for Operator Training

(4) JPO C-IED Interoperability Exercises (aka Raven's Challenges)

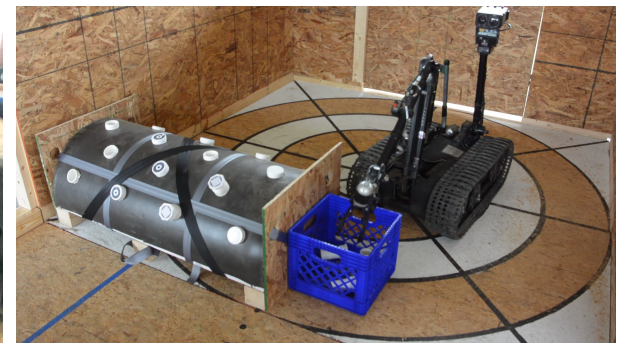
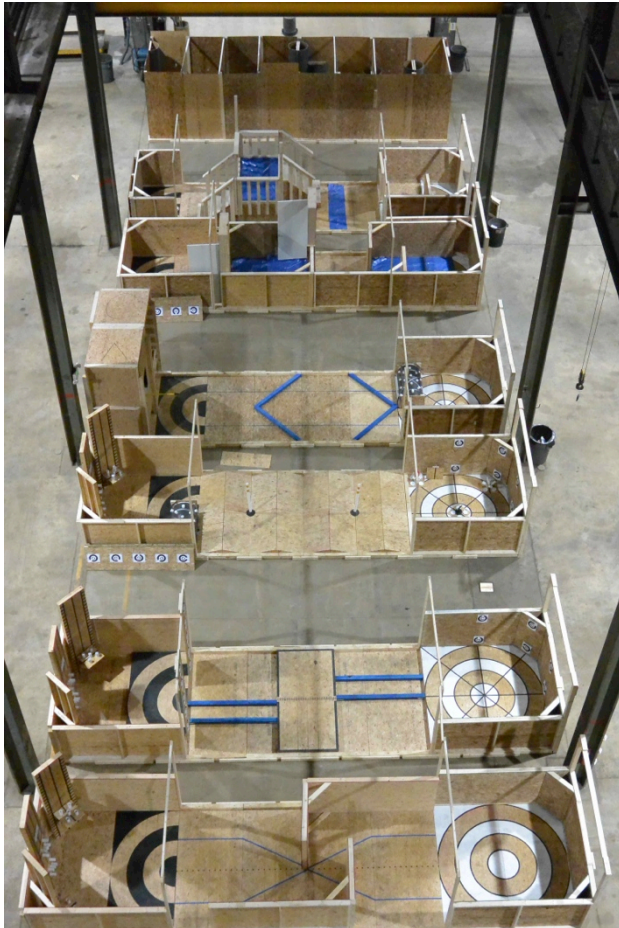
30 Test Methods: 10 Basic Skills, 15 IED/PBIED/VBIED, 5 Building Access



Validation Exercises for Operator Training

(4) JPO C-IED Interoperability Exercises (aka Raven's Challenges)

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“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!**

“Standard Test Methods in a Box”

Focus Training, Repeat Tasks and Sequences, Measure Proficiency and Readiness

Practice Tasks



- Repeat to gain muscle memory
- Identify weaknesses
- Measure proficiency using several different tasks in 5-10 minute trials (60 minutes total)

Combine/Sequence



- Repeat to improve interactions/tempo
- Increase complexity in stepwise ways
- Measure proficiency using repeatable sequences in 30-60 minute trials

Embed into Scenarios



- Repeat to quantify readiness
- Uncontrolled variables involved
- Measure readiness using repeatable sequences in 60-90 minute trials

Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



“Standard Test Methods in a Box”

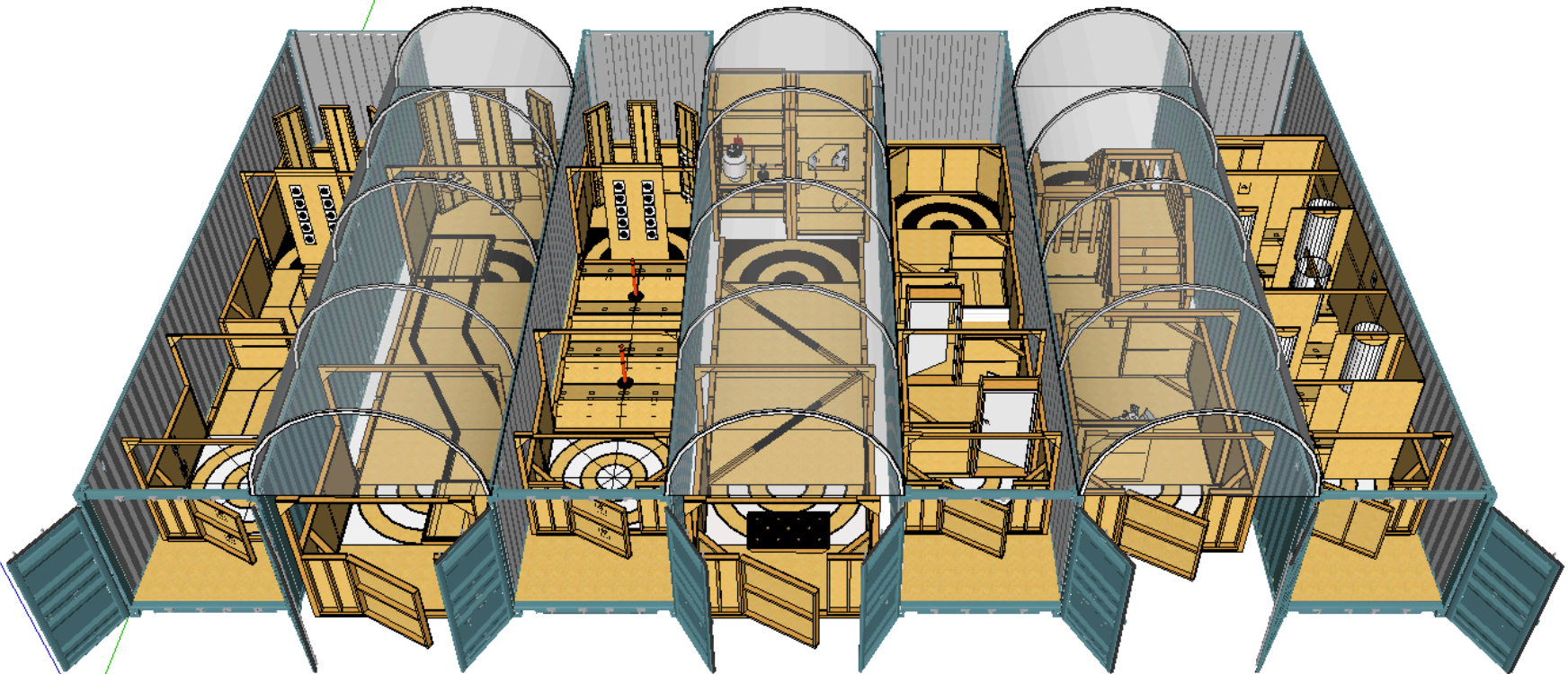
Focus Training, Repeat Tasks and Sequences, Measure Proficiency and Readiness



“Standard Test Methods in a Box”

Idea for ISO Container Facility

- 4 lanes inside ISOs have easy lights out testing, radio attenuated, all weather.
- 3 lanes between ISOs have higher arched canvas tarp covers secured to ISOs, good for stairs, doors, taller dexterity test methods.



Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
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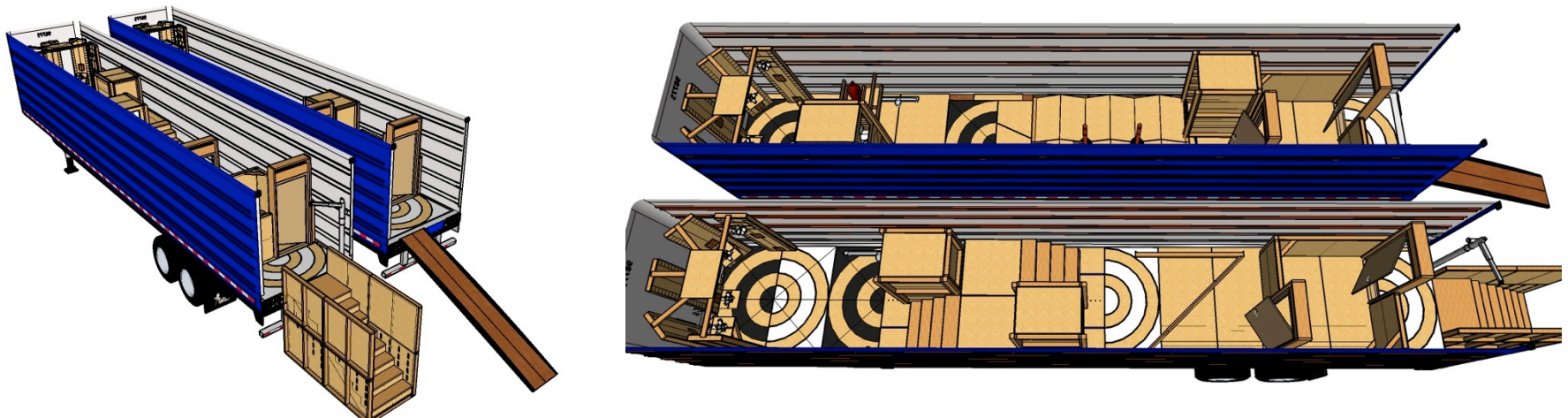
“Standard Test Methods in a Box” Idea for Tractor Trailer Mobile Facility

Each 53ft long trailer can hold 10 test methods, themed as:

- Basic skills
- Mobility or Dexterity
- Combo sequence

All trailers can be different, so rotating among users maintains interest.

Gather all regional trailers at Special Events (Super Bowl or Regional IABTI Training Exercise) to form a full facility.



Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
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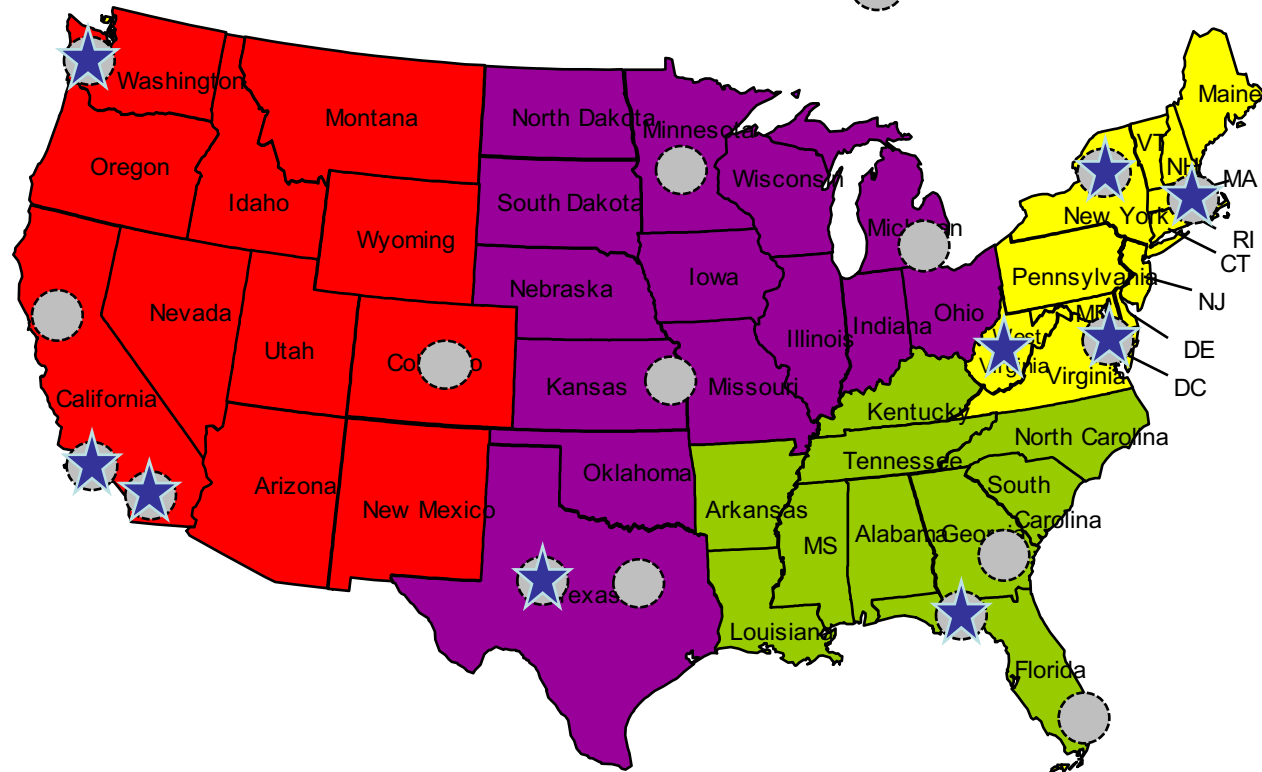


- NIST's Robot Test Facility
Gaithersburg, MD (2006)
- Southwest Research Institute
San Antonio, TX (2010)
- University of Massachusetts
Lowell, MA (2013)
- Army Camp Dawson
WV (2013)
- Air Force Tyndall AFB
Panama City, FL (2014)
- San Diego Fire Department
San Diego, CA (2014)
- Port of Seattle Police Dept.
Seattle, WA (June 2015)
- NY State Dept. of Homeland Security
Oriskany, NY (June 2015)
- Navy SPAWAR
San Diego, CA (2016)

Facilities in USA

110 Requests from Bomb Squads
(of 466 nationwide)

- ★ Existing Facilities
(Validate/Train)
- FY16 Plan



Standard Test Methods For Response Robots

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Southwest Research Institute
Dept. of Electronics and Robotics
San Antonio, TX, USA
(Established 2010)



Test Director: Holly Yanco
New England Robot Validation
and Experimentation Center
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Test Director: Johannes Pellenz
Bundeswehr Technical Center for
Engineer and General Field Equipment
Koblenz, Germany
(Established 2012)



Test Director: Satoshi Tadokoro
International Rescue System
Institute and Tohoku University
Kobe and Sendai, Japan
(Established 2011)



NIST
National Institute of
Standards and Technology
U.S. Department of Commerce
Test Director: Adam Jacoff
National Institute of Standards and Technology
Intelligent Systems Division
Gaithersburg, MD, USA
(Established 2005)

New Facilities

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



Test Director: Christopher Scrapper
SPAWAR
Systems Center Pacific
San Diego, CA, USA
(Opening 2014)

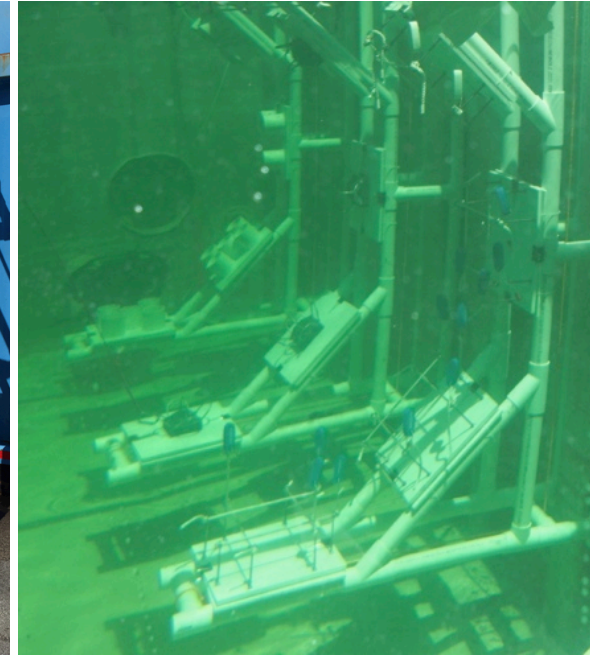


Test Directors: Raymond Sheh and Bill Collidge
Curtin University of Technology and
Western Australia Police Bomb Response Unit
Perth, WA, Australia
(Opening 2013)

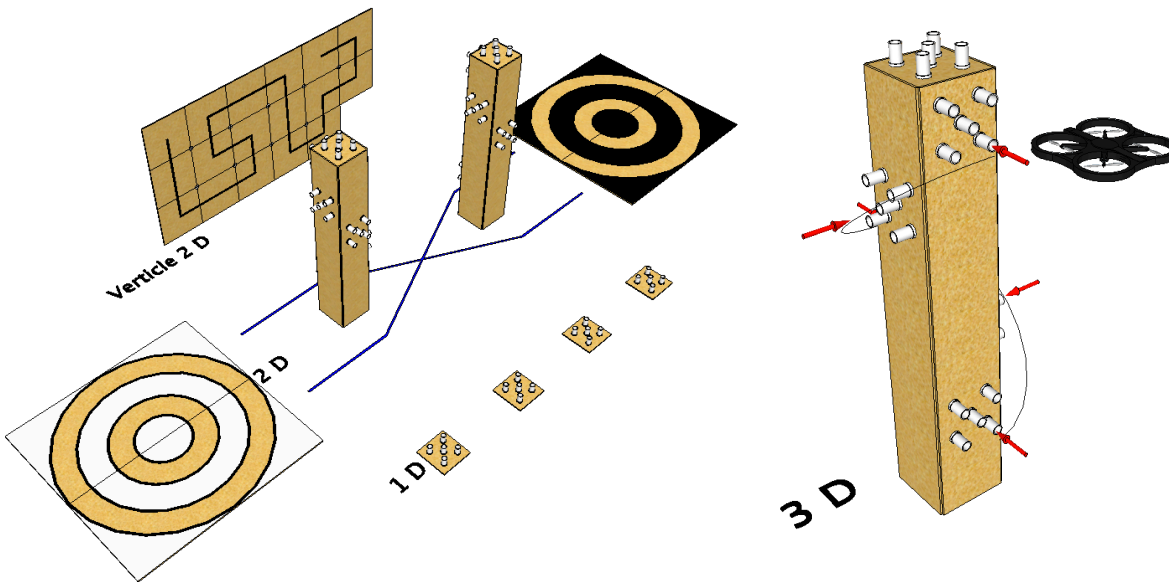


Examples of Aquatic Test Methods

Baseline Capabilities in a Water Tank Before Adding Variables



Examples of Aerial Test Methods Baseline Capabilities for Small UAS (<5kg)

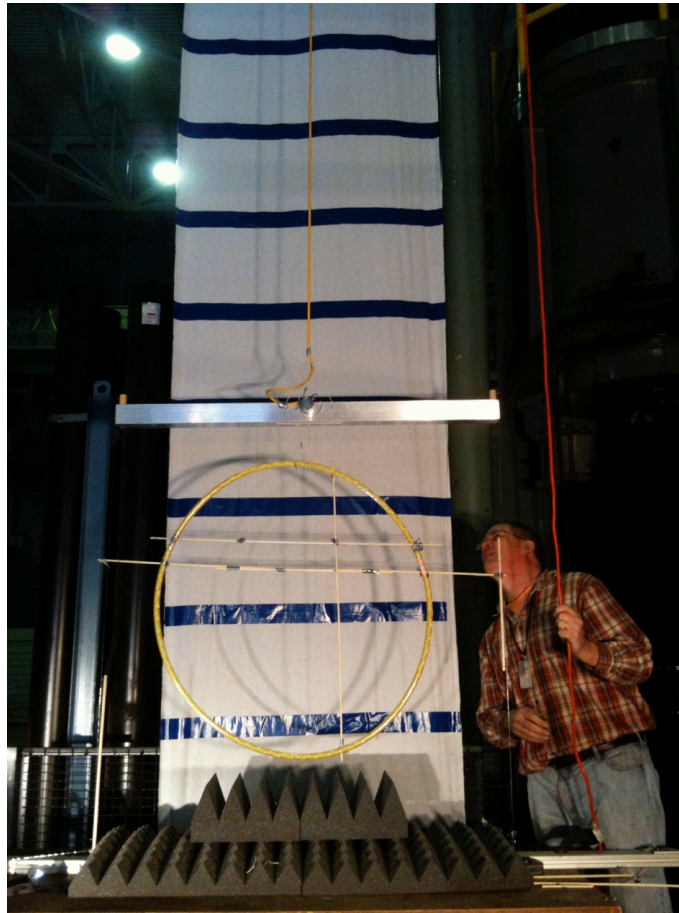


Standard Test Methods For Response Robots

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Examples of Aerial Test Methods Air Worthiness and Safety for Small UAS (<5kg)



Standard Test Methods For Response Robots

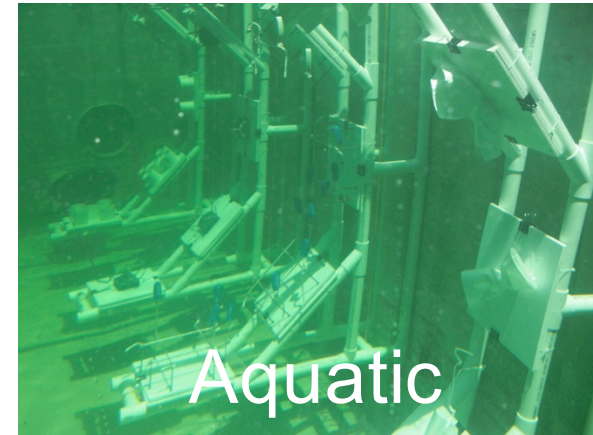
ASTM International Standards Committee on Homeland Security Applications;
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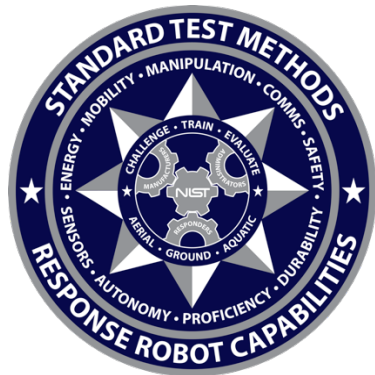
Ground



Aerial



Aquatic



Adam Jacoff

Intelligent Systems Division, Engineering Laboratory

National Institute of Standards and Technology

Gaithersburg, MD 20899 USA

RobotTestMethods@nist.gov

www.nist.gov/el/isd/ms/RobotTestMethods.cfm

**Download
Assembly Guide
and
Usage Guide**

Standard Test Methods For Response Robots

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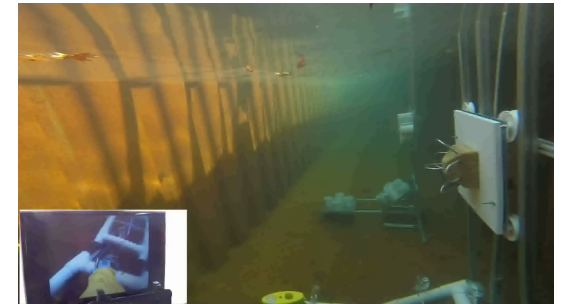
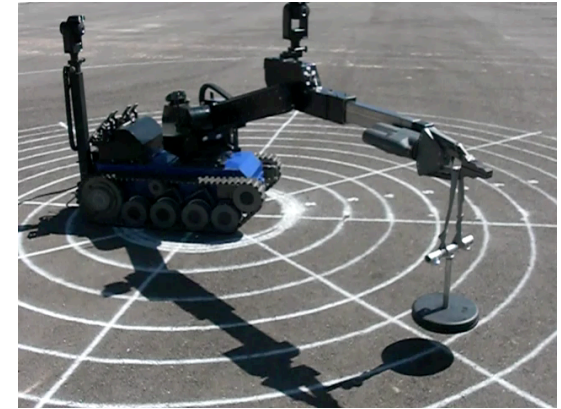


It's a small robotics world out there, but too big and fast moving to get your mind around.

- Linguistics is hard!
- Quantitative data is easy to understand.
- Standard test methods provide that tangible language of capabilities for researchers, manufacturers, and users to communicate.

So how do we connect emerging robotic capabilities with those that need to know about them?

- Regional test facilities collaborating to develop, validate, and use the standards test methods.
- Competitions to inspire innovation and measure progress.



Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
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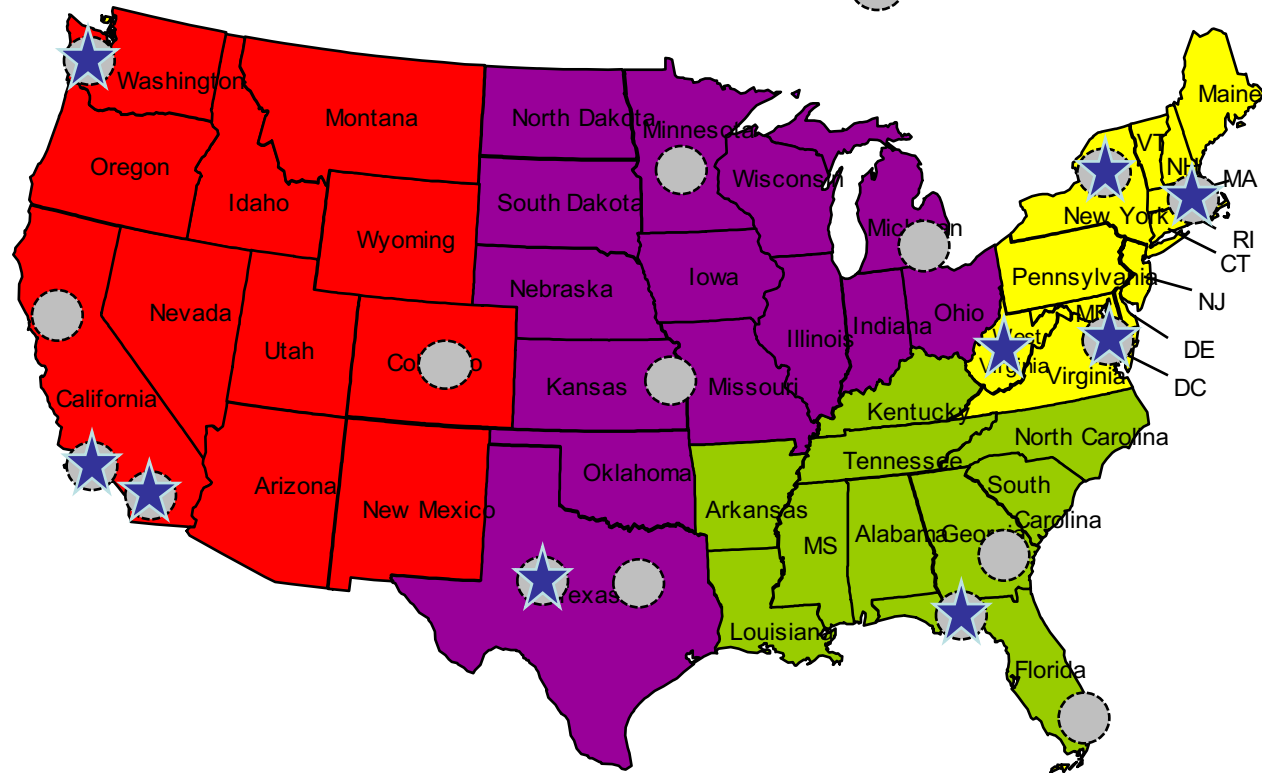


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Seattle, WA (June 2015)
- NY State Dept. of Homeland Security
Oriskany, NY (June 2015)
- Navy SPAWAR
San Diego, CA (2016)

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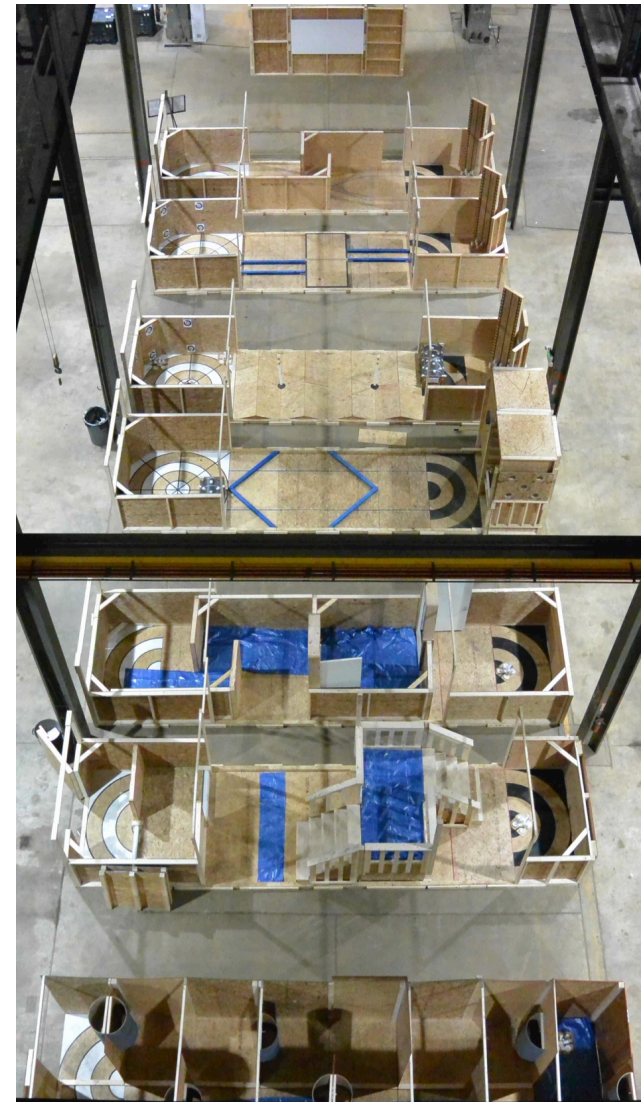
Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
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Calendar of Events:

- 2016.03.1-6
Inter-laboratory calibration (autonomy tests).
BWB, Koblenz, Germany
- 2016.03.29-31
Aerial test method validation and training for firefighting
and emergency response applications.
Austin Fire Department, Austin, TX
- 2016.06-17
Aquatic test method validation and training for
countering improvised explosive device.
FBI, Port Hueneme, CA
- 2016.06.13-17
Ground test methods validation and training.
Western Regional Robot Rodeo, Los Alamos, NM
- 2016.06.30 – 07.04
Comprehensive test method validation exercise,
RoboCupRescue Robot League Championship
Leipzig, Germany



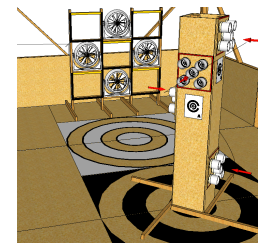
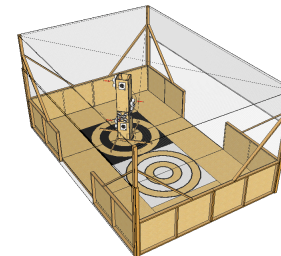
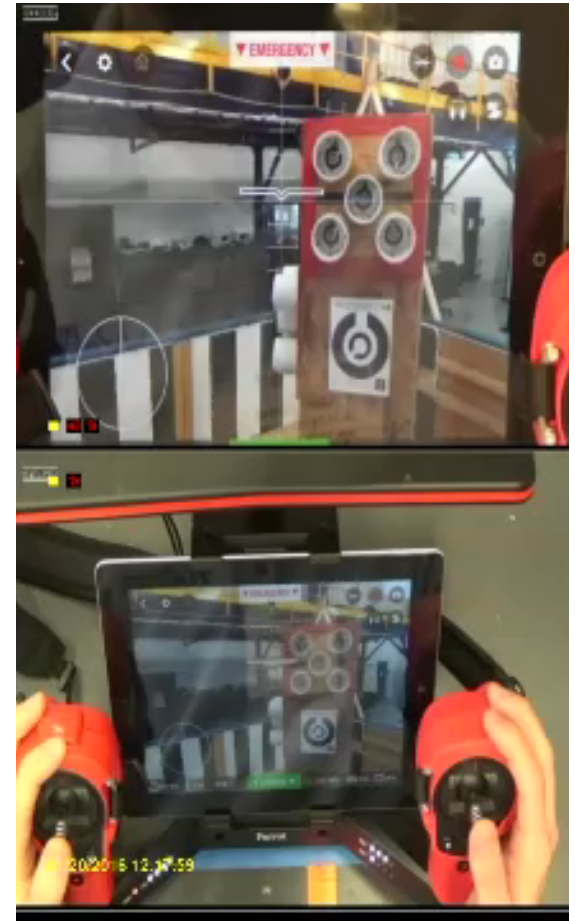
Standard Test Methods For Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Operational Equipment; Robots (E54.08.01)



Calendar of Events:

- 2016.03.1-6
Inter-laboratory calibration (autonomy tests).
BWB, Koblenz, Germany
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- 2016.06.30 – 07.04
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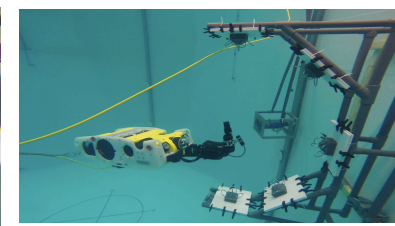
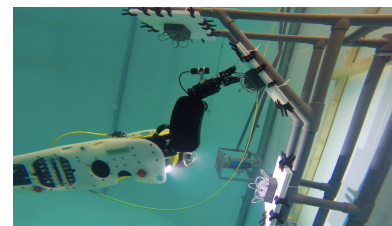
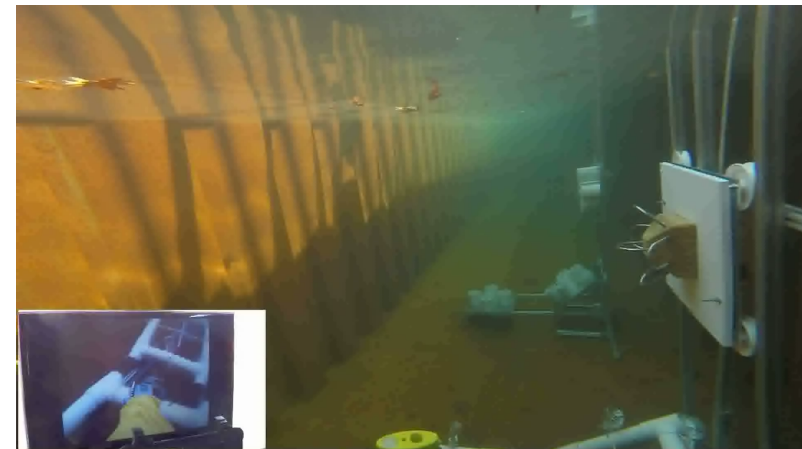
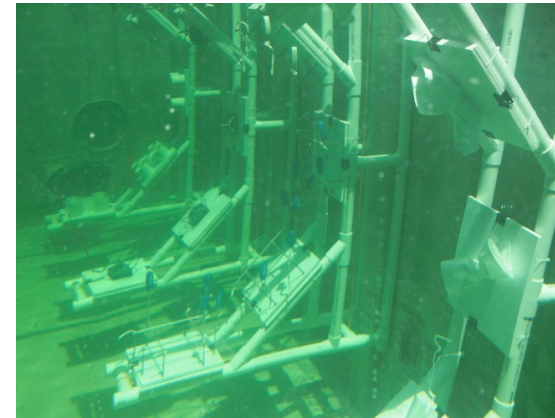
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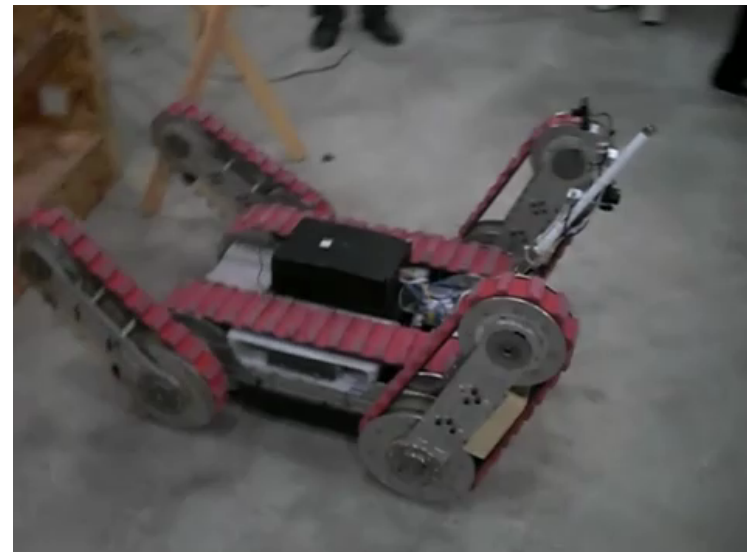
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Thank you!...

- Workshop organizers
- Conference facilities
- Robotics Test Facility team

... and to all of you who travelled from
far and wide! Thank you for contributing!

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