ASTM E54.09 Homeland Security Applications; Response Robots
Introduction to Ground Robot Test Methods

Version 2022A

STARTS AT 10:00 AM EST
WASHINGTON, DC TIME

Sub Committee Chair:
Adam Jacoff
Intelligent Systems Division
National Institute of Standards and Technology
U.S. Department of Commerce

Committee Chair:
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Science and Technology Directorate
U.S. Department of Homeland Security

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RobotTestMethods.nist.gov

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RobotTestMethods@nist.gov

"Start Remote, Stay Remote?"

Project Overview

Mission Success = Robotic System Capabilities + Remote Operator Proficiency

“Start Remote, Stay Remote?”

Project Overview

Mission Success = Robotic System Capabilities + Remote Operator Proficiency

Break Glass Tasks
(VERTICAL REPETITIONS)

Bore Holes Tasks
(VERTICAL REPETITIONS)

Conventional Systems

Break Glass Tasks
(3x3 REPETITIONS)

Emerging Technologies

Project Vision

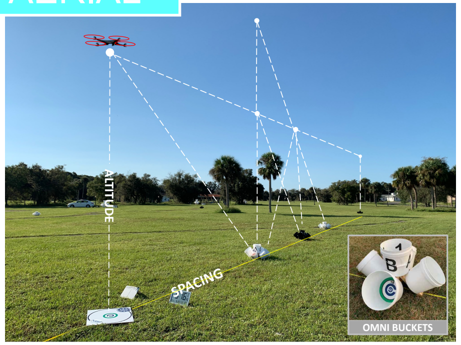
Project Overview

Remotely operated robots, including ground, aerial, and aquatic systems, enable emergency responders to perform extremely hazardous tasks from safer stand-off distances.

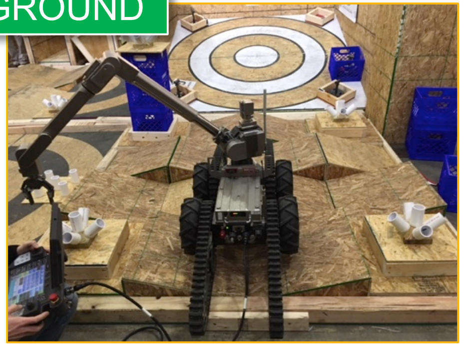
Standard test methods help robot researchers, manufacturers and users objectively evaluate system capabilities to align with mission requirements.

We're developing the measurements and standards infrastructure necessary to quantitatively evaluate and compare robotic system capabilities and remote operator proficiency because:

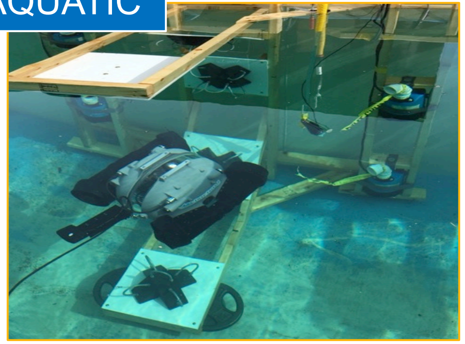
AERIAL



GROUND



AQUATIC



National Institute of Standards and Technology
U.S. Department of Commerce

Standard Test Methods for Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Response Robots (E54.09) | Website: RobotTestMethods.nist.gov

ASTM INTERNATIONAL

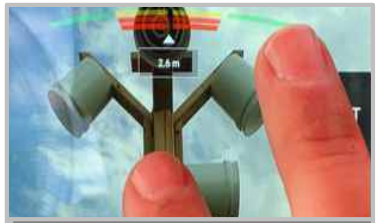
Open Test Lane

Aerial Tests

MEASURE & COMPARE


SMALL DRONES


LARGE DRONES

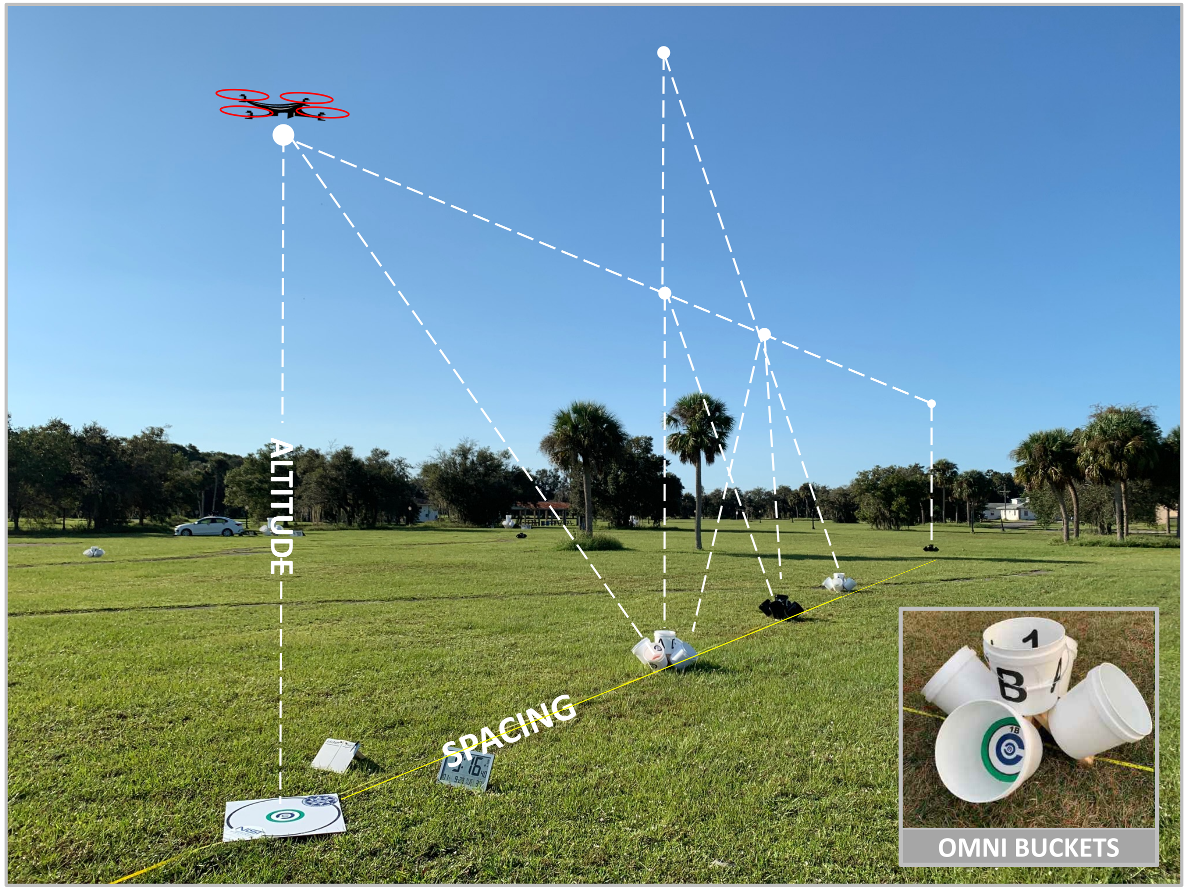

INTERFACES


PROCEDURES


SENSORS

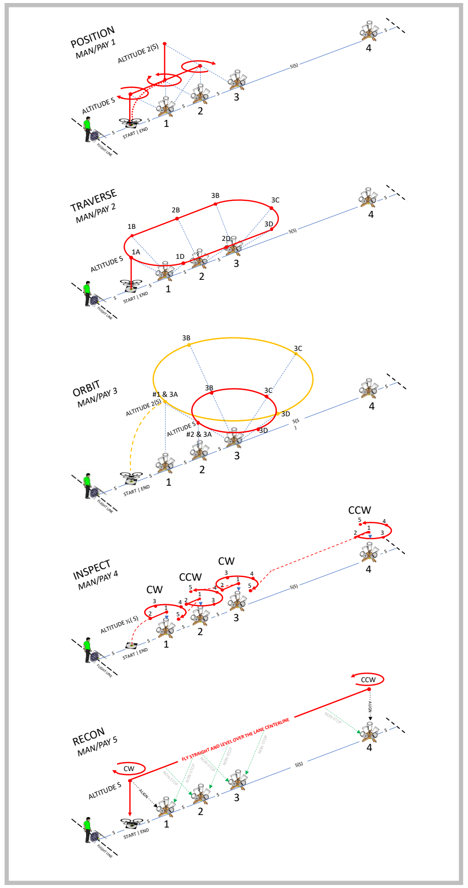

MANEUVERING

SCALABLE (ALTITUDE = SPACING)



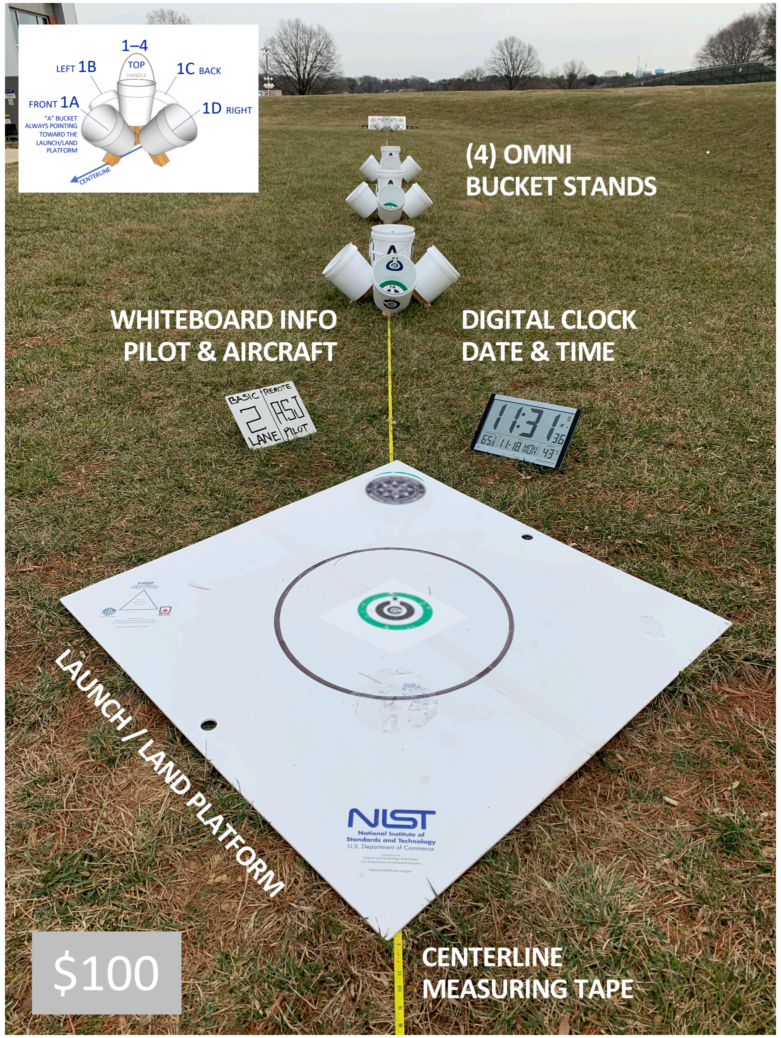
OMNI BUCKETS

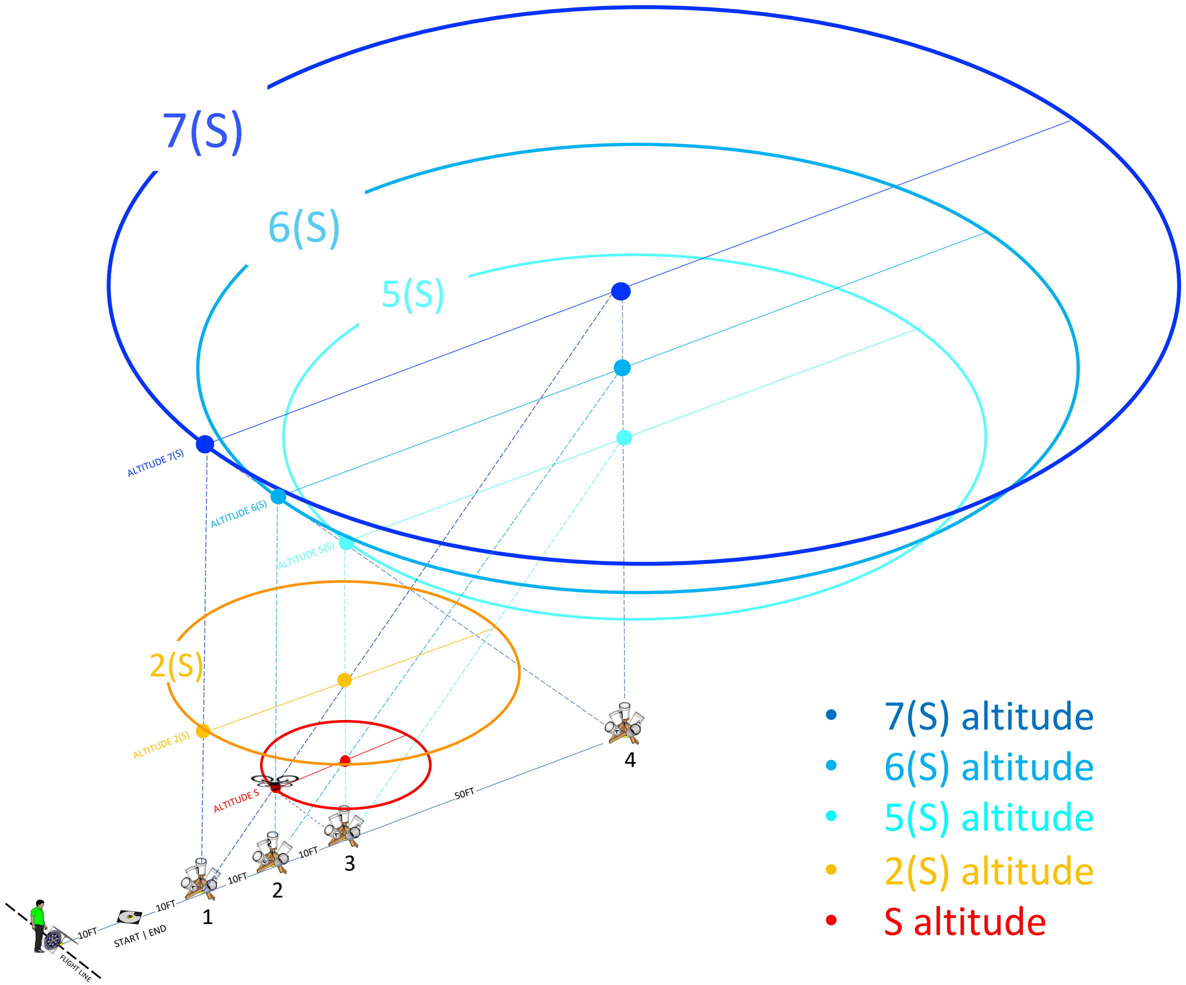
5 FLIGHT PATHS



Easy and Inexpensive to Fabricate

Aerial Tests

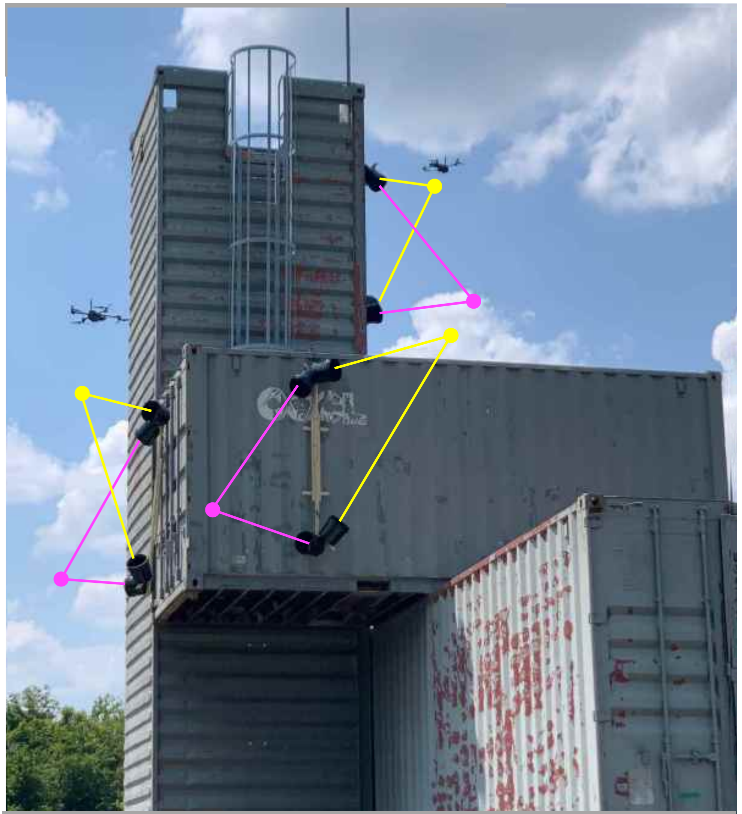




- 7(S) altitude
- 6(S) altitude
- 5(S) altitude
- 2(S) altitude
- S altitude

Obstructed Test Lane and Related Scenarios

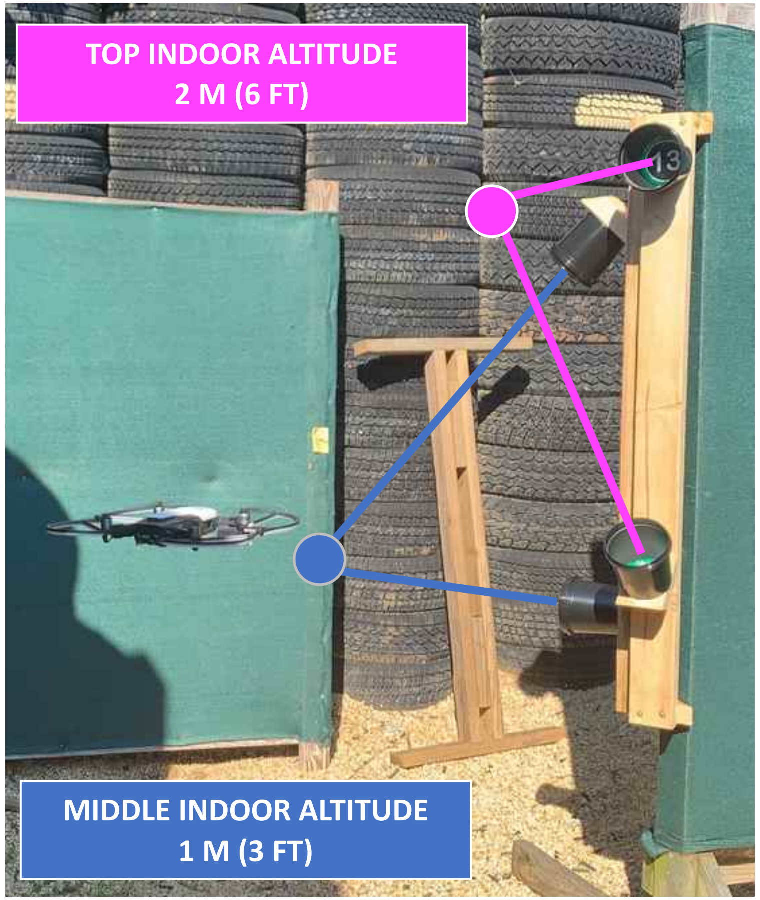
Aerial Tests

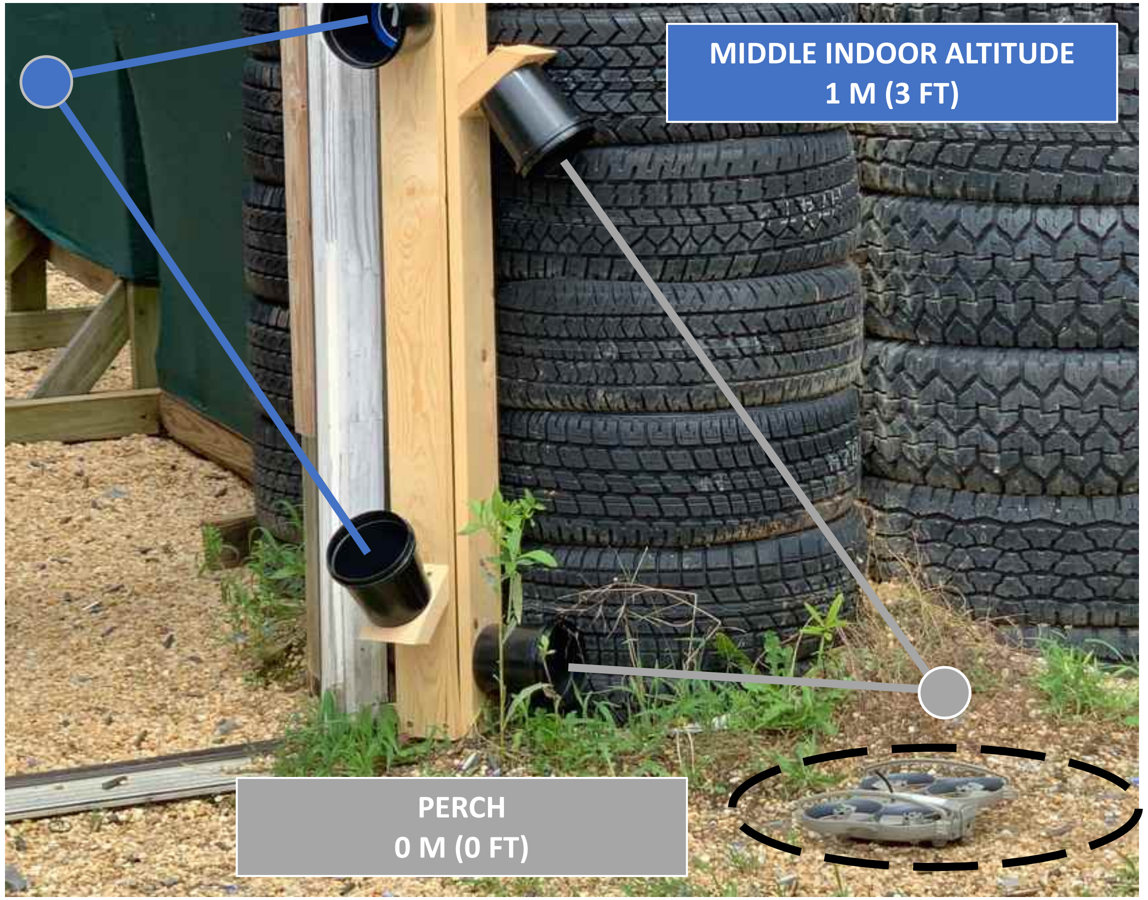


DUAL BUCKET ALIGNMENTS GUIDE PILOTS INTO SAFE POSITIONS WITHIN PROXIMITY TO OBJECTS

Confined Test Lane and Related Scenarios

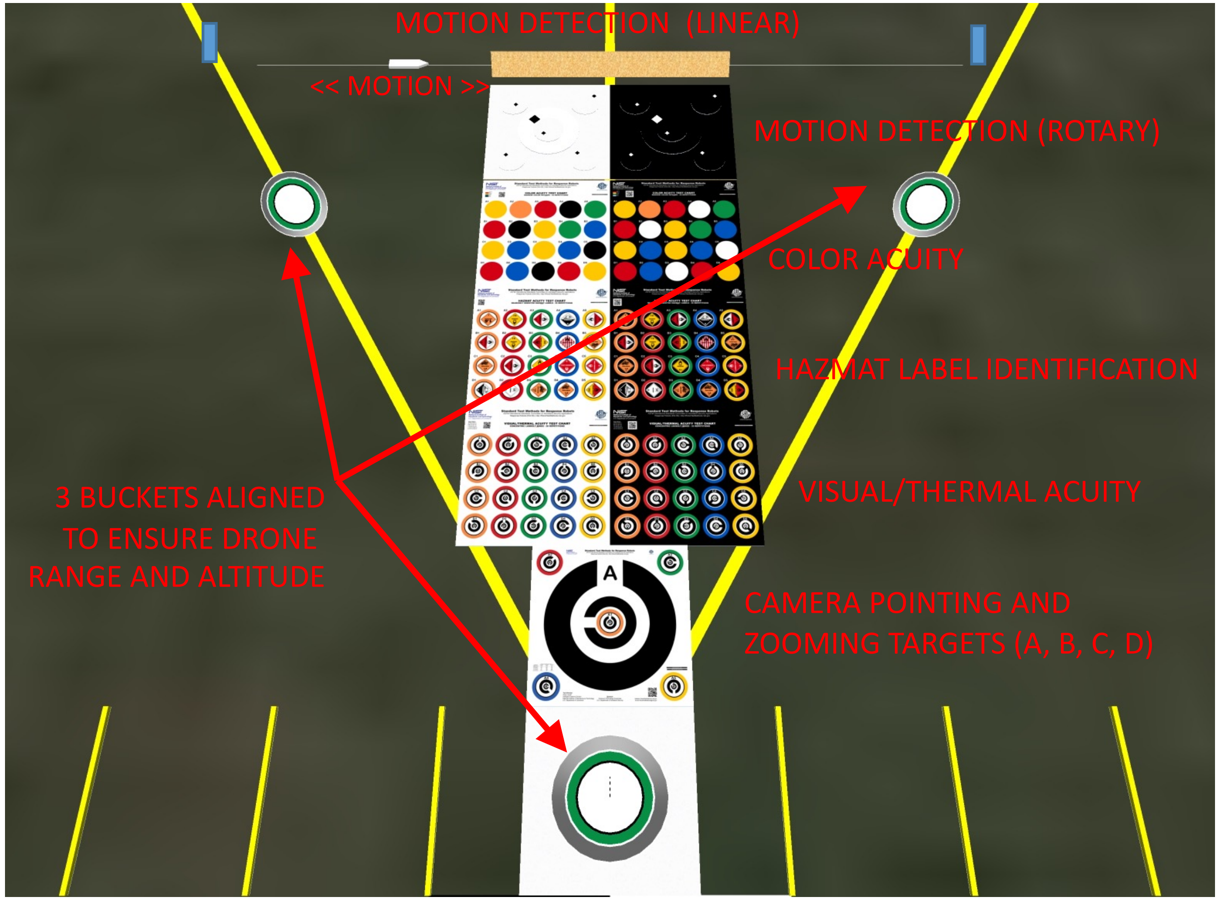
Aerial Tests





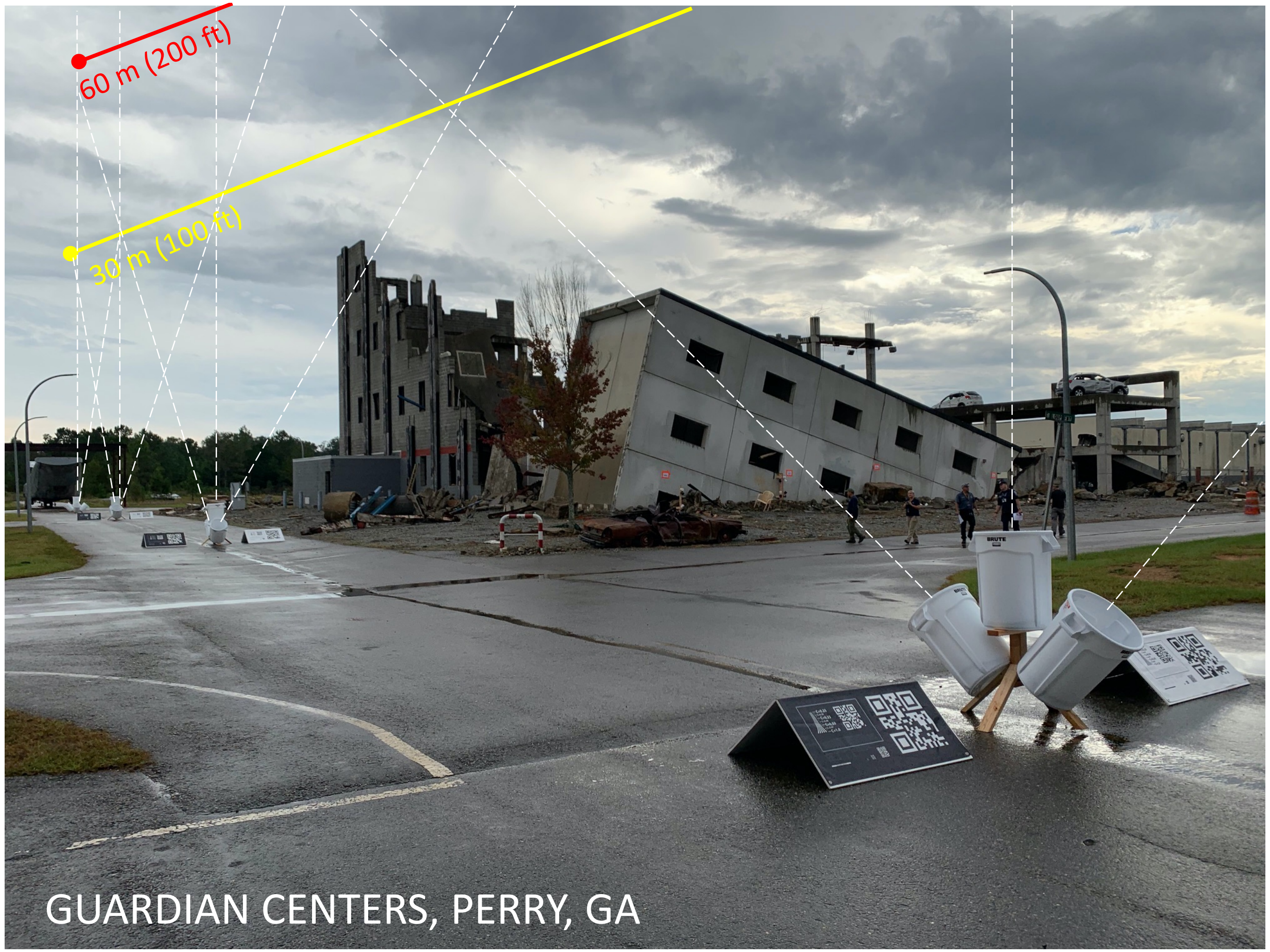
Sensor Test Lane

Aerial Tests



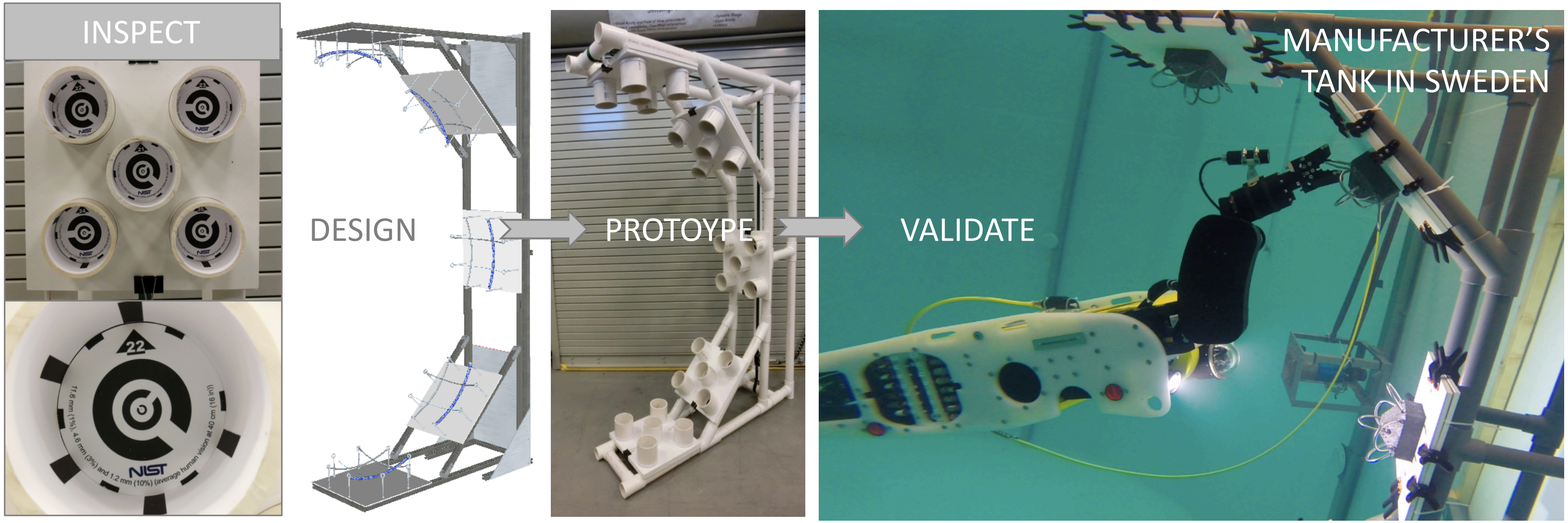
Sensor Test Lane

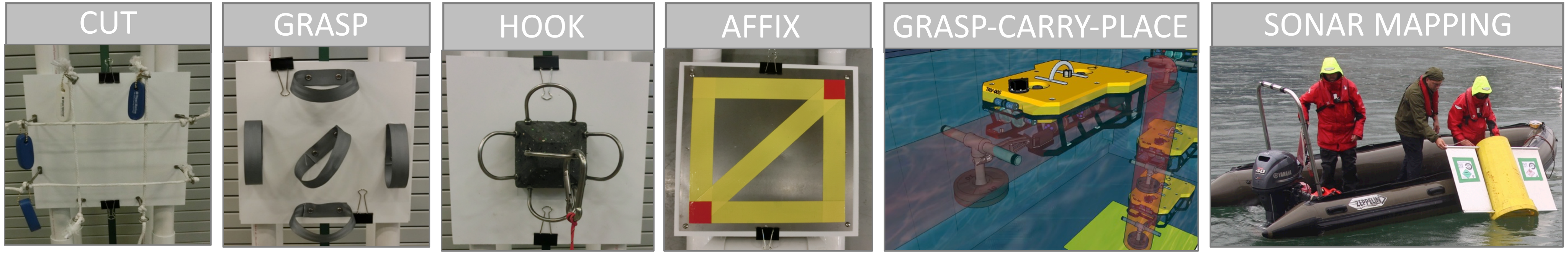
Aerial Tests



Aquatic Tests in Tanks and Scenarios

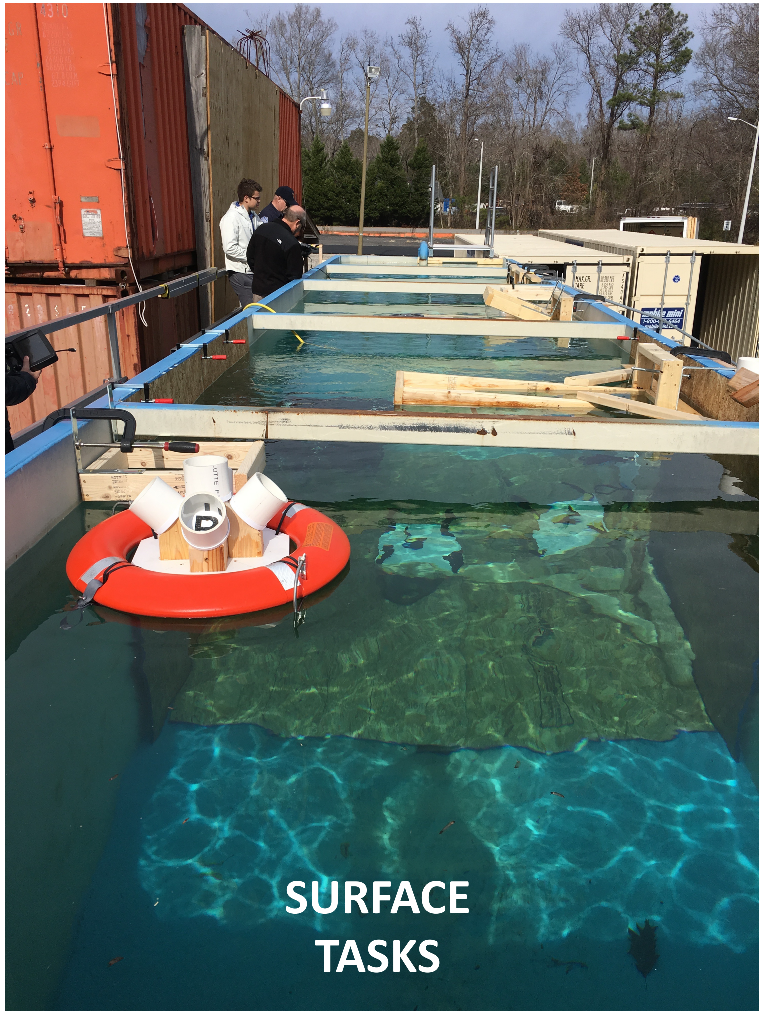
Underwater Tests

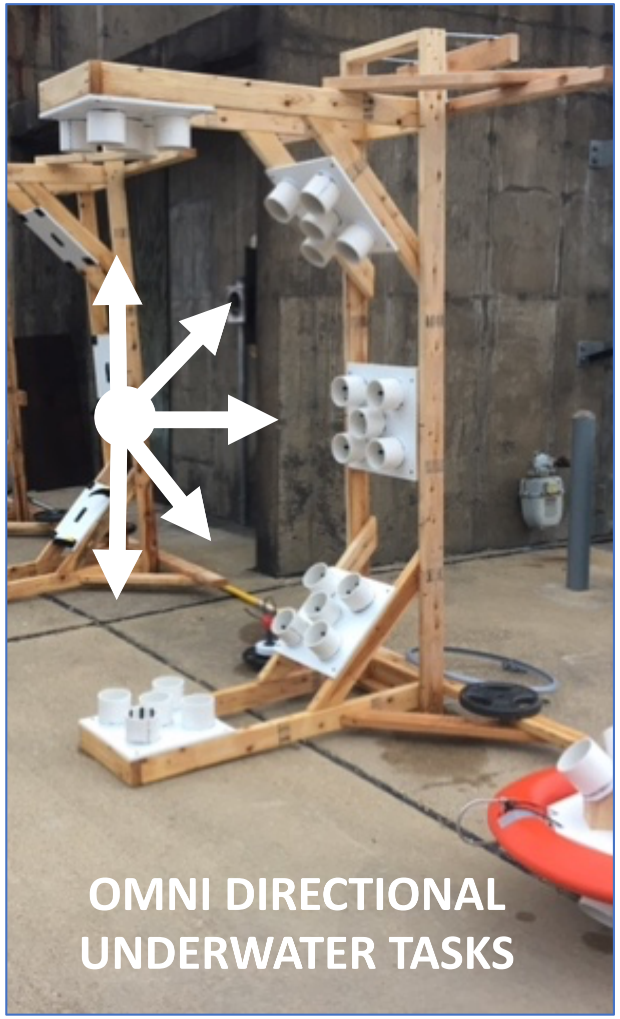


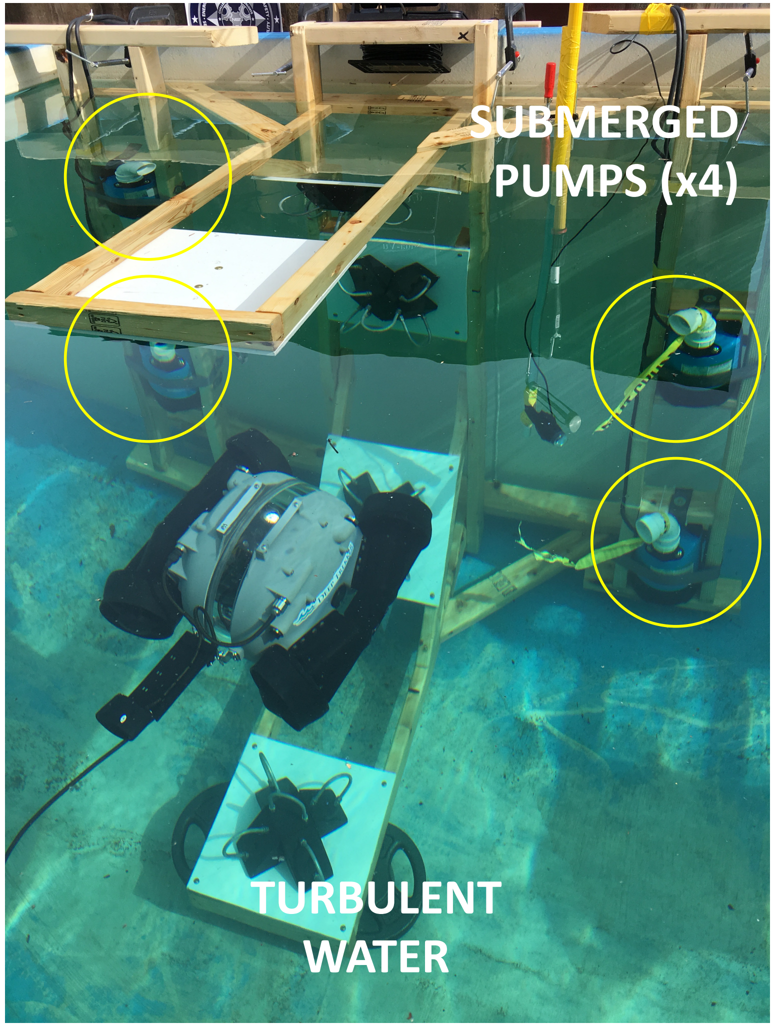


Aquatic Tests in Tanks and Scenarios

Underwater Tests







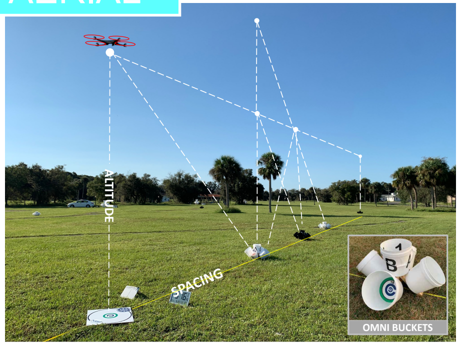
When We Started

Project Overview

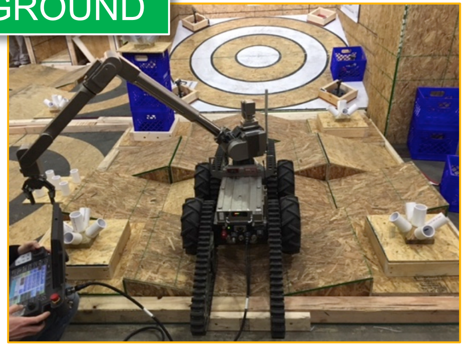
- **Lack of Coordinated Innovation and Commercialization**
  - Difficult to assess performance of robotic systems
  - Robots were not addressing end-user needs
  - No mechanism to tangibly communicate operational requirements
  - No structured training for operators to improve proficiency
  - No credentialing of remote operators and pilots

- **Standard Test Methods Need To…**
  - **Communicate** operational needs to robot researchers and developers.
  - **Promote** innovation through commercial manufacturers.
  - **Enable** users to understand emerging robot capabilities.
  - **Guide** robot purchasing, acceptance testing, and deployment decisions.
  - **Focus** training and measure operator proficiency for credentialing.

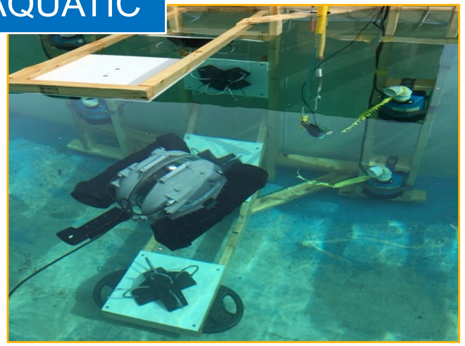
AERIAL



GROUND



AQUATIC



Stakeholders & Priorities

Project Overview

Identifying our priorities:

- **Requirements workshops** with all interested stakeholders identify capability gaps and priorities.
- **Test validation exercises** with users refine and validate apparatuses, procedures, and data collection.
- **Robot evaluations** with manufacturers capture statistically significant capabilities data.
- **Standards committee meetings and exercises** prepare the tests for balloting and adoption.
- **Research competitions** validate and disseminate tests, inspire innovation, and measure progress.

FEDERAL SPONSORS AND COLLABORATORS

COMMERCIAL PROCUREMENTS

$200 M THROUGH 2020

STANDARDS ORGANIZATIONS

ROBOTICS RESEARCH COMPETITONS

Our Approach

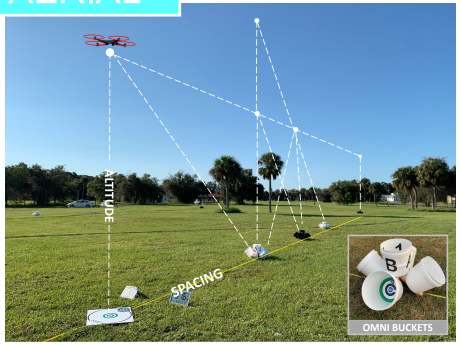
Project Overview

- **Develop test methods**
  - Representative
  - Repeatable
  - Reproducible
  - Science-based
  - Inexpensive & easy to conduct
- **Enable innovation**
  - Competition challenges
  - Identify and communicate gaps
- **Measure performance**
  - Compare different system capabilities
  - Track and compare operator proficiency

50+ TESTS FOR

Maneuvering
Mobility
Sensing
Endurance
Radio Comms
Dexterity
Durability
Logistics
Safety
Mapping
Autonomy

AERIAL



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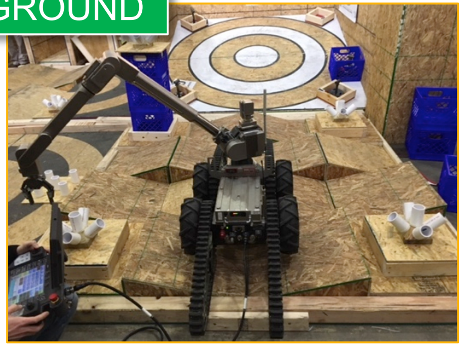

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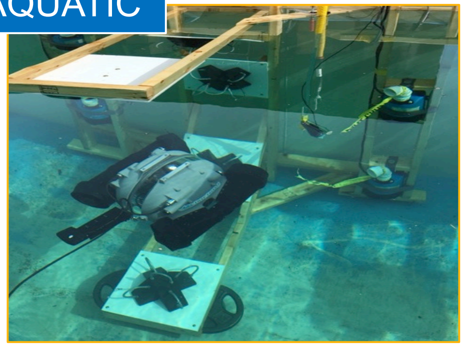


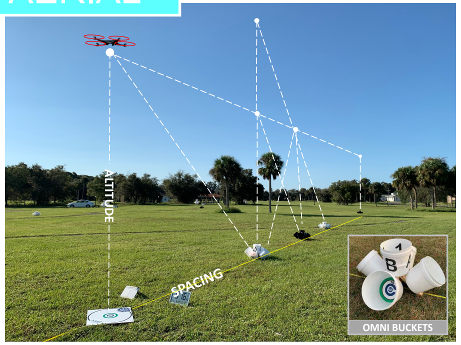
Our Process

Project Overview

REPEAT

- ***Develop*** suites of reproducible test methods that are quick and easy to conduct repeatedly.
- ***Measure*** combinations of existing capabilities and emerging technologies.
- ***Inspire*** innovation using tests to communicate operational needs and technological gaps.
- ***Guide*** purchasing and deployment decisions with objective capabilities data.
- ***Focus*** training with repeatable tasks to measure and compare operator proficiency.
- ***Identify*** readiness issues with equipment and/or training through local, regional, or national averages.

AERIAL



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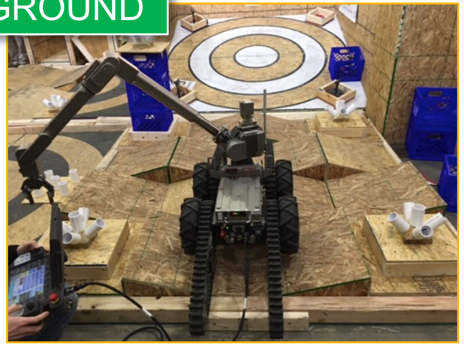

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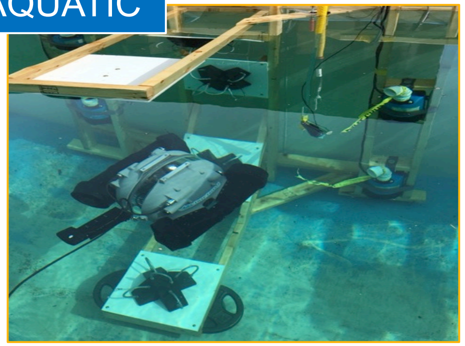


Same Tests Help Different Users and Robots

Project Overview

Robot Developers

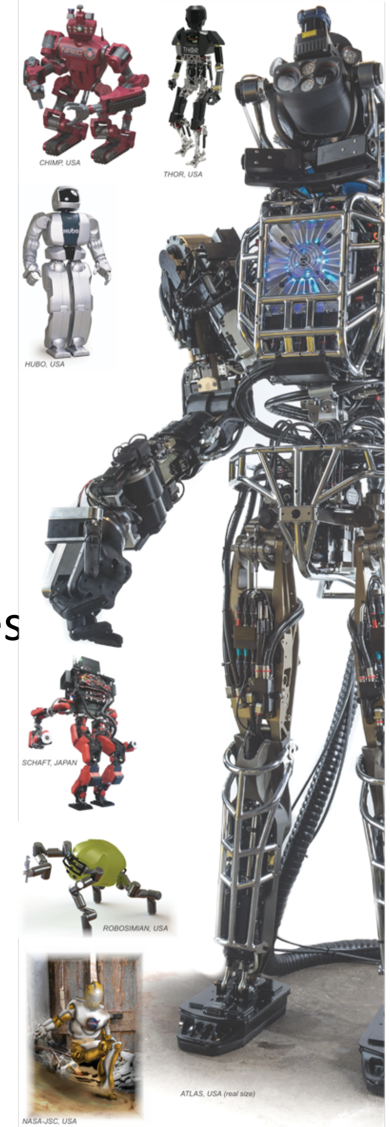
- Understand missions through tangible test apparatuses
- Practice and refine robot designs, make trade-off decisions
- Highlight “Best-In-Class” capabilities

Responders, Soldiers, 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



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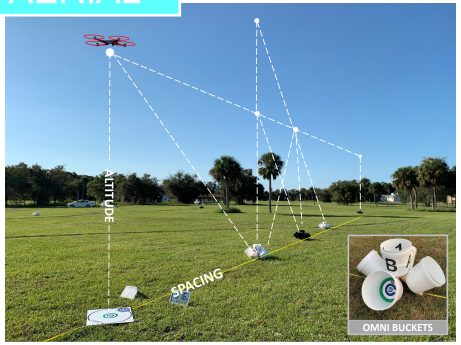
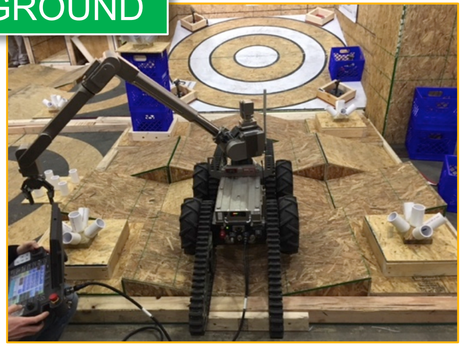


GROUND



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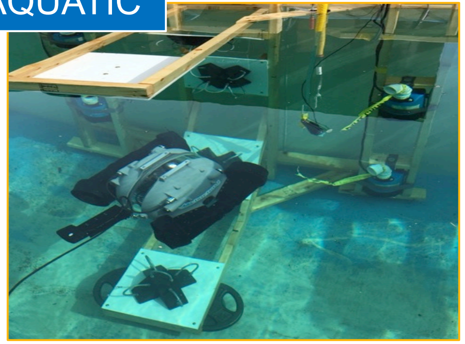
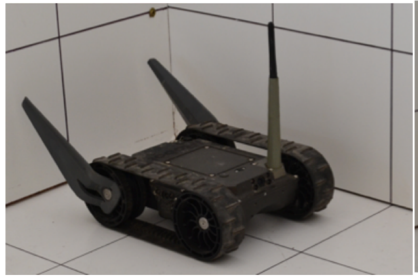


Example Spectrum of Ground Robots

Project Overview


iRobot 110 FirstLook
2.4kg (5.2lbs)


Qinetiq Dragon Runner 10
4.5kg (10lbs)

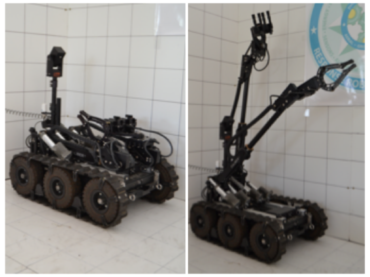

iRobot 310 SUGV
13.2kg (29lbs)


ICOR Caliber Mini
27kg (65lbs)


Remotec Titus
61kg (135lbs)

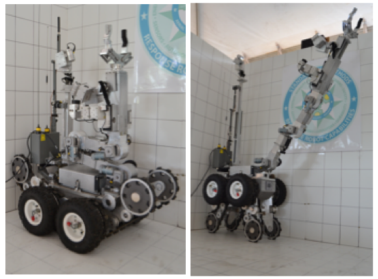

ICOR Caliber T5
64kg (140lbs)


Cobham Telemax
80kg (175lbs)

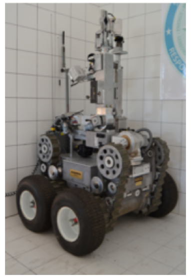

ICOR Caliber MK3
84kg (185lbs)


Remotec HD-SEL
111kg (245lb)


iRobot 710 Kobra
166.5kg (367lbs)


Remotec F6B
220kg (485lb)


WM Robotics Knight
249kg (550lbs)


Remotec Mark 5-A1
358kg (790lbs)


Remotec Wolverine
367kg (810lbs)

Howe & Howe Thermite RS1 & RS3
550kg (1200lbs) 1200 Gallons per Minute

New Firefighting Class of Robots

Project Overview

New Firefighting Class of Robots

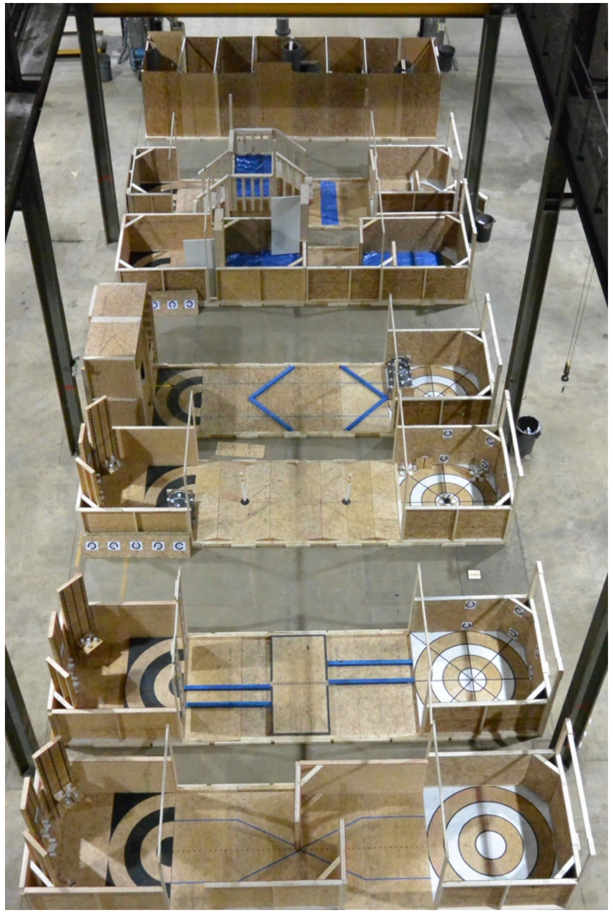
Project Overview

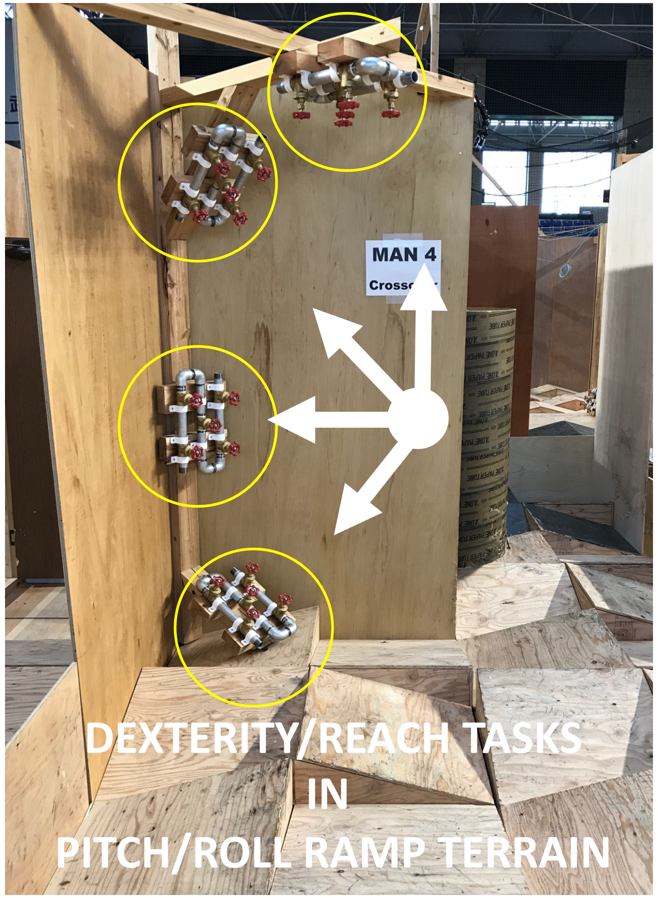
Scale for Outdoor Environments

Project Overview

120 cm (48 in) Lateral Clearance

Individual Maneuvering, Terrain and Obstacle Lanes, with Dexterity Tasks in the Terrains



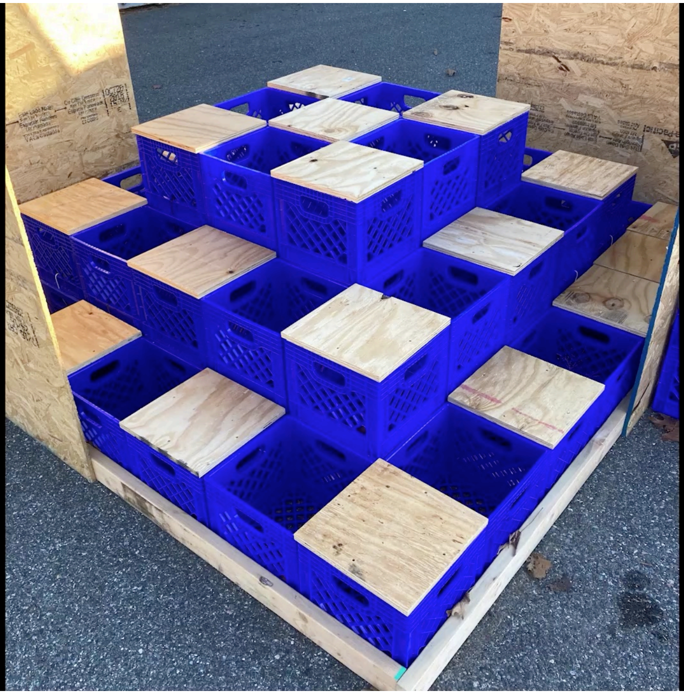


Comparing Emerging Capabilities

Project Overview

Comparing Emerging Capabilities

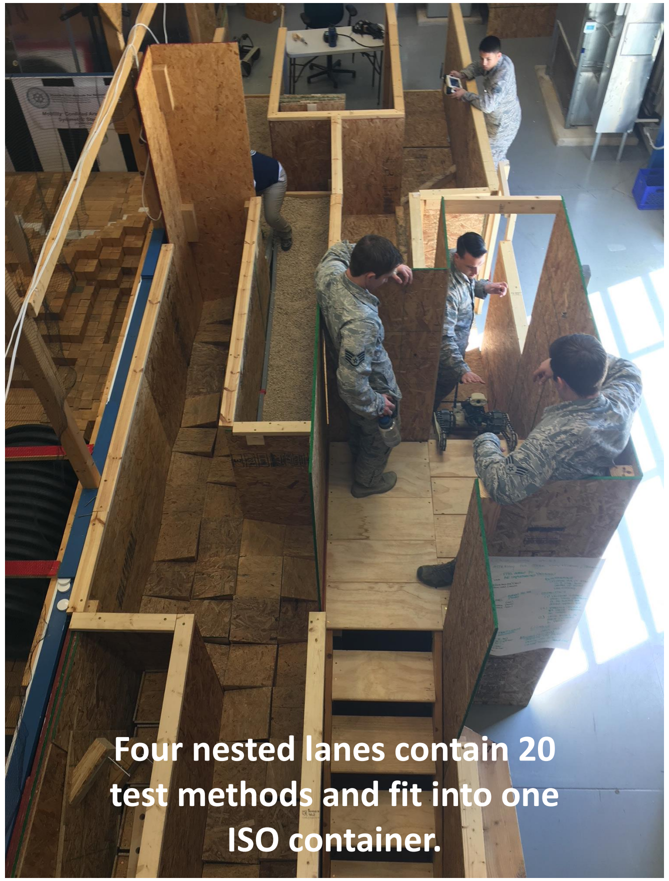
Project Overview



Scale for Indoor/Outdoor Environments

Project Overview

60 cm (24 in) Lateral Clearance
Trains, Busses, Planes, Dwellings, Parked Cars, etc.



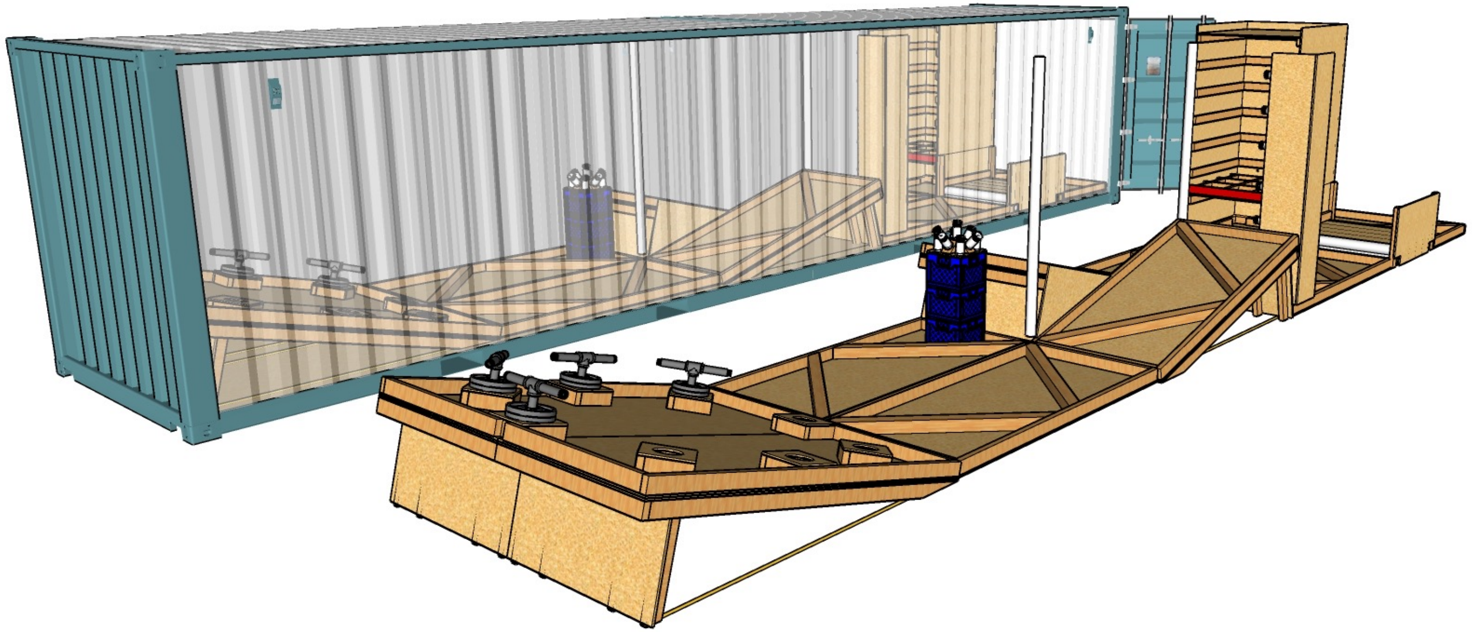
Scale for Confined Access Environments

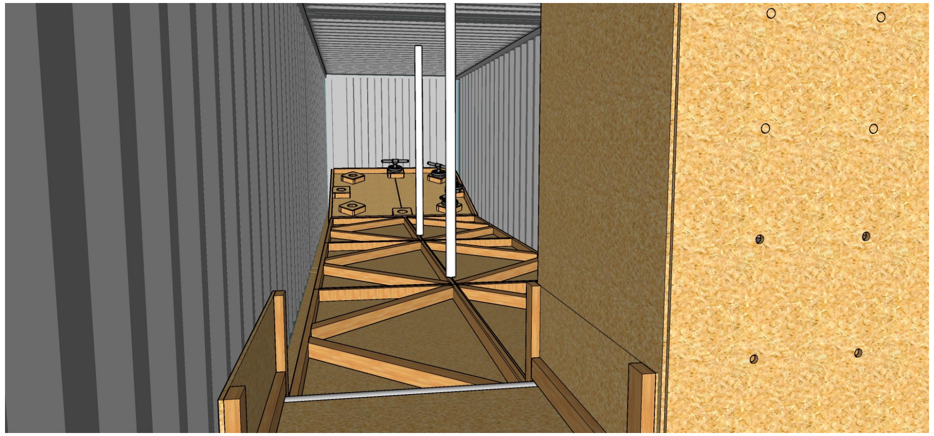
Project Overview

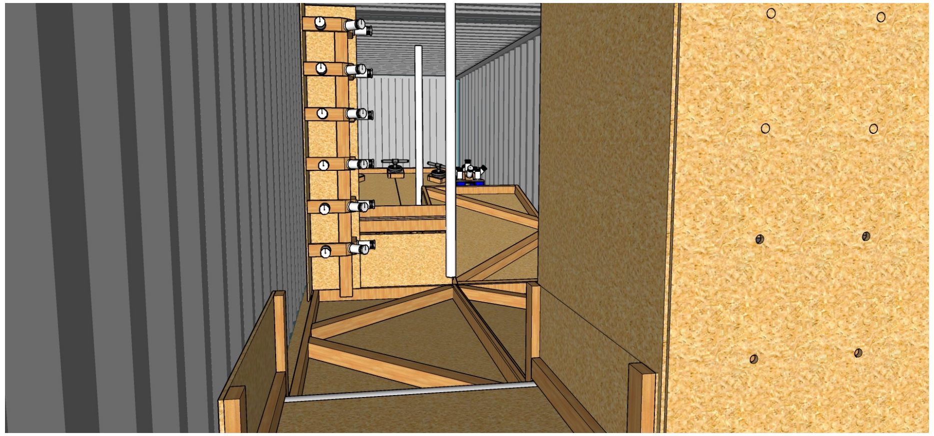
30 cm (12 in) Lateral Clearance
Robots Deployed Through Access Holes, Throwable, Disposable

All Tests Fit Into Shipping Containers (Rent or Buy)

Project Overview







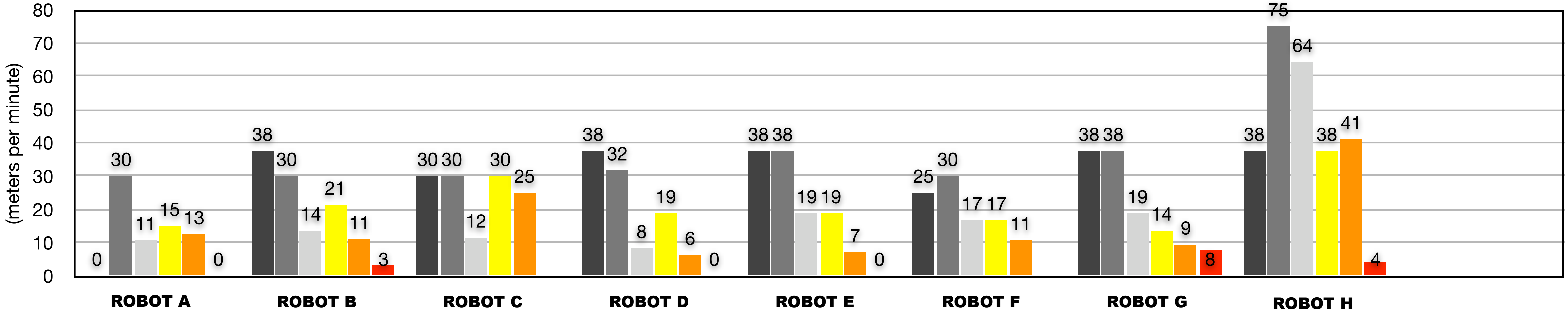
Compare Robot Capabilities or Proficiency

Safety | Capabilities | Proficiency

Sand | Gravel | Flat Line Following | Continuous Ramps | Crossing Ramps | Stepfields





Average Rate of Advance on Terrain for At Least 100m (meters/minute)

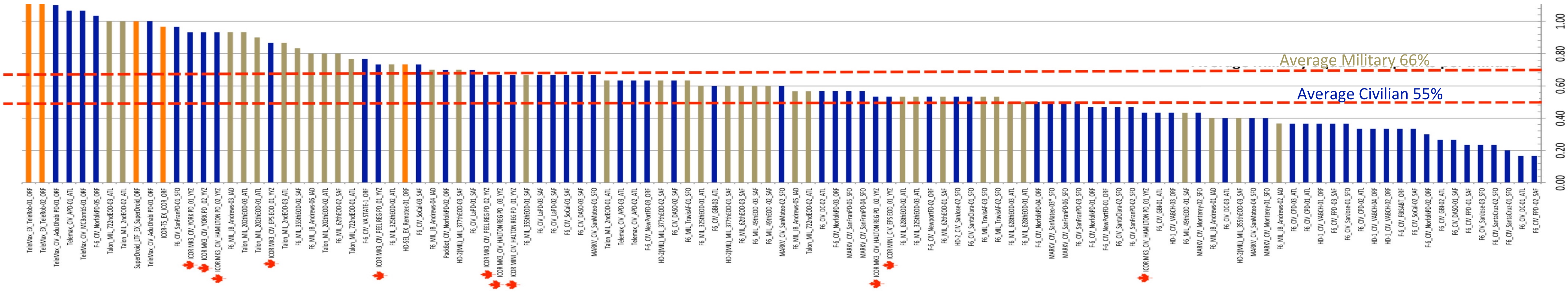
Set Your Minimum Thresholds for Pass/Fail

Focus Training and Evaluate Proficiency for Credentialing

- Organizations can set their own threshold for pass/fail in these tests based on their tolerance for reliability and/or efficiency. Complete trials are assumed.

- Measure everybody repeatedly over time and graph the results to help people understand their strengths and weaknesses. Then set minimum thresholds relative to the average or “expert” scores. Or adopt other organization’s thresholds as a central credentialing reference.

- At deployment time, each organization needs to consider their environmental variables, and mission complexity (night ops, BVLOS, etc.) to select a robot and operator that is likely to succeed.



Example proficiency data shown from bomb squads in ground robot tests

39 Ground Robot Tests

STANDARDS	BALLOTING	PROTOTYPE
20	11	8

Logistics
- E2521-16 Terminology
- E3132-17 System Configuration
- E2592-16 Packaging for Equipment Caches

Sensing
- E2566-17 Visual Acuity
- WK42364 Visual Dynamic Range
- WK54755 Visual Color Acuity
- WK57967 Thermal Image Acuity
- WK49478 Latency of Video and Control
- WK33261 Point and Zoom Cameras
- WK60783 Audio Speech Intelligibility

Radio Comms
- E2854-21 Line-of-Sight Range
- E2855- Non-Line-of-Sight Range
- WK60731 Attenuated Range (APC)

Mobility
- E2829-20 Sustained Speed
- E2991-17 Terrains: Gravel
- E2992-17 Terrains: Sand
- E2826-20 Terrains: Continuous Pitch/Roll Ramps
- E2827-20 Terrains: Crossing Pitch/Roll Ramps
- E2828-20 Terrains: Symmetric Stepfields
- WK##### Terrains: Reconfigurable Pallets
- WK##### Terrains: Reconfigurable Crates
- E2803-20 Obstacles: Variable Inclined Planes
- E2801-20 Obstacles: Variable Gaps
- E2802-20 Obstacles: Variable Hurdles
- E2804-20 Obstacles: Variable Stairs/Landings
- E3310-21 Obstacles: Variable Parallel Rails
- E3311-21 Obstacles: Variable Diagonal Rails

Dexterity
- E2830-20 Tow Grasped Sleds
- WK54271 Inspect
- WK54272 Touch/Insert Tools
- WK54273 Rotate
- WK54274 Extract and Place
- WK54276 Grasp, Carry, and Place
- WK54290 Break/Bore Panels
- WK54278 Cut Straps and Ropes
- WK54287 Inspect Underbody
- WK54289 Inspect Cab Interior

Situational Awareness
- E2853-21 Search Tasks

Energy/Power
- WK55025 Endurance

Test Facilities Worldwide

Project Overview

1:
Test Director: Andrew Moore
Southwest Research Institute
Dept. of Electronics and Robotics
San Antonio, TX, USA
(Established 2010)

2:
Test Director: Satoshi Tadokoro
International Rescue System
Institute and Tohoku University
Kobe and Sendai, Japan
(Established 2011)

3:
Test Director: Johannes Pellenz
Bundeswehr Technical Center for
Engineer and General Field Equipment
Koblenz, Germany
(Established 2012)

4:
Test Director: Holly Yanco
New England Robot Validation
and Experimentation Center
Lowell, MA, USA
(Established 2013)

5:
Test Directors: Raymond Sheh and Bill Collidge
Curtin University of Technology and
Western Australia Police Bomb Response Unit
Perth, WA, Australia
(Established 2013)

6:
Test Director: Christopher Scrapper
SPAWAR
Systems Center Pacific
San Diego, CA, USA
(Established 2014)

7:
Test Director: Capt. Sam Hsu
U.S. State Department
Anti-Terrorism Assistance Training Facility
Kabul, Afghanistan
(Established 2015)

8:
Test Director: Michal Karczewski
Industrial Research Institute
for Automation and Measurements
Warsaw, Poland
(Established 2015)

9:
Test Director: Shinji Kawatsuma
Fukushima Robot Test Facility
Japanese Atomic Energy Agency
Naraha, Fukushima, Japan
(Established 2016)

10:
Test Director: Steve Wheeler
Remote Applications in Challenging Environments
UK Atomic Energy Agency
Oxford, United Kingdom
(Established 2016)

11:
Test Director:
Korean Atomic Energy
Research Institute
Daejeon, South Korea
(Established 2016)

12:
Test Director: Tom Prentice
Reveille Ranch Test Facility
Burnet, TX
(Established 2018)

13:
Test Director: Ben Miller
Colorado Center of Excellence
Aerial Technology Firefighting
Rifle, CO, USA
(Established 2018)

14:
Test Director: Andy Olesen
Fire and Emergency Service Training Institute
Pearson International Airport
Mississauga Ontario Canada
(Established 2019)

15:
Test Director: Andy Olesen
Grimsby Regional Training Centre
Grimsby Ontario, Canada
(Established 2019)

Our same process works similarly well for AERIAL and AQUATIC systems.

Awards and Recognition

For developing the first ever comprehensive suite of emergency response robot test methods and data collection tools to evaluate and improve **bomb-disposal robots and operators**. These efforts led to enhanced testing and use of advanced robot capabilities that enable emergency responders to perform extremely hazardous missions from safer standoff distances.

Service to America Medal: Safety, Security, and International Affairs Finalist (2021)

See the project award description at https://servicetoamericamedals.org/honorees/adam-jacoff/

Presidential Gears of Government Award (2020), across all the various departments.

Dept. of Commerce Secretary Excellence in Innovation Award (2019), their highest singular award.

Dept. of Commerce Gold Medal Award (2019), given to 30 projects across the department.

ASTM International Award of Merit (2015), their highest award.

NIST Measurement Science Award (2014)

Commendations from Dept. of Justice (2020, 2016), Air Force (2018), DARPA (2015), Dept. of Homeland Security (2014), Dept. of State (2014), JIEDDO (2010), several state and local responder organizations and other international organizations.

Meetings with Validation Exercises

ASTM E54.09 Meeting and Test Validation Exercise

Host:
Virginia Beach Fire Dept.,
Virginia Beach, VA

January 2017

Interview with Kathy Morgan, President of ASTM International

Meetings with Validation Exercises

ASTM E54.09 Meeting and Test Validation Exercise

Host:
Canadian Explosives Technicians Association

Hamilton, Ontario, Canada

June 2017

*"The tremendous work in design, validation, and delivery of NIST's Emergency Response Robots Project has opened the door to operationalization of a training/qualification environment. **Similar to weapon qualifications, CETA sees the NIST program as just that for public safety professionals, minimum standards**."*

National Institute of Standards and Technology
U.S. Department of Commerce

Standard Test Methods for Response Robots

ASTM International Standards Committee on Homeland Security Applications;
Response Robots (E54.09) | Website: RobotTestMethods.nist.gov

ASTM INTERNATIONAL

Sub Committee Chair:

Adam Jacoff

Intelligent Systems Division
National Institute of Standards and Technology
U.S. Department of Commerce

Committee Chair:

Phil Mattson

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