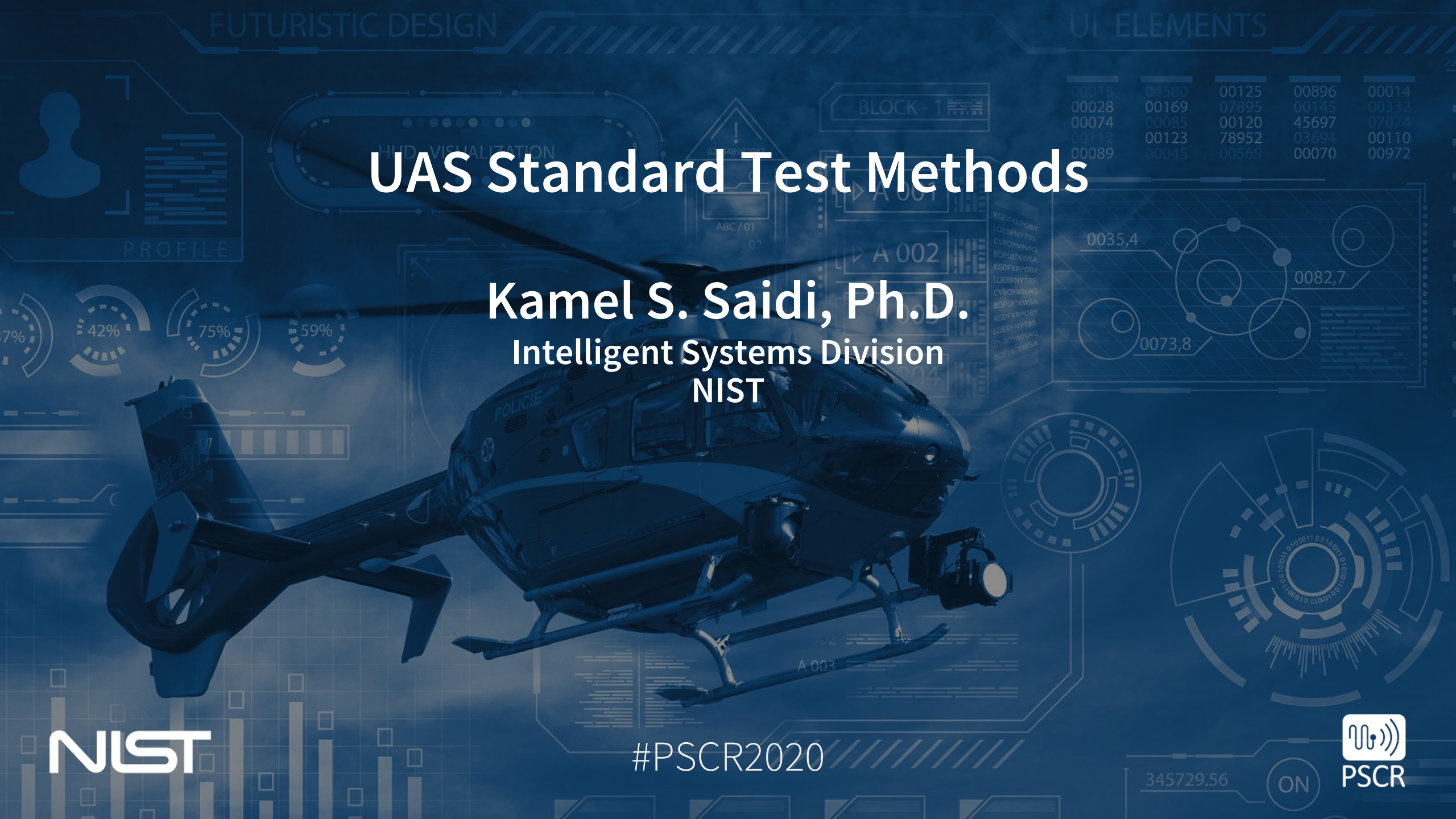


UAS Standard Test Methods

Kamel S. Saidi, Ph.D.

Intelligent Systems Division
NIST

#PSCR2020

NIST

PSCR

DISCLAIMER

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately.

Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

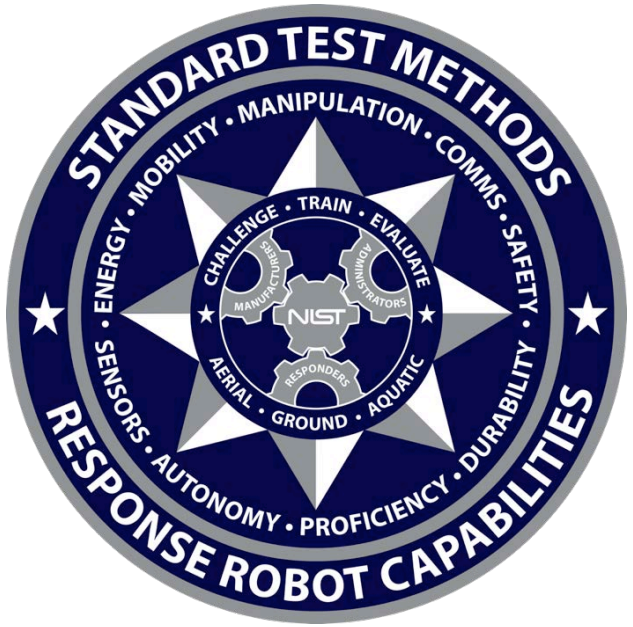
*** Please note, unless mentioned in reference to a NIST Publication, all information and data presented is preliminary/in-progress and subject to change**

Presentation Outline

- Project Background & Motivation
- Test Method Theory
- Test Procedures
- Test Methods used in UAS1 and UAS2
- Apparatus Fabrication
- Other UAS Test Methods

Project Background & Motivation

The NIST Emergency Response Robots Project



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1. Intelligent Systems Division, Engineering Laboratory
   National Institute of Standards and Technology
   Department of Commerce
   Gaithersburg, MD USA
2. Institute for Soft Matter Synthesis and Metrology
   Georgetown University
   Washington, DC USA

Science and Technology Directorate

ASTM INTERNATIONAL
Committee E54.09

Website: RobotTestMethods.nist.gov
Email: RobotTestMethods@nist.gov

Project Overview

Objective:

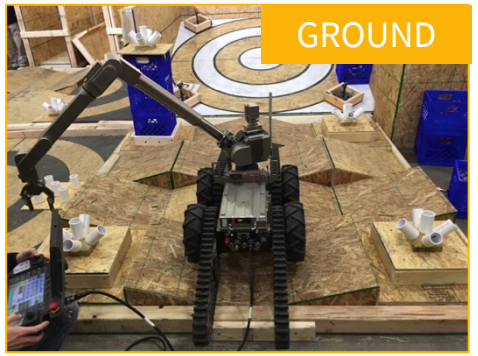
- Provide emergency responders a way to *quantitatively measure* whether robots are *capable* and *reliable* enough to perform operational tasks.
- Encourage integration of onboard sensors and intelligent controls to improve remote operator capabilities.

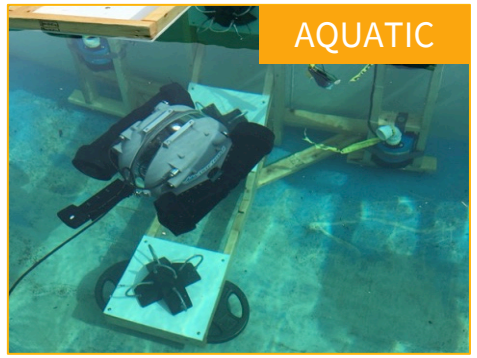
Approach:

- Develop **test methods** that measure robot maneuvering, mobility, sensors, energy, radio comms, dexterity, durability, logistics, autonomy, and operator proficiency.

Impacts:

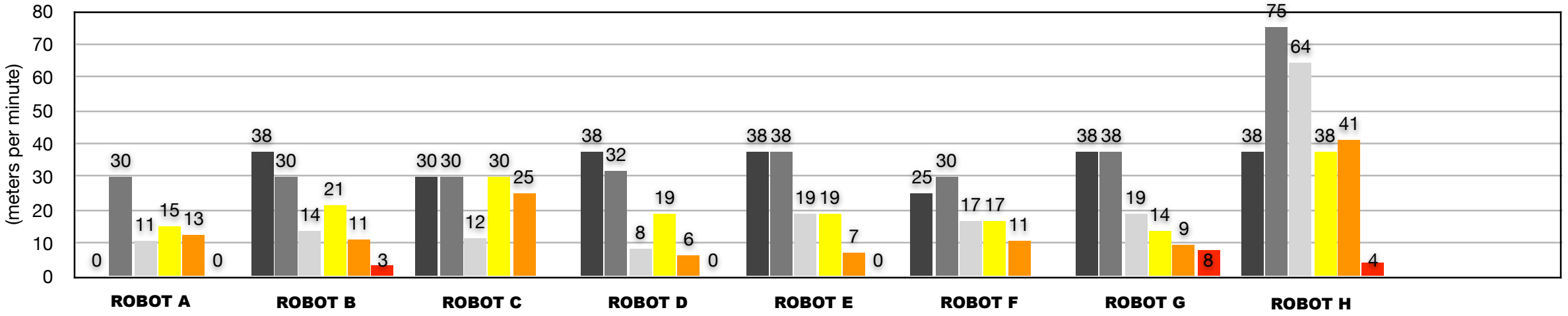
- Communicate operational needs to robot developers.
- Enable users to understand emerging robot capabilities.
- Guide robot purchasing and deployment decisions
- Focus training and measure operator proficiency





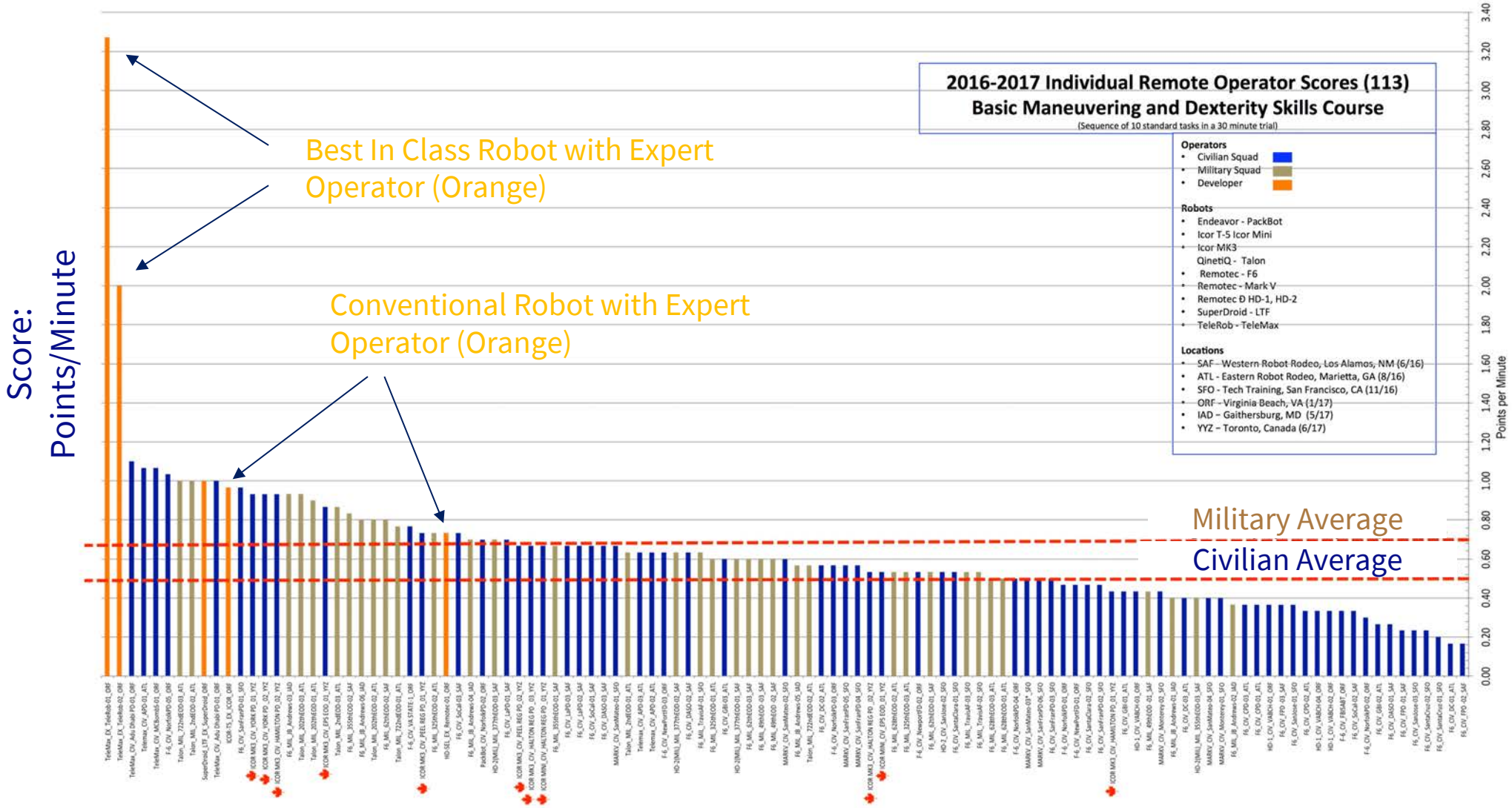
The NIST Robotics Test Facility

Example of Quantitative Robot Performance Data



Average Rate of Advance on Terrain for At Least 100m

Example of Robot Operator Proficiency Data



100+ Bomb Squad Technicians Using Their Operational Robots (USA & Canada)

Track and Compare Proficiency - Trial Forms (v2020A)

SCORE SUMMARY ON COVER

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

Standard Test Methods for Small Unmanned Aircraft Systems
ASTM International Standards Committee on Homeland Security Applications; Response Robots (E54.09) | Website: RobotTestMethods.nist.gov

ASTM INTERNATIONAL

Basic Maneuvering and Payload Functionality

Safety | Capabilities | Proficiency

Forms Version: 2019-G

Make: _____

Model: _____

Config: _____

Pilot Code: _____ VO Code: _____

Date: _____

Facility: _____

Location: _____

Event: _____

MAN 1-5	COMPLETED (points)	RELIABILITY (%)	EFFICIENCY (buckets/min)
1) POSITION:			
2) TRAVERSE:			
3) ORBIT:			
4) SPIRAL:			
5) SPEED:			

MAN 1-5 TOTAL SCORE
100 Points Max

PAY 1-5	COMPLETED (points)	ACUITY (average Cs)	EFFICIENCY (buckets/min)
1) POSITION:			
2) TRAVERSE:			
3) ORBIT:			
4) SPIRAL:			
5) DELIVER:			

PAY 1-5 TOTAL SCORE
500 Points Max

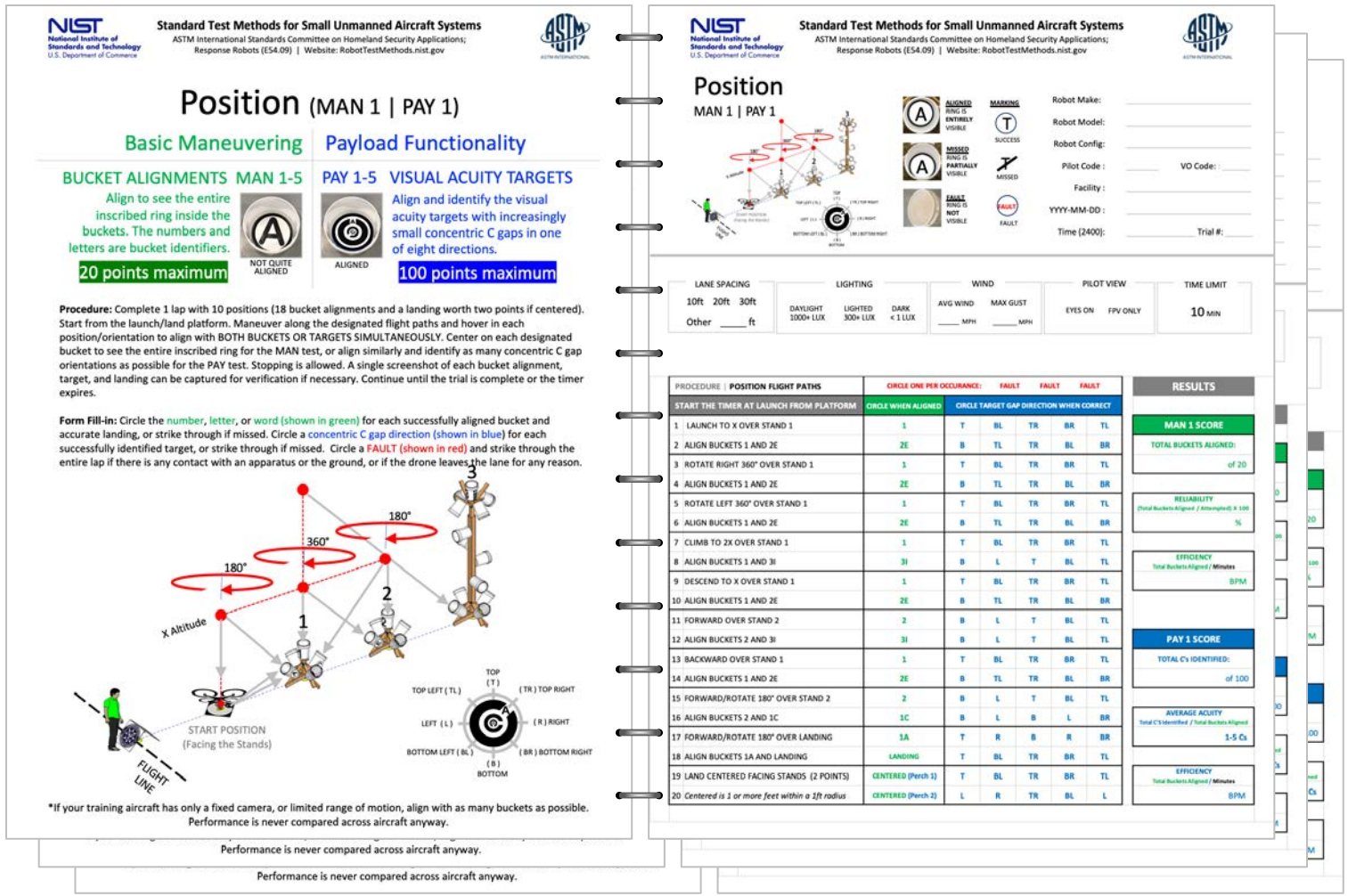
Test Director:
Adam Jacoff
Intelligent Systems Division
National Institute of Standards and Technology
U.S. Department of Commerce

Sponsor:
Phil Mattson
Science and Technology Directorate
U.S. Department of Homeland Security

Internet
RobotTestMethods.nist.gov

Email
RobotTestMethods@nist.gov

PILOT BOOKLET WITH INSTRUCTIONS, FORMS, SCENARIOS, ETC.



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

Standard Test Methods for Small Unmanned Aircraft Systems
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ASTM INTERNATIONAL

Position (MAN 1 | PAY 1)

Basic Maneuvering | **Payload Functionality**

BUCKET ALIGNMENTS MAN 1-5

Align to see the entire inscribed ring inside the buckets. The numbers and letters are bucket identifiers.

20 points maximum

NOT QUITE ALIGNED

PAY 1-5 VISUAL ACUITY TARGETS

Align and identify the visual acuity targets with increasingly small concentric C gaps in one of eight directions.

100 points maximum

ALIGNED

Procedure: Complete 1 lap with 10 positions (18 bucket alignments and a landing worth two points if centered). Start from the launch/land platform. Maneuver along the designated flight paths and hover in each position/orientation to align with BOTH BUCKETS OR TARGETS SIMULTANEOUSLY. Center on each designated bucket to see the entire inscribed ring for the MAN test, or align similarly and identify as many concentric C gap orientations as possible for the PAY test. Stopping is allowed. A single screenshot of each bucket alignment, target, and landing can be captured for verification if necessary. Continue until the trial is complete or the timer expires.

Form Fill-in: Circle the number, letter, or word (shown in green) for each successfully aligned bucket and accurate landing, or strike through if missed. Circle a concentric C gap direction (shown in blue) for each successfully identified target, or strike through if missed. Circle a FAULT (shown in red) and strike through the entire lap if there is any contact with an apparatus or the ground, or if the drone leaves the lane for any reason.

*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Performance is never compared across aircraft anyway.

Performance is never compared across aircraft anyway.

Performance is never compared across aircraft anyway.

Position
MAN 1 | PAY 1

ALIGNED RING IS ENTIRELY VISIBLE — MARKING: SUCCESS
MISSED RING IS PARTIALLY VISIBLE — MISSED
FAULT RING IS NOT VISIBLE — FAULT

Robot Make: _____
Robot Model: _____
Robot Config: _____
Pilot Code: _____ VO Code: _____
Facility: _____
YYYY-MM-DD: _____
Time (2400): _____ Trial #: _____

LANE SPACING	LIGHTING	WIND	PILOT VIEW	TIME LIMIT
10ft 20ft 30ft Other ____ft	DAYLIGHT 1000+ LUX; LIGHTED 300+ LUX; DARK < 1 LUX	AVG WIND ____ MPH; MAX GUST ____ MPH	EYES ON; FPV ONLY	10 MIN

PROCEDURE | POSITION FLIGHT PATHS	CIRCLE ONE PER OCCURANCE:	FAULT	FAULT	FAULT
START THE TIMER AT LAUNCH FROM PLATFORM	CIRCLE WHEN ALIGNED	CIRCLE TARGET GAP DIRECTION WHEN CORRECT		
1 LAUNCH TO X OVER STAND 1	1	T BL TR BR TL		
2 ALIGN BUCKETS 1 AND 2E	2E	B TL TR BL BR		
3 ROTATE RIGHT 360° OVER STAND 1	1	T BL TR BR TL		
4 ALIGN BUCKETS 1 AND 2E	2E	B TL TR BL BR		
5 ROTATE LEFT 360° OVER STAND 1	1	T BL TR BR TL		
6 ALIGN BUCKETS 1 AND 2E	2E	B TL TR BL BR		
7 CLIMB TO 2X OVER STAND 1	1	T BL TR BR TL		
8 ALIGN BUCKETS 1 AND 3I	3I	B L T BL TL		
9 DESCEND TO X OVER STAND 1	1	T BL TR BR TL		
10 ALIGN BUCKETS 1 AND 2E	2E	B TL TR BL BR		
11 FORWARD OVER STAND 2	2	B L T BL TL		
12 ALIGN BUCKETS 2 AND 3I	3I	B L T BL TL		
13 BACKWARD OVER STAND 1	1	T BL TR BR TL		
14 ALIGN BUCKETS 1 AND 2E	2E	B TL TR BL BR		
15 FORWARD/ROTATE 180° OVER STAND 2	2	B L T BL TL		
16 ALIGN BUCKETS 2 AND 1C	1C	B L B L BR		
17 FORWARD/ROTATE 180° OVER LANDING	1A	T R B R BR		
18 ALIGN BUCKETS 1A AND LANDING	LANDING	T BL TR BR TL		
19 LAND CENTERED FACING STANDS (2 POINTS)	CENTERED (Perch 1)	T BL TR BR TL		
20 *Centered is 1 or more feet within a 1ft radius*	CENTERED (Perch 2)	L R TR BL L		

RESULTS

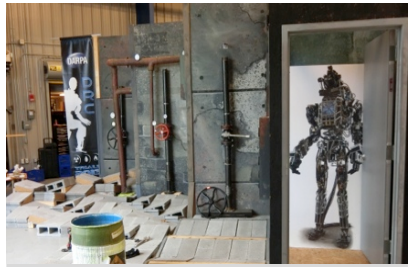
MAN 1 SCORE
TOTAL BUCKETS ALIGNED: of 20
RELIABILITY (Total Buckets Aligned / Attempted) X 100: %
EFFICIENCY Total Buckets Aligned / Minutes: BPM

PAY 1 SCORE
TOTAL C's IDENTIFIED: of 100
AVERAGE ACUITY Total C's Identified / Total Buckets Aligned: 1-5 Cs
EFFICIENCY Total Buckets Aligned / Minutes: BPM

Comprehensive Suite of 50+ Test Methods

Ground, Aerial, and Aquatic Systems

Mobility
Dexterity
Endurance
Sensors
Radio Comms
Durability
Logistics
Safety
Autonomy
Proficiency

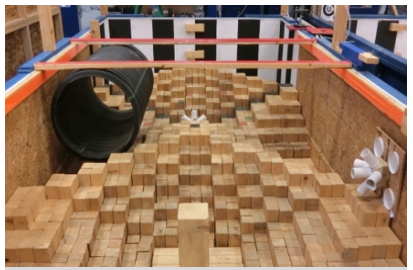

Humanoids


Humanoids


Dexterity


Standard Lanes


Vehicle Scenarios


120cm (48in) Scale

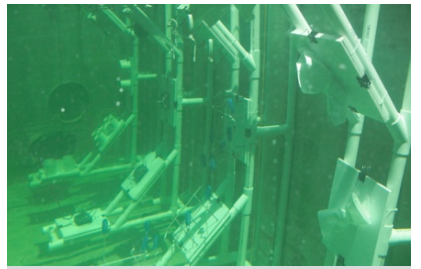

30cm (12in) Scale


Confined access


Aerial (netted)


Aerial (outdoor)


Aerial (hangar)


Underwater (tank)

Sponsors and Customers

Sponsors
Adopting and Developing
New Standard Test Methods

Robot Purchases
Using Robot Capabilities
Data From Test Methods

$70M to date

Working with the Nation's Bomb Techs

Western Region:

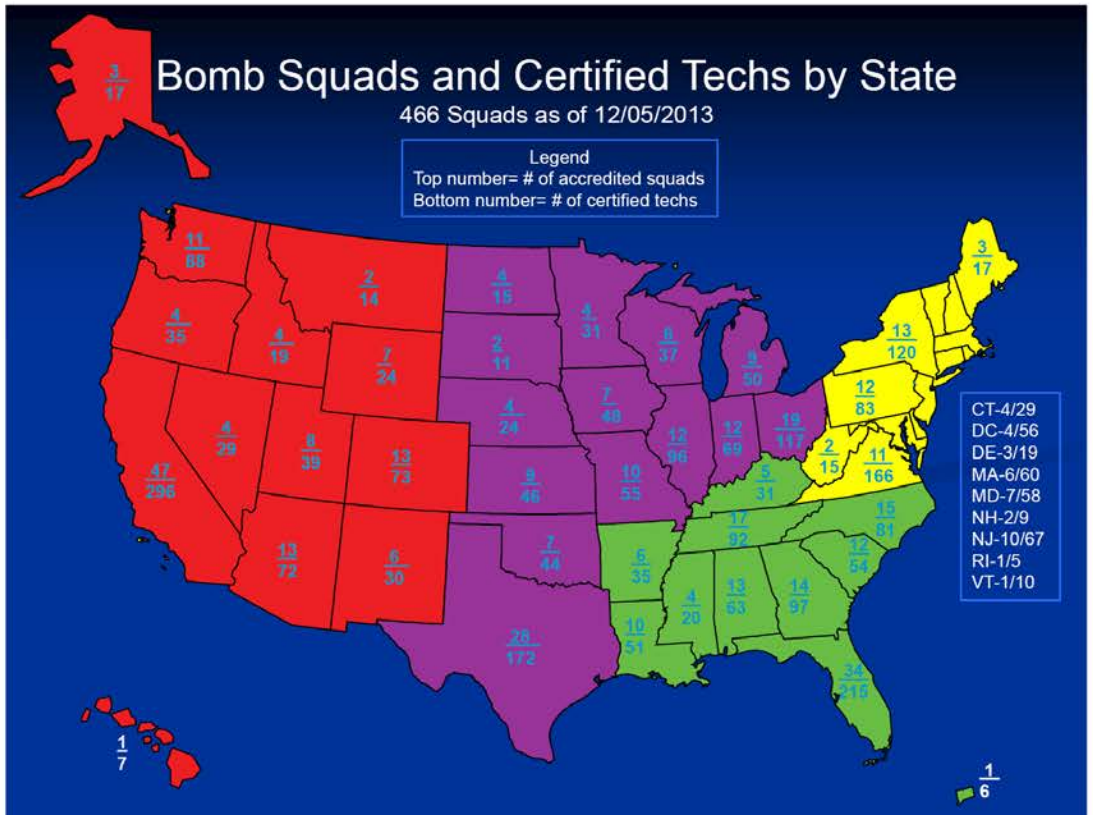
- CA San Diego Fire Rescue (2014)
- WA Port of Seattle Police (2015)
- CA Santa Clara Sheriff (2016)
- CA Navy SPAWAR, San Diego (2016)
- AZ Phoenix Police (2016)
- NV Las Vegas Fire (2016)
- CO Denver Police (2016)
- AZ Tucson Police (2016)

Central Region:

- TX Southwest Research Institute, San Antonio (2010)
- TX Austin Fire (2016)
- TX Houston Police (2016)
- TX Disaster City, College Station (2016)
- KS Kansas City, Olathe Fire (2016)
- MI Michigan State Police (2016)
- MI Detroit Police (2016)
- OH Cincinnati Fire (2016)

ENGAGING MORE THAN 25% OF BOMB SQUADS NATIONWIDE

28 Validation Sites of 120 Requests



Northern Region:

- MD NIST, Gaithersburg (2006, 2012)
- MA UMass Lowell (2013)
- WV ARMY Camp Dawson, Kingwood (2013)
- PA Penn State Uni., State College (2014)
- NY DHS Training Center, Oriskany (2015)
- MD Navy NAVEODTECHDIV, Indian Head (2016)
- VA Virginia State Police (2016)

Southern Region:

- FL Air Force Tyndall AFB, Pensacola (2014)
- FL Lee County Sheriff (2016)
- FL Boca Raton Police (2016)
- GA Atlanta Police (2016)
- GA Dobbins Air Force Reserve Base (2016)

Collaborating Test Facilities Worldwide

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 Directors: Jackrit Suthakorn and Syed Saqib Hussain Shah
Center for Biomedical and Robotics Technology (BART LAB)
Mahidol University
Bangkok, Thailand
(Established 2017)

Test Director: Seung Sub Oh
Disaster Robotics R&D Center
KIRO Institute for Robotics and Convergence
Established: 2017

Test Director: Tetsuya Kimura
Nagaoka University of Technology
Niigata Prefecture, Japan
Established: 2016

Test Director: Masayuki Okugawa
Aichi Institute of Technology
Nagoya Prefecture, Japan
Established: 2017

Test Director: TBD
Fukushima Robot Test Field
Fukushima Prefecture, Japan
Established 2018-2020

The UAS Test Methods

Test Methods for small Unmanned Aircraft Systems (sUAS)

Safety | Capabilities | Proficiency

Initial focus is on VTOL UAS, but some tests apply to forward flying aircraft when scaled up to the appropriate loiter radius.

Supporting NFPA 2400 and ASTM F38 Practical Skills Requirement

"Standard Guide for Training for Remote Pilot in Command of UAS Endorsement"

Qualitative Task Performance Levels:

4) PROFICIENT
Can do the complete task quickly and accurately.
Can tell or show others how to do the task.

3) COMPETENT
Can do all parts of the task.
Needs only a spot check of completed work.

2) PARTIALLY PROFICIENT
Can do most parts of the task.
Needs only help on hardest parts.

1) LIMITED
Can do simple parts of task.
Needs to be told or shown how to do most of task.

Quantitative Thresholds
(Examples, You May Set Your Own)

80-100% ◆

60-79% ■

40-59% ●

20-39% ○

Benefits

Scores captured in standard tests.

Relative to the "expert" provided by the manufacturer (or best score of all).

Same description applies, but thresholds can be chosen based on measured data.

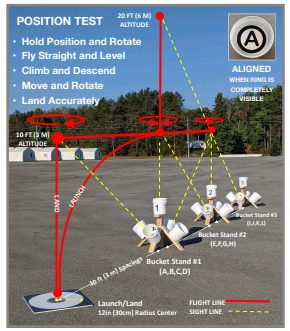
Provides clear thresholds for self-evaluation.

Test Methods Being Developed

Sensing

- Image Acuity
- Color Acuity
- Motion Acuity
- Thermal Acuity
- Latency (Video/Control)

Indoor



Outdoor

Embedded

Basic Pilot Proficiency Tests

Maneuvering & Payload Functionality

1. Position
    - Hold Position and Rotate
    - Climb and Descend
    - Fly Straight and Level
    - Move and Rotate
    - Land Accurately
2. Traverse
3. Orbit
4. Spiral
5. Recon

Maneuvering & Payload Funct. (contd.)

- Avoid Obstacles
- Pass Through Openings
- Map Wide Areas (Stitched Images)
- Survey Acuity
- Deliver Payload

Energy/Power

- Endurance (Mixed Use, High Speed)
- Perch Time (Landed w/ Sensors On)

Radio Communications

- Line-of-Sight Range
- Non-Line-of-Sight Range
- Interference/Attenuation

Safety

- Impact Forces
- Lights and Sounds
- Prop Guards
- Lost Power Behaviors
- Lost Comms Behaviors

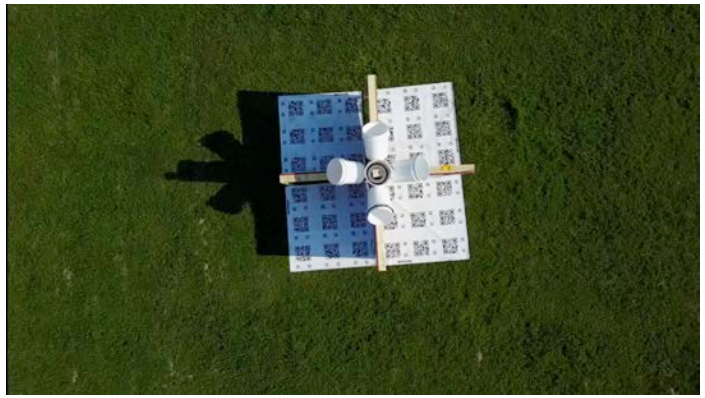
Durability

- Rain Tolerance

Logistics

- Configuration Identification, Packaging & Setup Time

Test Methods Being Developed



Orbit - Maneuvering

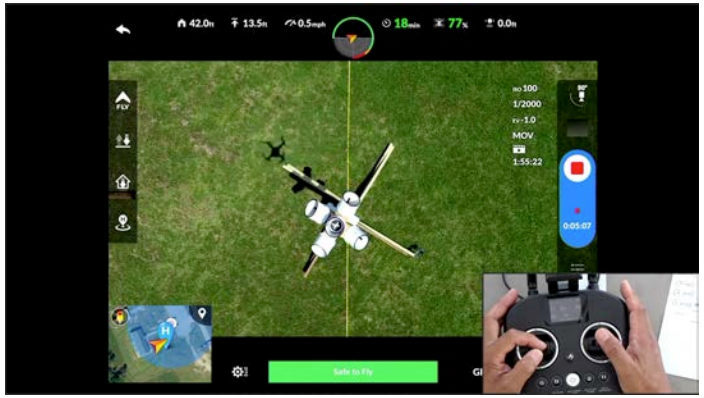
Hold Position and Rotate

Basic Pilot Proficiency Tests

Maneuvering & Payload Functionality

1. Position
    - Hold Position and Rotate
    - Climb and Descend
    - Fly Straight and Level
    - Move and Rotate
    - Land Accurately
2. Traverse
3. Orbit
4. Spiral
5. Recon

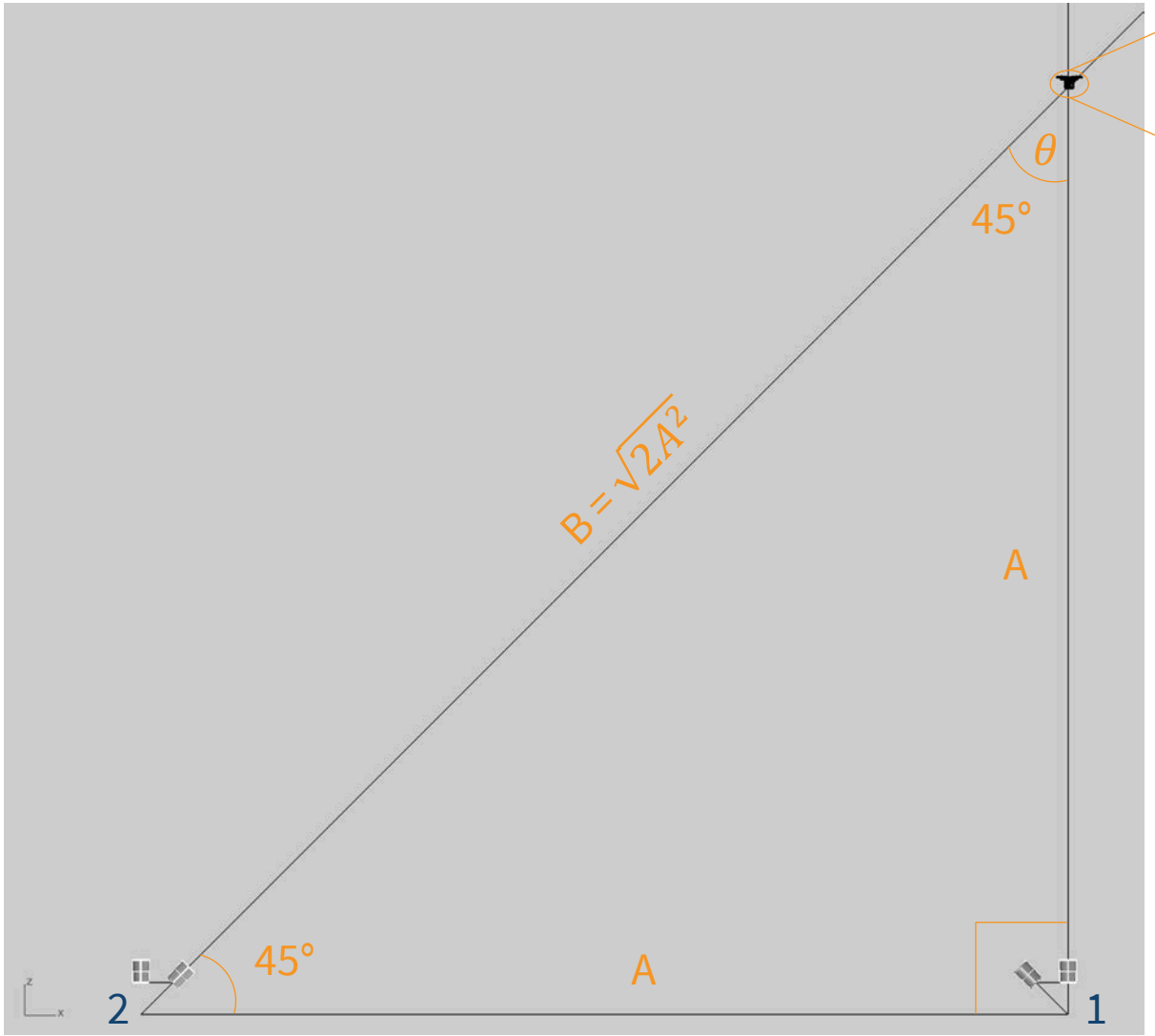
Orbit – Payload Functionality

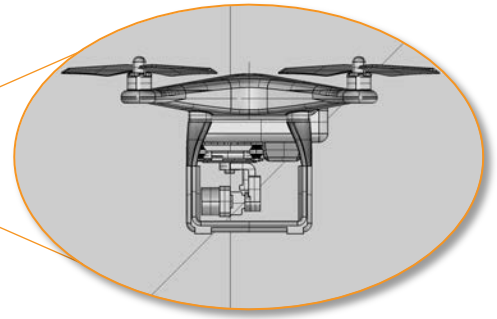


Recon

The Theory Behind the Test Methods

Using Right Triangles to Localize an Aircraft in Space





Sum of angles of a triangle = 180°

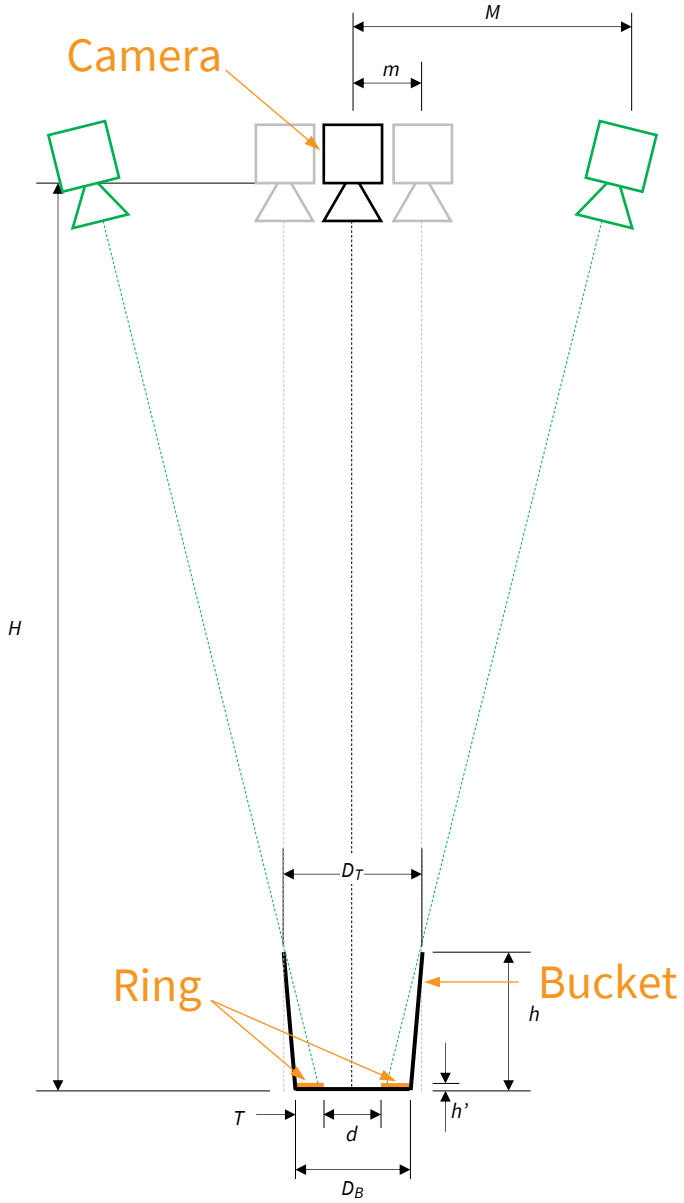
$\Rightarrow \theta + 90° + 45° = 180°$

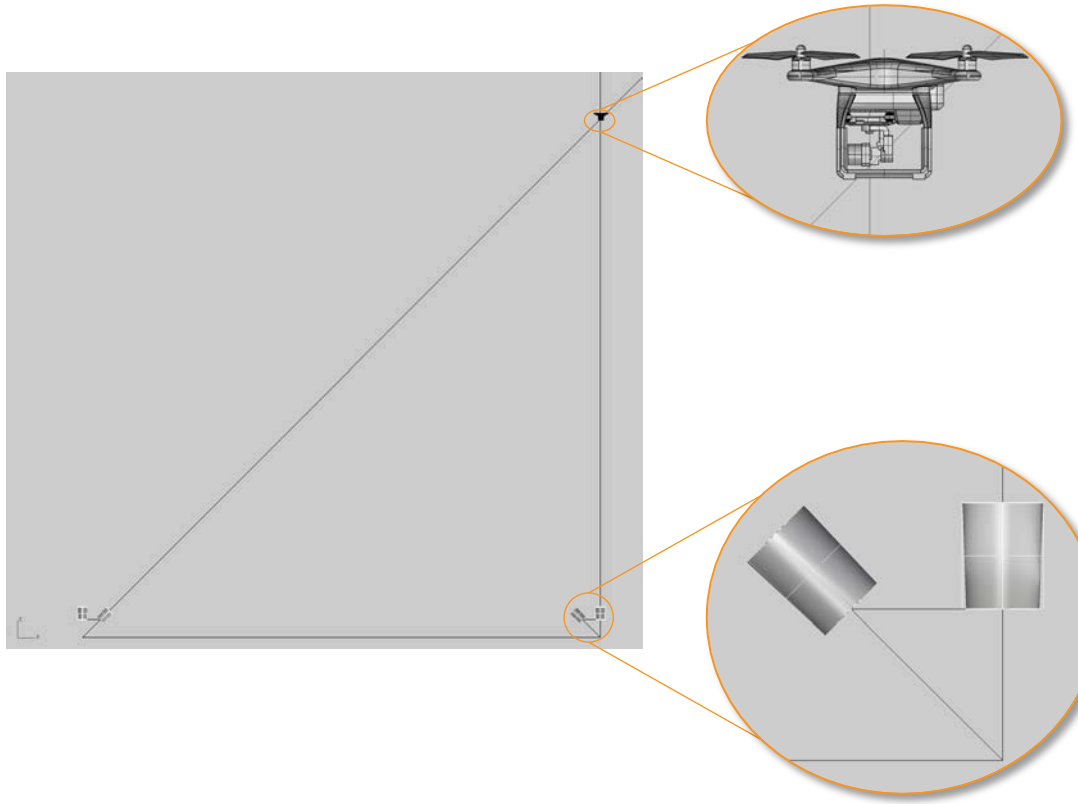
$\Rightarrow \theta = 180° - (90° + 45°)$

$\Rightarrow \theta = 45°$

Therefore, aircraft elevation = A

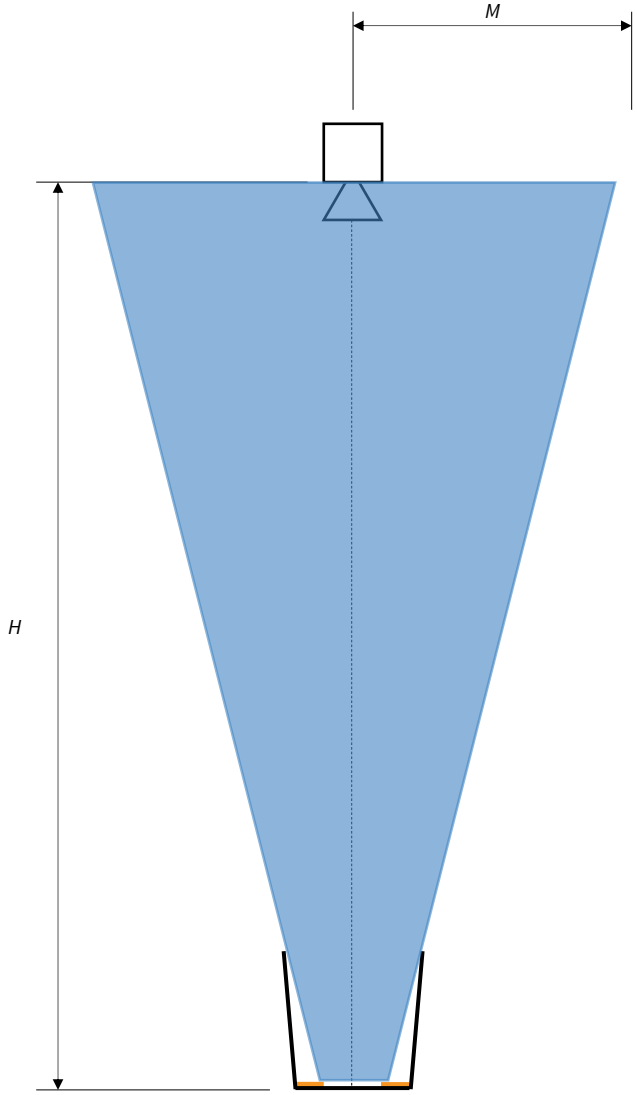
Cameras, Rings, and Buckets

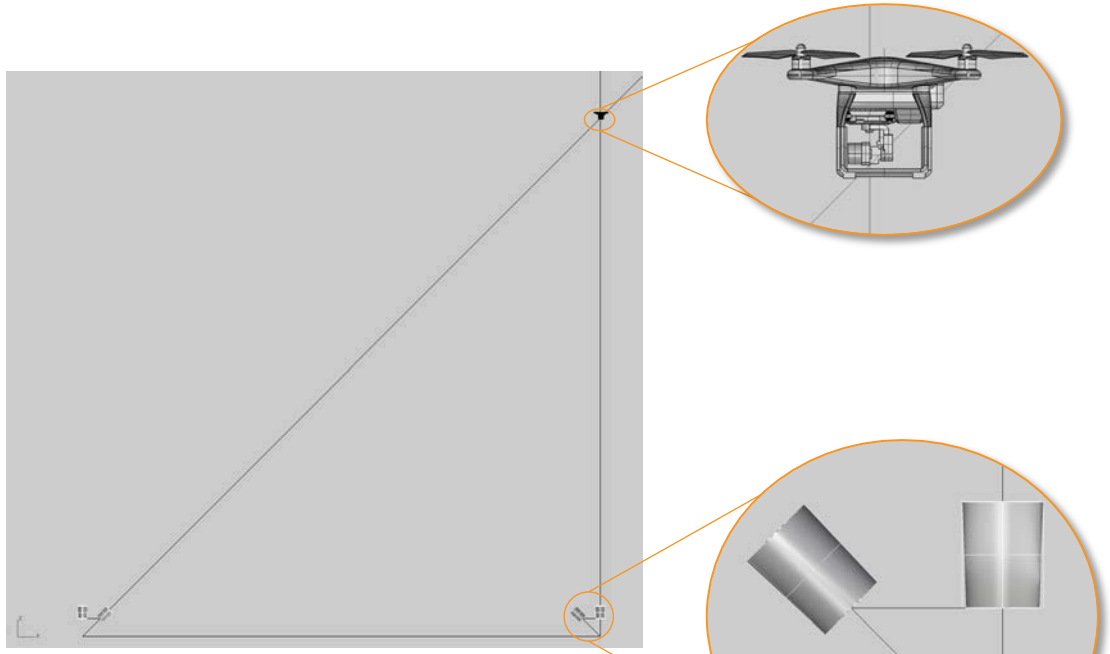




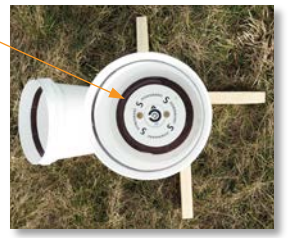
Ring

Cameras, Rings, and Buckets

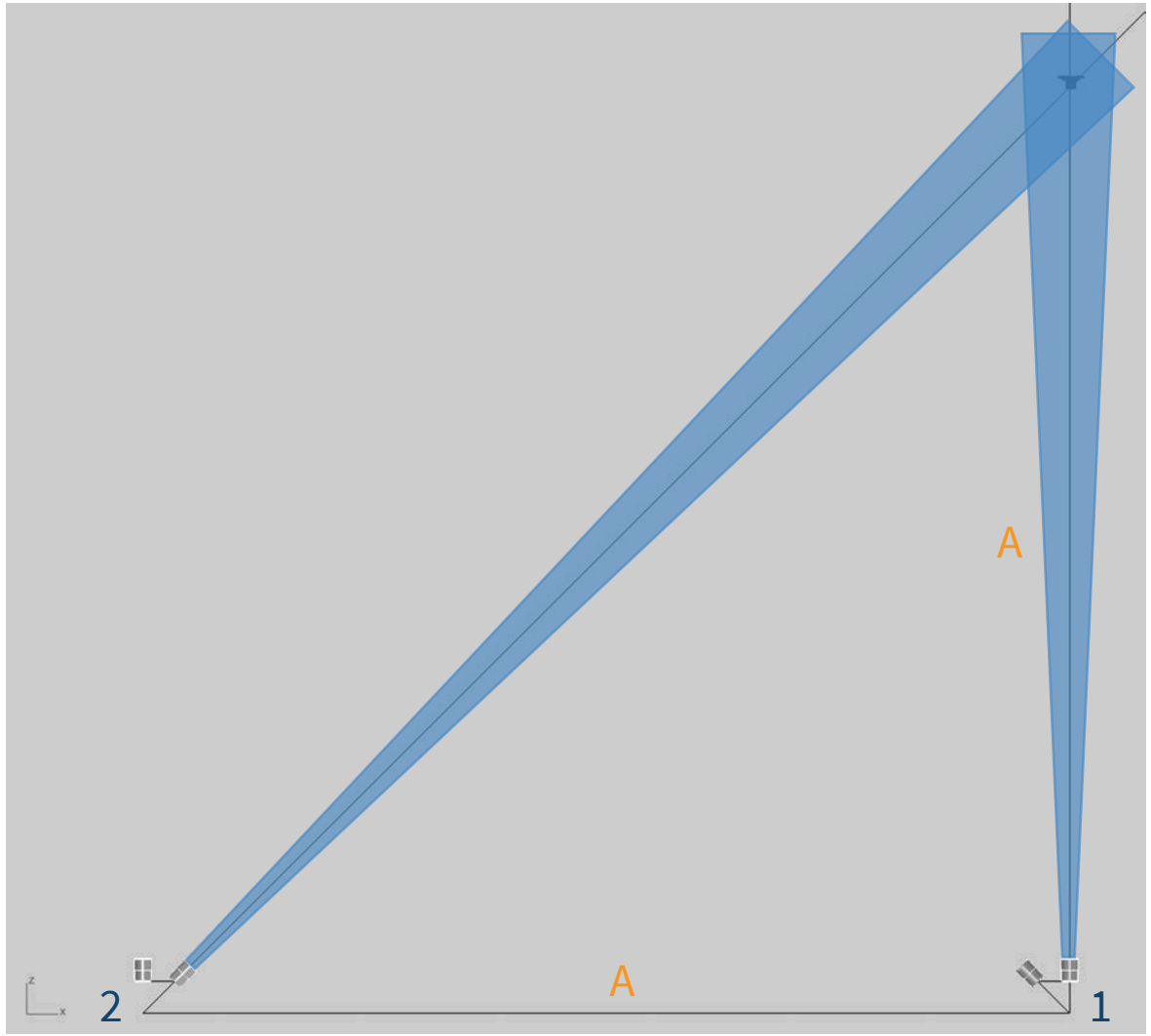


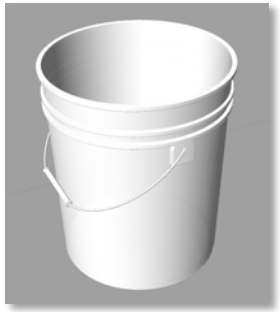


Ring



Cameras, Rings, and Buckets





Bucket Alignments Define Points of View

COMPLETE GREEN RING

ALIGNED

PARTIAL GREEN RING

ALIGNED

BROKEN GREEN RING

NOT ALIGNED

Bucket Alignments Define Points of View

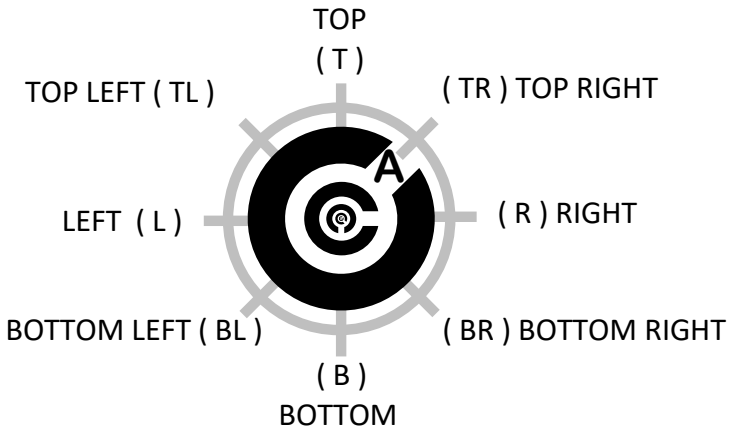
WHITE TEST LANES

WHITE TEST LANES

BLACK EMBEDDED SCENARIOS

Visual Acuity Targets for Payload Functionality

Align green (or multi-color) ring first
Then read as many “Concentric Cs” as possible.



Identify “Concentric C” gap directions
There are 5 increasingly smaller sizes of Cs to identify. For each readable size, identify the gap direction as shown.

Basic Maneuvering / Payload Functionality Procedures

MANEUVERING MAN 1-5

ALIGN WITH BUCKETS

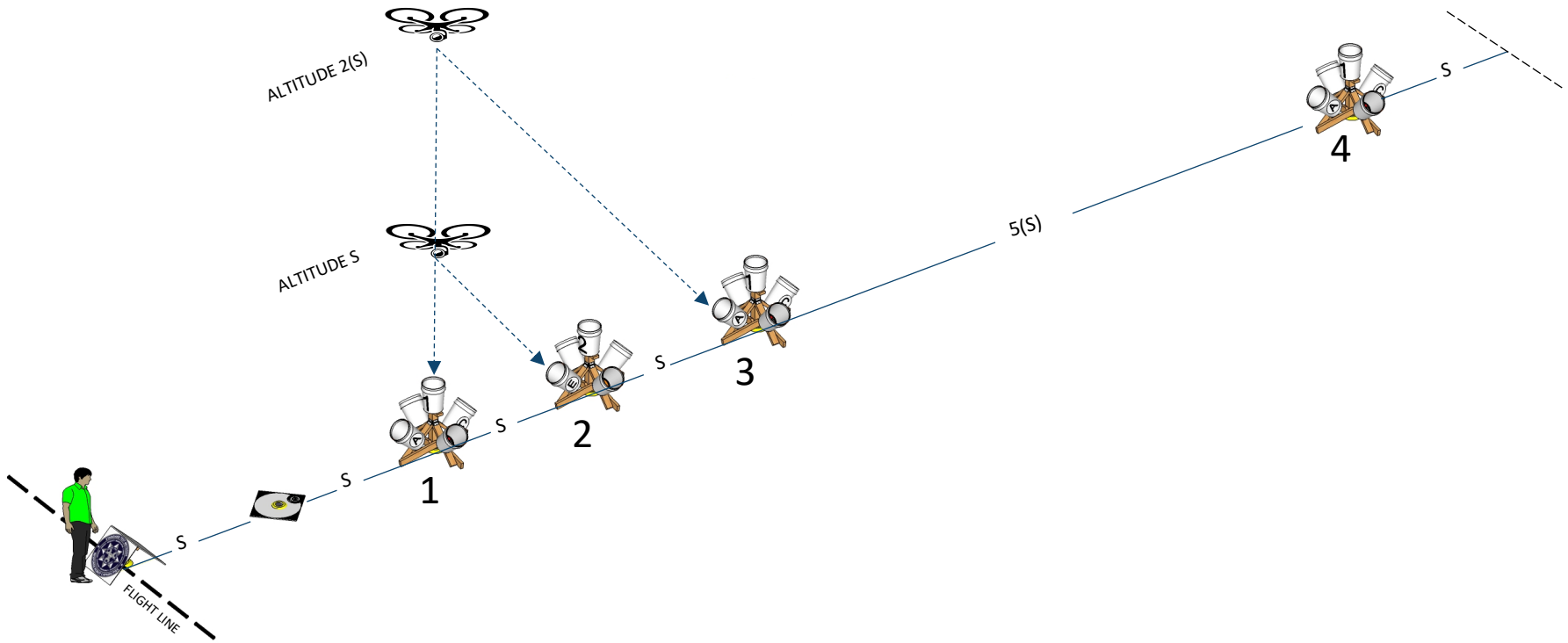
See a continuous GREEN ring inside each designated bucket to determine successful alignment. The numbers/letters are bucket identifiers for captured images.

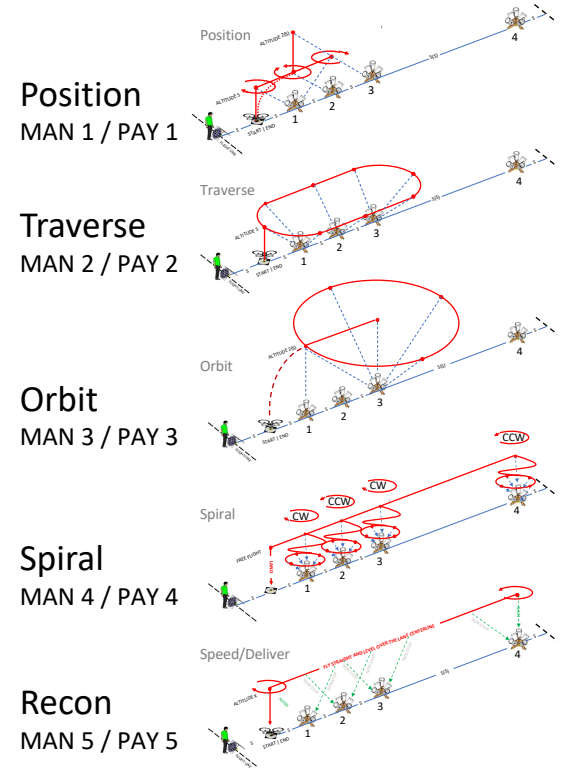
NOT ALIGNED BARELY ALIGNED ALIGNED

PAY 1-5 PAYLOAD FUNCTIONALITY

IDENTIFY VISUAL ACUITY TARGETS

Align with each designated bucket then identify the concentric C gap orientations. There are 5 increasingly small gaps to identify in 8 different orientations.





Position
MAN 1 / PAY 1

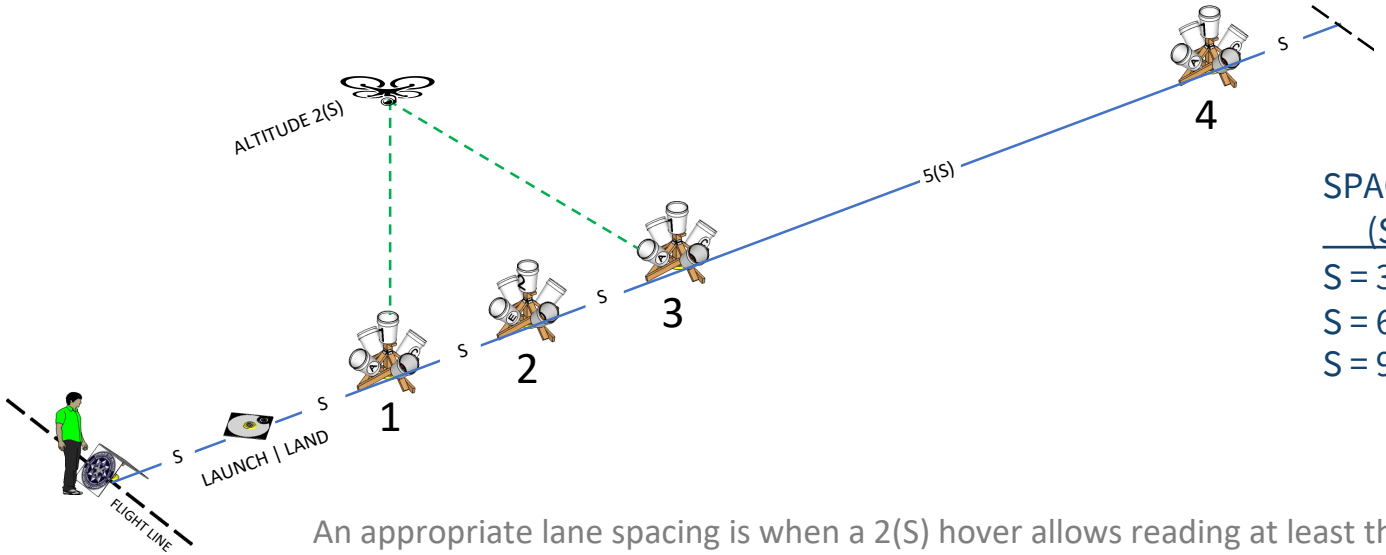
Traverse
MAN 2 / PAY 2

Orbit
MAN 3 / PAY 3

Spiral
MAN 4 / PAY 4

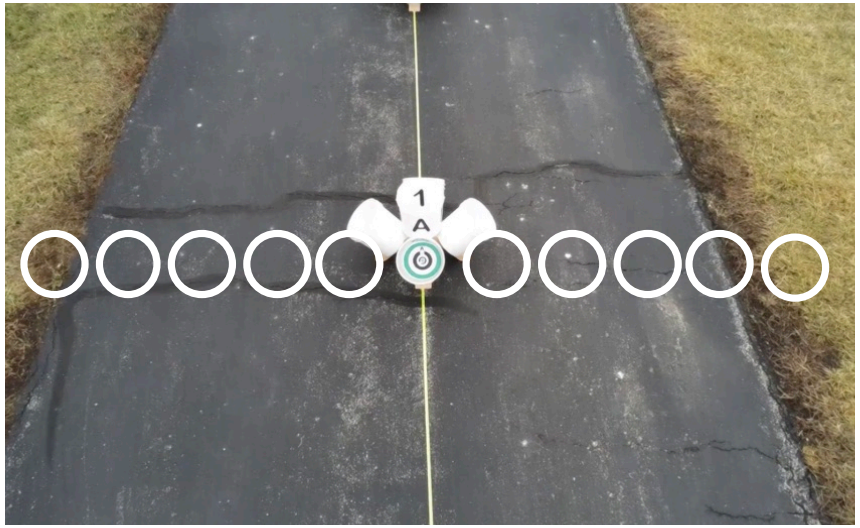
Recon
MAN 5 / PAY 5

Choose An Appropriate Lane Spacing for the Aircraft



SPACING (S)	LANE LENGTH (10S)	ALTITUDES (S, 2S, 5S)
S = 3 m (10 ft)	30 m (100 FT)	3, 6, 15 m (10, 20, 50 ft)
S = 6 m (20 ft)	60 m (200 FT)	6, 12, 30 m (20, 40, 100 ft)
S = 9 m (30 ft)	90 m (300 FT)	9, 18, 45 m (30, 60, 150 ft)

An appropriate lane spacing is when a 2(S) hover allows reading at least the outer concentric C target two stands away.

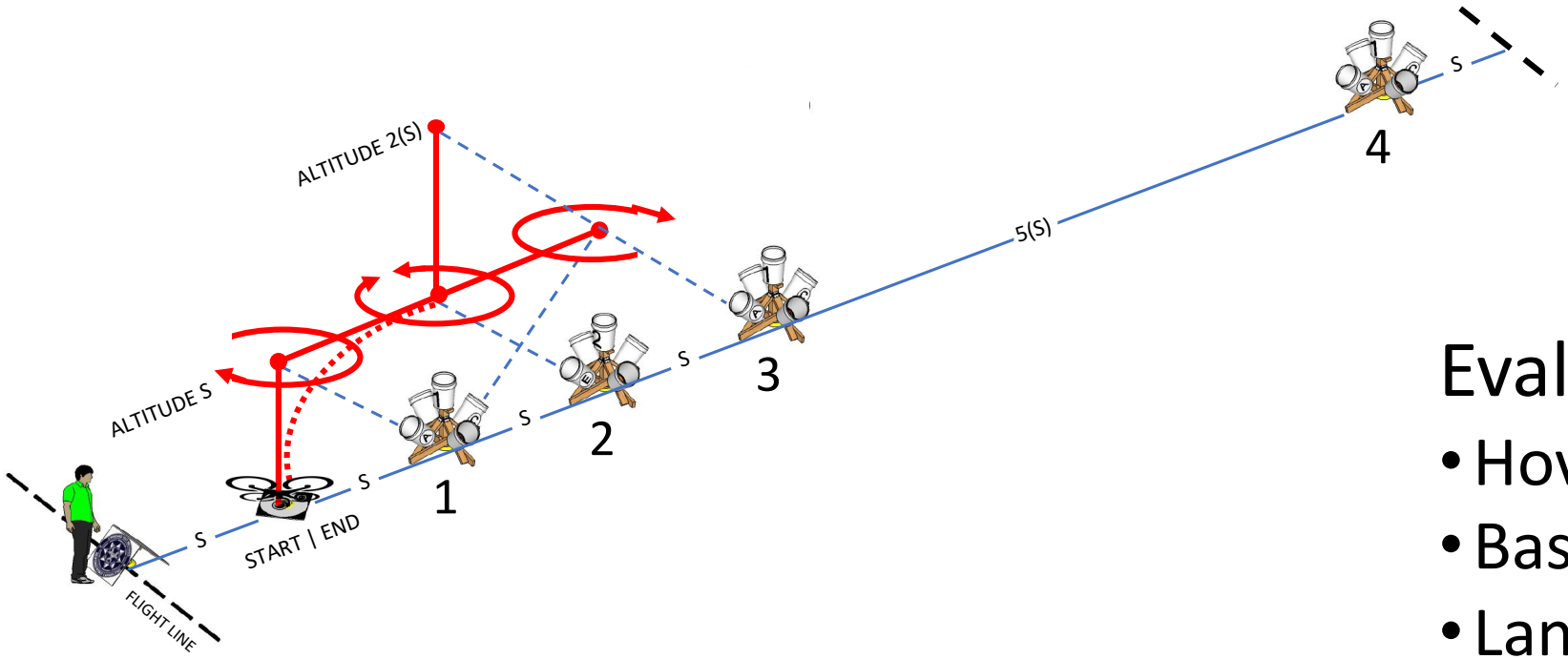


Altitude = Spacing between bucket stands.

Test Method Procedures

POSITION (MAN 1 | PAY 1)

Safety | Capabilities | Proficiency



Evaluates

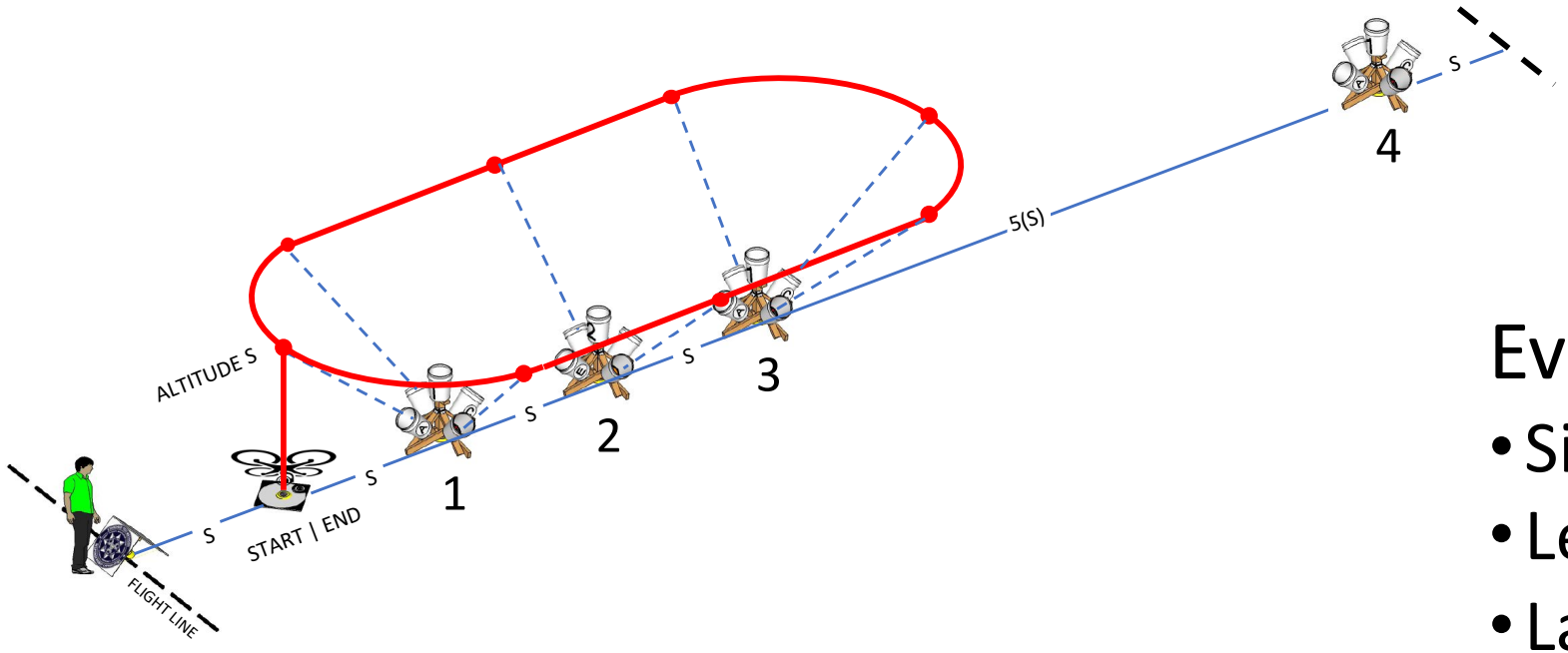
- Hover position stability
- Basic maneuvers
- Landing accuracy
- 20 tasks in 1 lap

MAN: Align only

PAY: Align and Identify

TRAVERSE (MAN 2 | PAY 2)

Safety | Capabilities | Proficiency



Evaluates

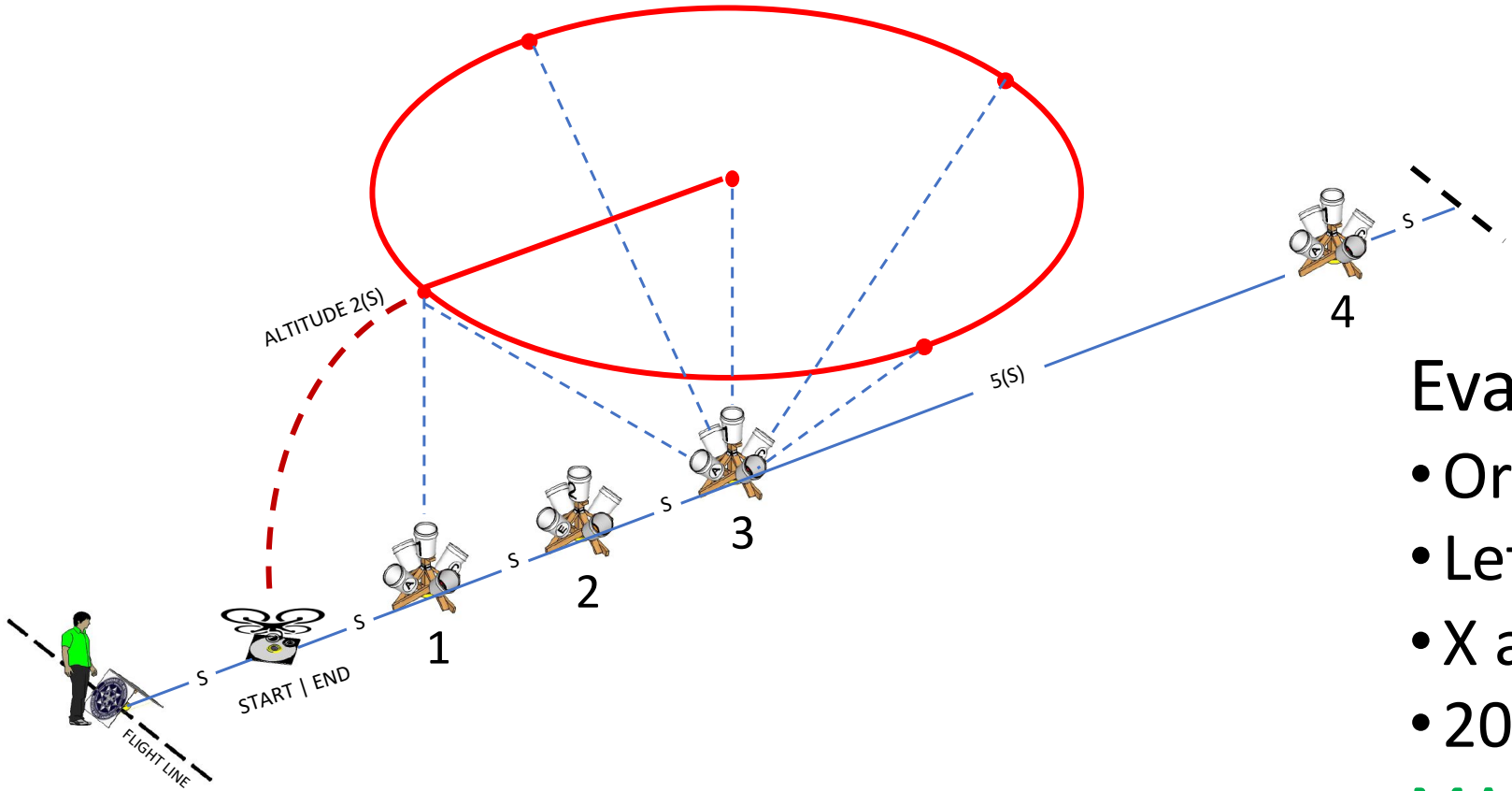
- Sideways flight along a line
- Left and right directions
- Landing accuracy
- 20 tasks in 1 lap

MAN: Align only

PAY: Align and Identify

ORBIT (MAN 3 | PAY 3)

Safety | Capabilities | Proficiency



Evaluates

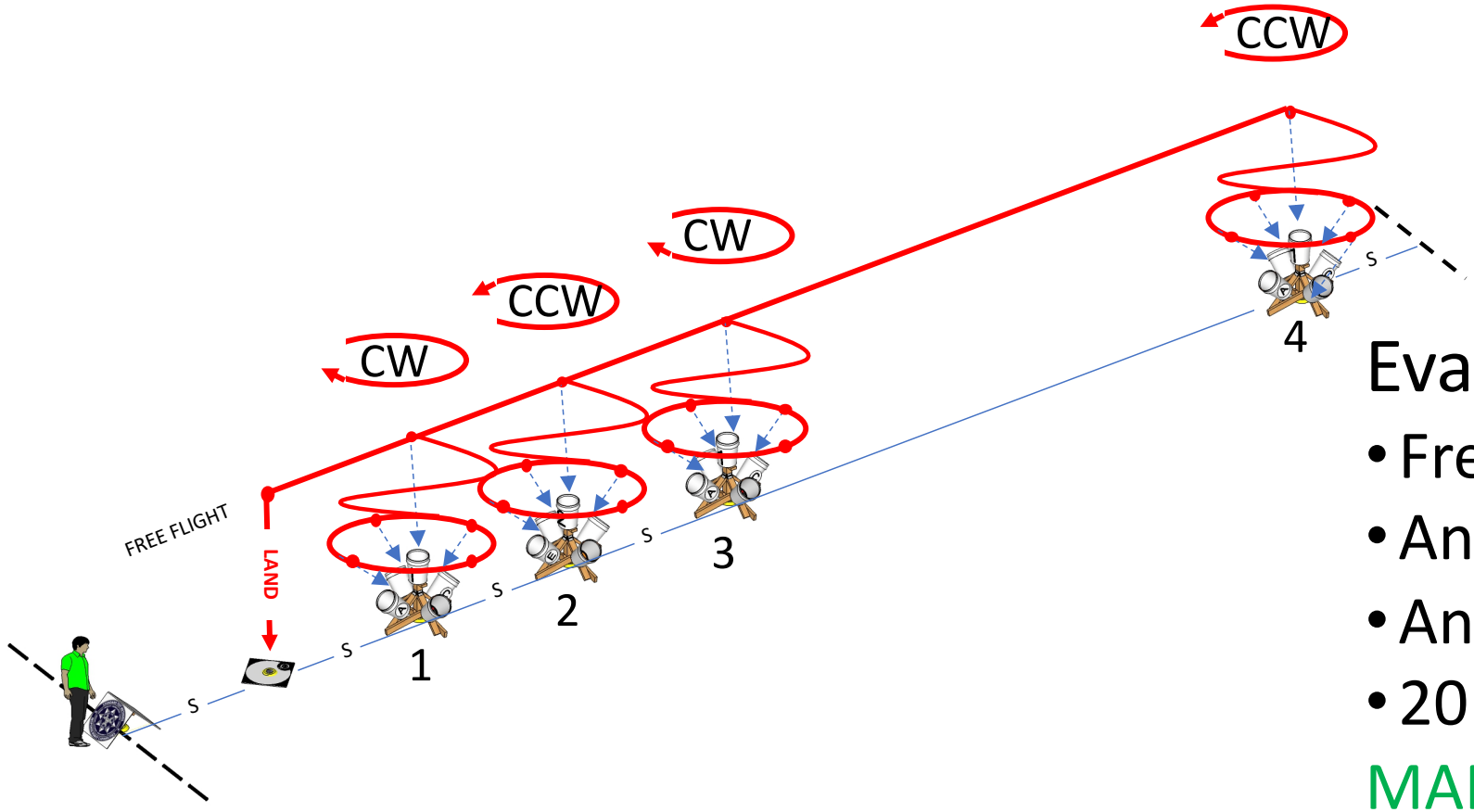
- Orbits to identify objects
- Left and right directions
- X and 2X altitudes
- 20 tasks in 4 laps

MAN: Align only

PAY: Align and Identify

SPIRAL (MAN 4 | PAY 4)

Safety | Capabilities | Proficiency



Evaluates

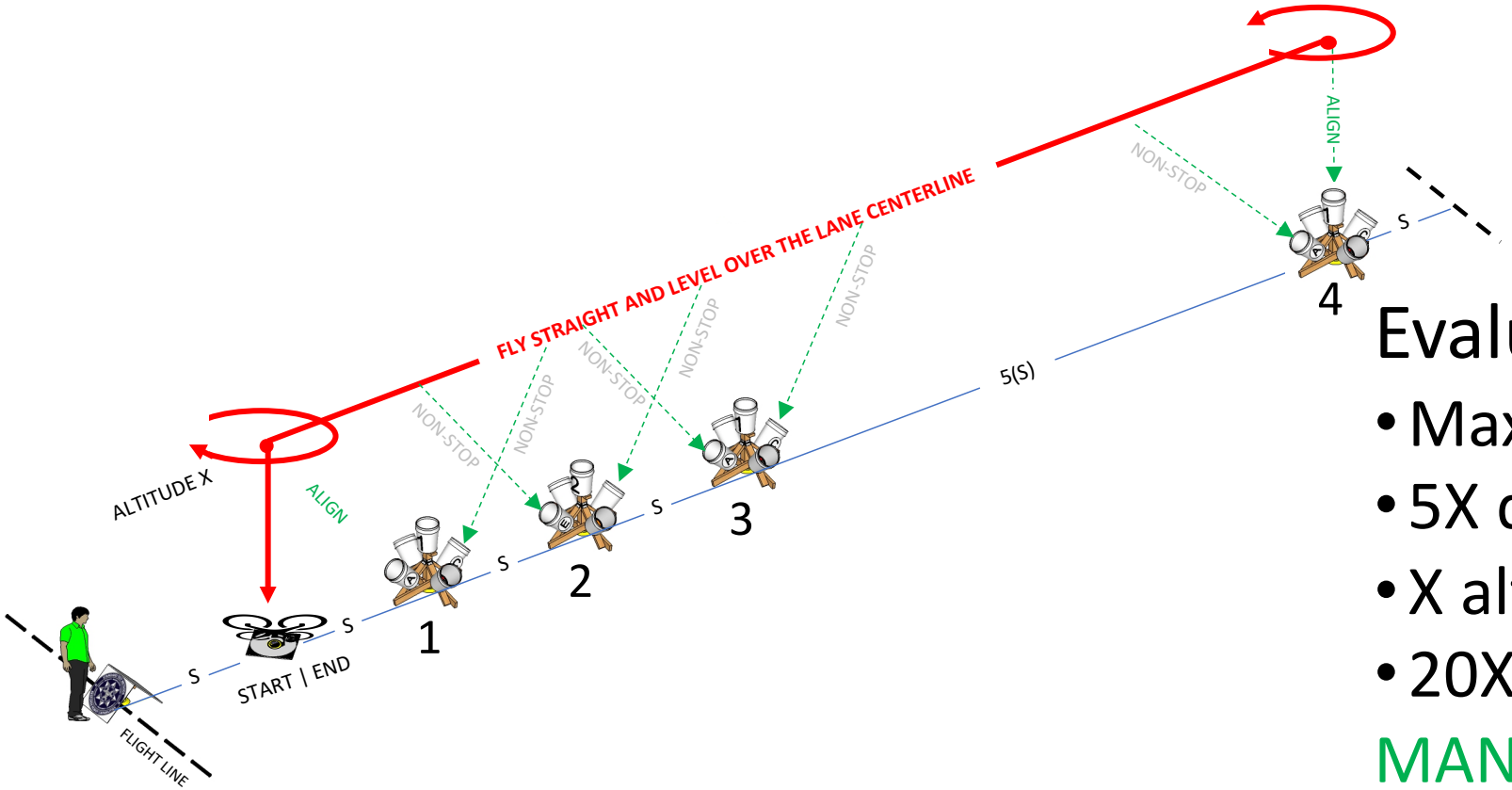
- Free flight to inspect objects
- Any proximity (use zooms)
- Any altitude
- 20 tasks in 1 lap

MAN: Align only

PAY: Align and Identify

SPEED/RECON (MAN 5 | PAY 5)

Safety | Capabilities | Proficiency



Evaluates

- Max speed following a line
- 5X distance
- X altitude
- 20X distance per lap

MAN: Align only

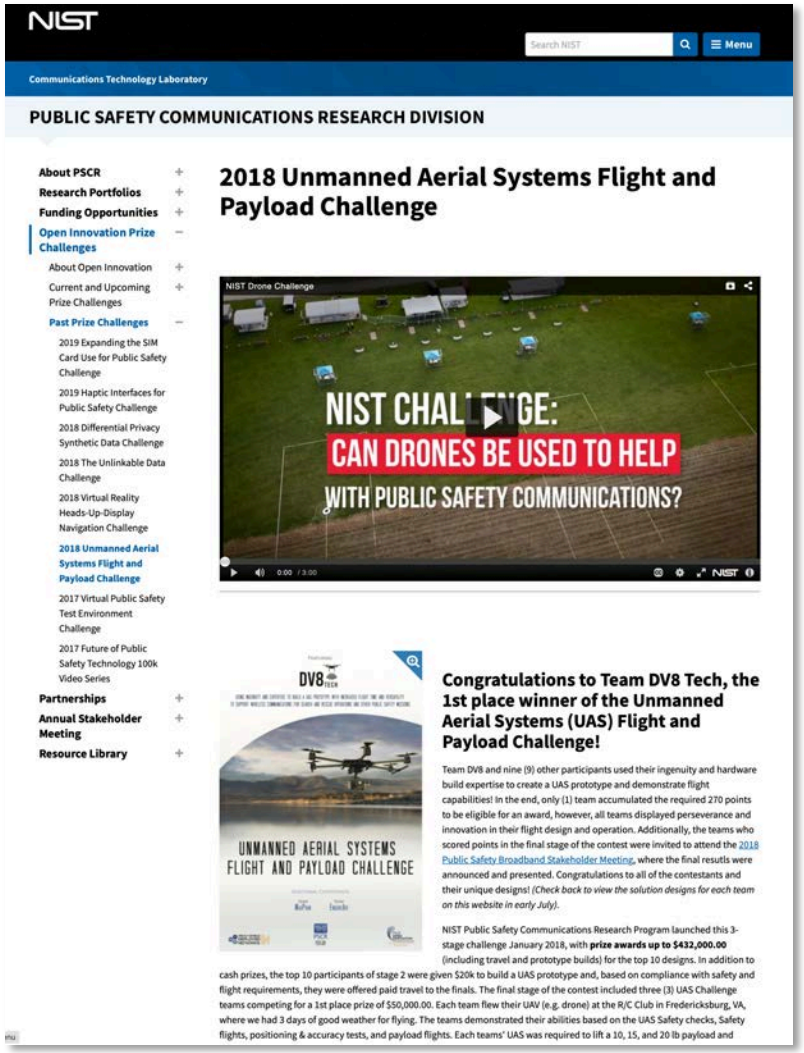
PAY: Align and Identify

Payload Functionality – Positions (PAY1)

Test Methods used in UAS1 and UAS2

PSCR UAS Flight and Payload Challenge (UAS1)
2018

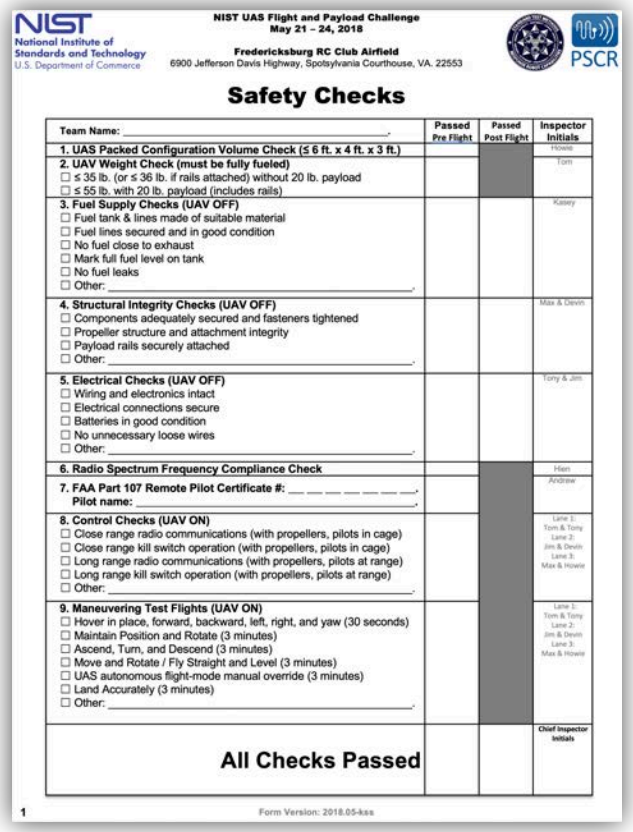
- VTOL
- Maximum flight time
- 10 lbs, 15 lbs, 20 lbs payload categories
- Hover stability within ± 5 ft
- Weight < 55 lbs
- Cost <= $20,000
- No forward flying aircraft



https://bit.ly/2BPbEdz

PSCR UAS Flight and Payload Challenge (UAS1)

2018



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

NIST UAS Flight and Payload Challenge
May 21 – 24, 2018
Fredericksburg RC Club Airfield
6900 Jefferson Davis Highway, Spotsylvania Courthouse, VA. 22553

PSCR

Safety Checks

Team Name: _____	Passed Pre Flight	Passed Post Flight	Inspector Initials
1. UAS Packed Configuration Volume Check (≤ 6 ft. x 4 ft. x 3 ft.)			Howie
2. UAV Weight Check (must be fully fueled) ☐ ≤ 35 lb. (or ≤ 36 lb. if rails attached) without 20 lb. payload ☐ ≤ 55 lb. with 20 lb. payload (includes rails)			Tom
3. Fuel Supply Checks (UAV OFF) ☐ Fuel tank & lines made of suitable material ☐ Fuel lines secured and in good condition ☐ No fuel close to exhaust ☐ Mark full fuel level on tank ☐ No fuel leaks ☐ Other: _____			Kasey
4. Structural Integrity Checks (UAV OFF) ☐ Components adequately secured and fasteners tightened ☐ Propeller structure and attachment integrity ☐ Payload rails securely attached ☐ Other: _____			Max & Devin
5. Electrical Checks (UAV OFF) ☐ Wiring and electronics intact ☐ Electrical connections secure ☐ Batteries in good condition ☐ No unnecessary loose wires ☐ Other: _____			Tony & Jim
6. Radio Spectrum Frequency Compliance Check			Hien
7. FAA Part 107 Remote Pilot Certificate #: __ __ __ __ __ __ __ __ __ __ **Pilot name:** _____			Andrew
8. Control Checks (UAV ON) ☐ Close range radio communications (with propellers, pilots in cage) ☐ Close range kill switch operation (with propellers, pilots in cage) ☐ Long range radio communications (with propellers, pilots at range) ☐ Long range kill switch operation (with propellers, pilots at range) ☐ Other: _____			Lane 1: Tom & Tony Lane 2: Jim & Devin Lane 3: Max & Howie
9. Maneuvering Test Flights (UAV ON) ☐ Hover in place, forward, backward, left, right, and yaw (30 seconds) ☐ Maintain Position and Rotate (3 minutes) ☐ Ascend, Turn, and Descend (3 minutes) ☐ Move and Rotate / Fly Straight and Level (3 minutes) ☐ UAS autonomous flight-mode manual override (3 minutes) ☐ Land Accurately (3 minutes) ☐ Other: _____			Lane 1: Tom & Tony Lane 2: Jim & Devin Lane 3: Max & Howie
All Checks Passed			Chief Inspector Initials

1 Form Version: 2018.05-kss

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

NIST UAS Flight and Payload Challenge
May 21 – 24, 2018
Fredericksburg RC Club Airfield
6900 Jefferson Davis Highway, Spotsylvania Courthouse, VA. 22553

PSCR

Flight Test Scoring Sheet

Team Name: _____ **Date:** 05 / ____ / 2018

Administrator Name: _____ **Time:** __ __ : __ __ AM / PM

Payload weight: ☐ 10 lbs. (x1) ☐ 15 lbs. (x3) ☐ 20 lbs. (x6) **Total Flight Time:** _____ mins

Band number before takeoff:

First Takeoff Time: __ __ : __ __ AM / PM

Launch Band: _____

Instructions:
Circle the number in which the UAV's outermost ground contact points are in before takeoff and write the number in the box above (white lines are considered inside the corresponding smaller band).

UAV Weight: _____ lbs.

Pilot: _____

Kill Switch Operator: _____

Start Video Recording

Traverses: Waypoint 1, Waypoint 2, Waypoint 3 (see reverse)

Passed: Yes / No

Hover start time: __ __ : __ __ : __ __ AM / PM (Eastern Standard Time)
H H M M S S

Instructions:
Write down the time (to the nearest second) when the pilot says that the UAV is in the hover position (please make sure you use a cell phone clock that is automatically synchronized with a time server).

Hover Score =
Hover Time (min) x Weighting Factor

X (Hover Time / Weighting Factor) = _____

Band number after landing:

Last Landing Time: __ __ : __ __ AM / PM

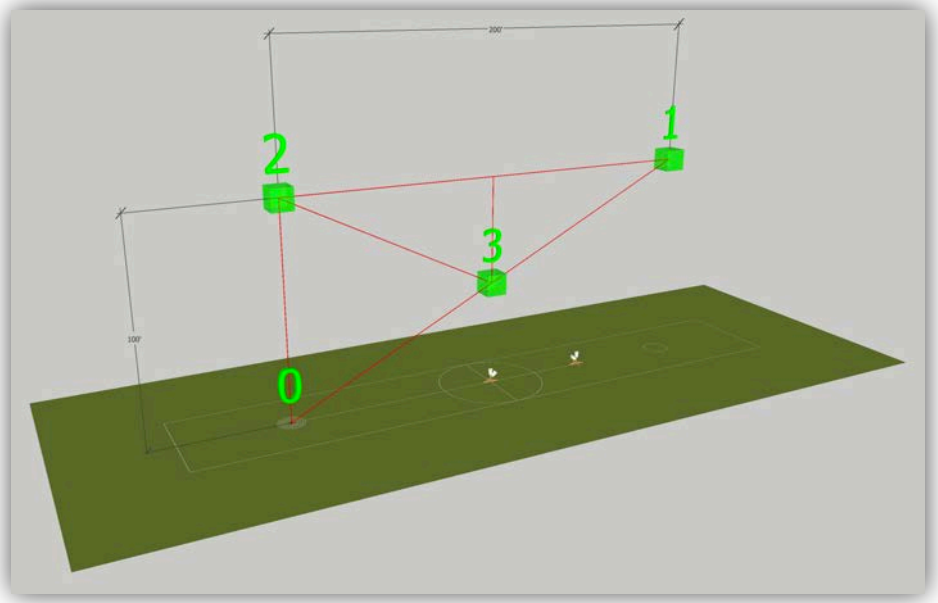
Land Band: _____

Instructions:
Circle the number in which the UAV's outermost ground contact point are in after landing (white lines are considered inside the corresponding smaller band).

Landing Score =
10 – 2 (Land Band – Launch Band)

$$10 - 2\left(\text{Launch Band} - \text{Land Band}\right) = \_\_\_\_$$

Form Version: 2018.05-kss



PSCR UAS1 Overview

Test Method Lanes Setup

Setup 3 standard test method lanes with well-demarcated fly and no-fly zones for each contestant's aircraft.

Test Methods Used

Used the NIST "fly straight and level," "maintain position and orientation," and "land accurately" tests to evaluate the aircrafts' performance.

https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2018-unmanned-aerial-systems-flight

PSCR UAS1 Test Flights 2018

NIST Test Flight

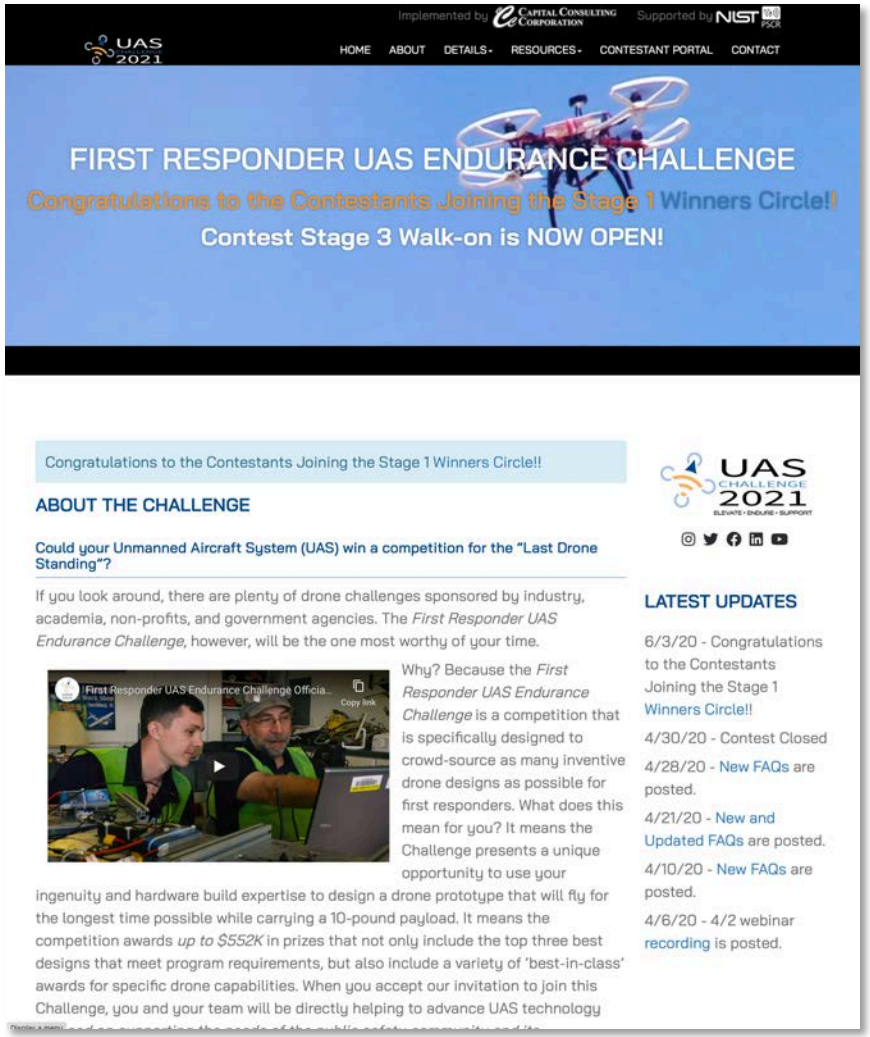
NIST commercial-off-the-shelf aircraft with no payload and an integrated video downlink.

Contestant Test Flight

Contestant's aircraft with a 20 lb. payload and a NIST-provided video downlink.

First Responder UAS Endurance Challenge (UAS2) 2021

- VTOL
- Flight time >= 60 minutes
- 10 lbs payload only
- Hover in place or loiter around
- Weight <= 100 lbs
- Cost <= $30,000
- Forward flying aircraft OK



https://www.firstresponderuaschallenge.org

PSCR First Responder UAS Endurance Challenge (UAS2)

2021

Check out our UAS2 Session!

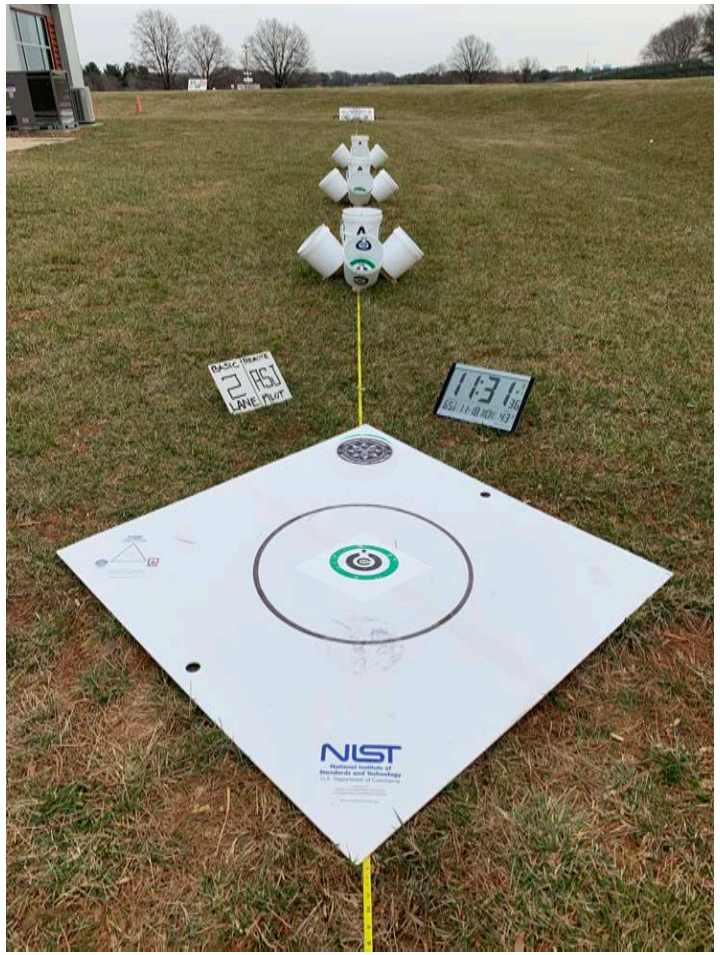
"Innovating on Drone Technology to Support First Responder Missions"

UAS CHALLENGE 2021
ELEVATE • ENDURE • SUPPORT

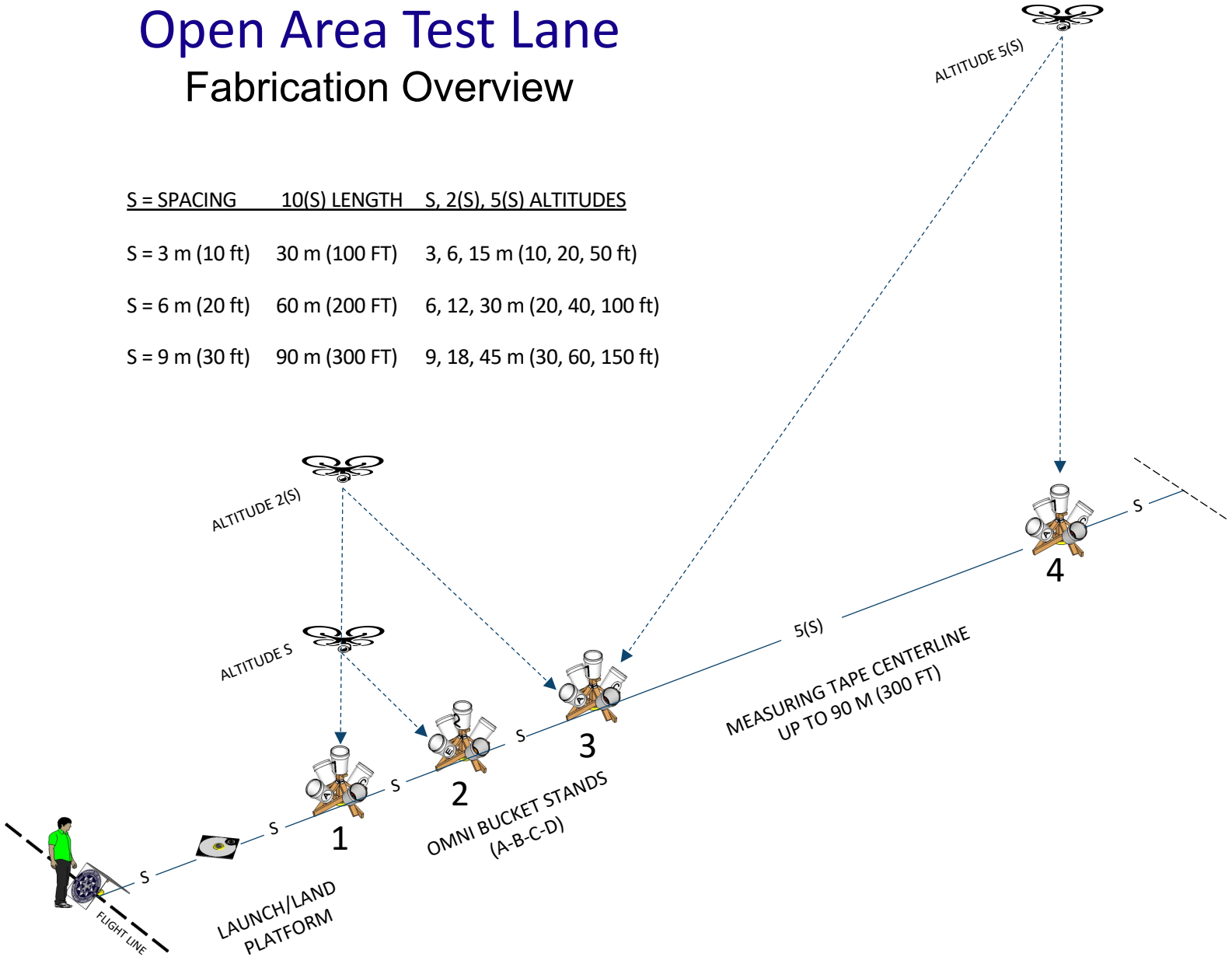
Apparatus Fabrication

Open Area Test Lane

Fabrication Overview

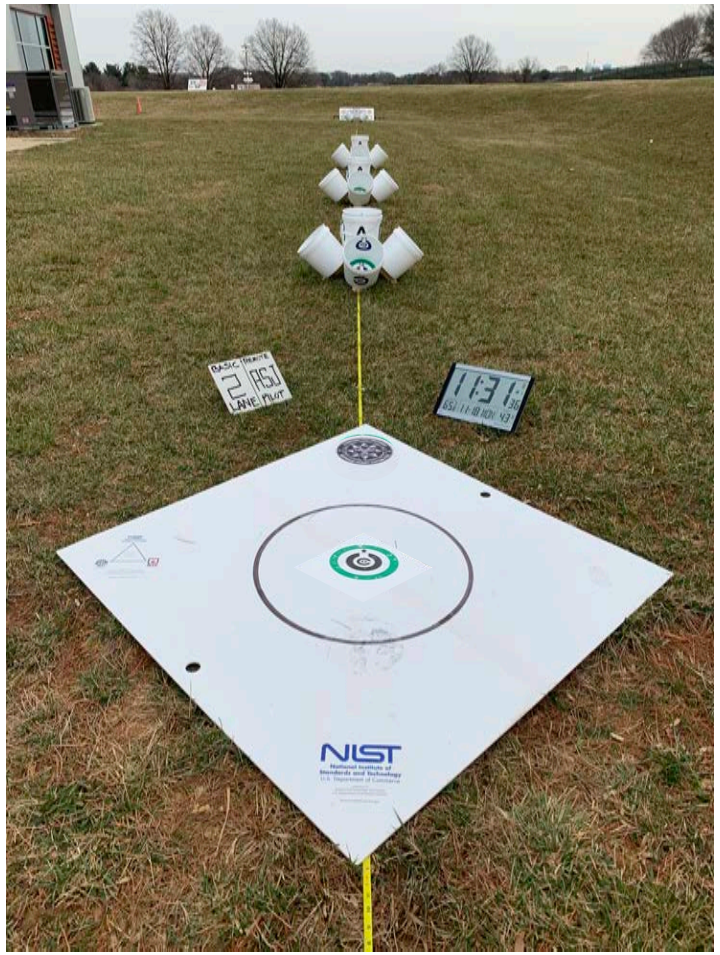


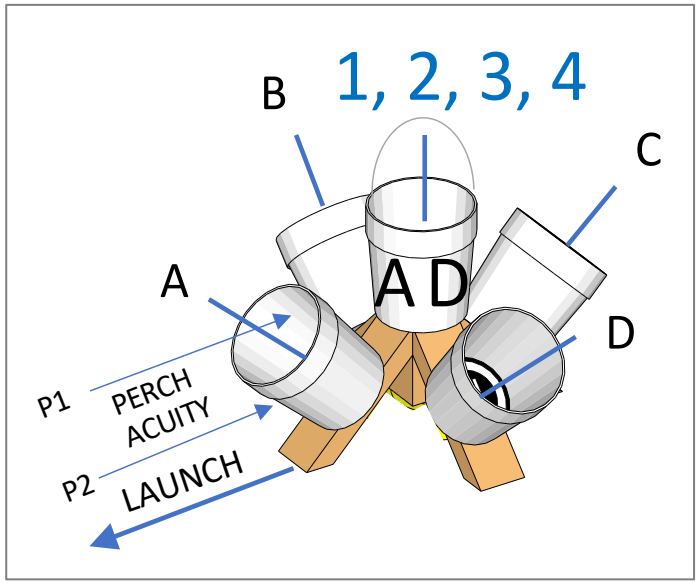
S = SPACING	10(S) LENGTH	S, 2(S), 5(S) ALTITUDES
S = 3 m (10 ft)	30 m (100 FT)	3, 6, 15 m (10, 20, 50 ft)
S = 6 m (20 ft)	60 m (200 FT)	6, 12, 30 m (20, 40, 100 ft)
S = 9 m (30 ft)	90 m (300 FT)	9, 18, 45 m (30, 60, 150 ft)

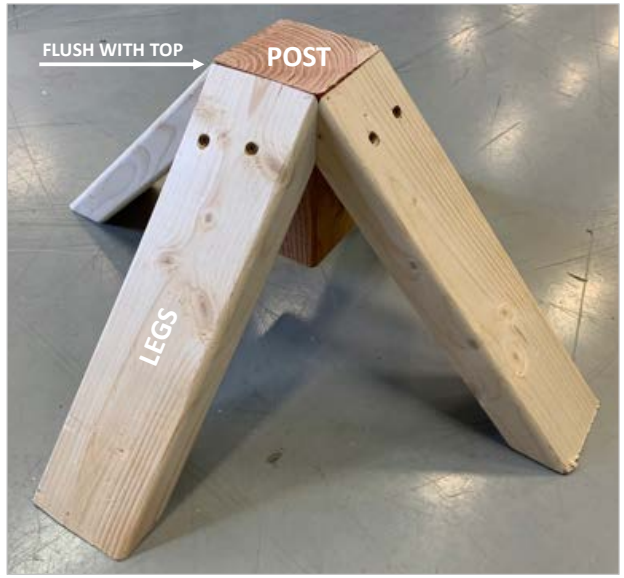


Open Area Test Lane

Fabrication Overview







Omni Bucket Stands

Fabrication Overview

Fabricate Stand:

[1] POST 4 x 4 x 6 inch.

[4] LEGS 2 x 4 x 12 inch with 45-degree tapers on both ends
cut tall on the miter saw with opposing tapers.

[8] 3 in screws to affix the legs flush with the top of the POST.
Use 2 screws per leg through the tapered top end.

Sticker Buckets: *(see pointers to download the sticker files)*

[5] White buckets 2-gallon or 8 in diameter.

[15] 8in diameter matte weatherproof polyester stickers.

[4] Big numbers inside each top bucket 1111 , 2222, 3333, 4444.

[4] Big letters around each top bucket ABCD, ABCD, ABCD, ABCD.

[5] Acuity targets inside all bottoms 1-1A-1B-1C-1D, 2-2A-2B-2C-2D, etc.

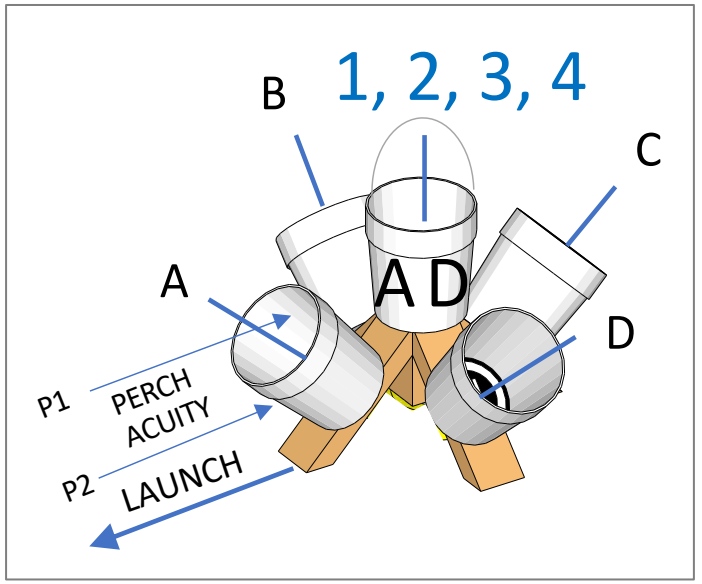
[2]Perch acuity targets inside and under bucket 1A only (see picture).

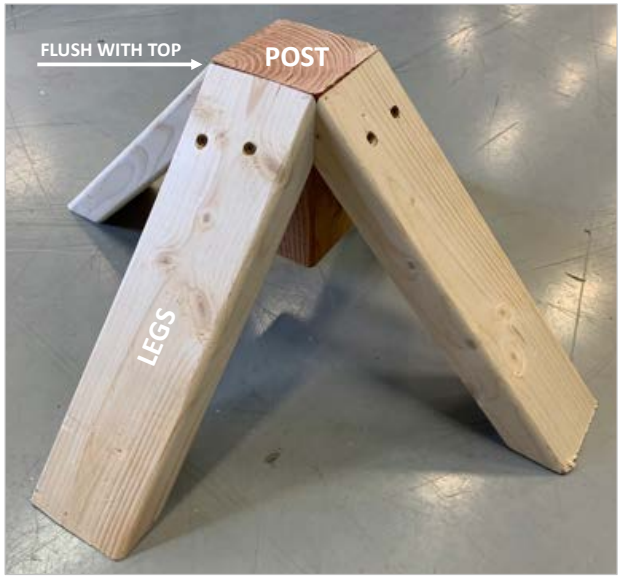
Affix Buckets to Stand

- Leave the carry handle on top numbered buckets.
- Remove the handles from all angled lettered buckets.

[2] 3 in screws with washer heads to affix the top bucket into the post end grain.
This enables the handled bucket to carry the entire weight of the stand.
Both screws should go through the largest Concentric C in the target.

[10] 1-1/2 in screws with washer heads to affix the angled buckets.
Angled buckets <u>should be touching the top bucket</u> to support stacking.
Both screws should go through the green inscribed alignment ring.



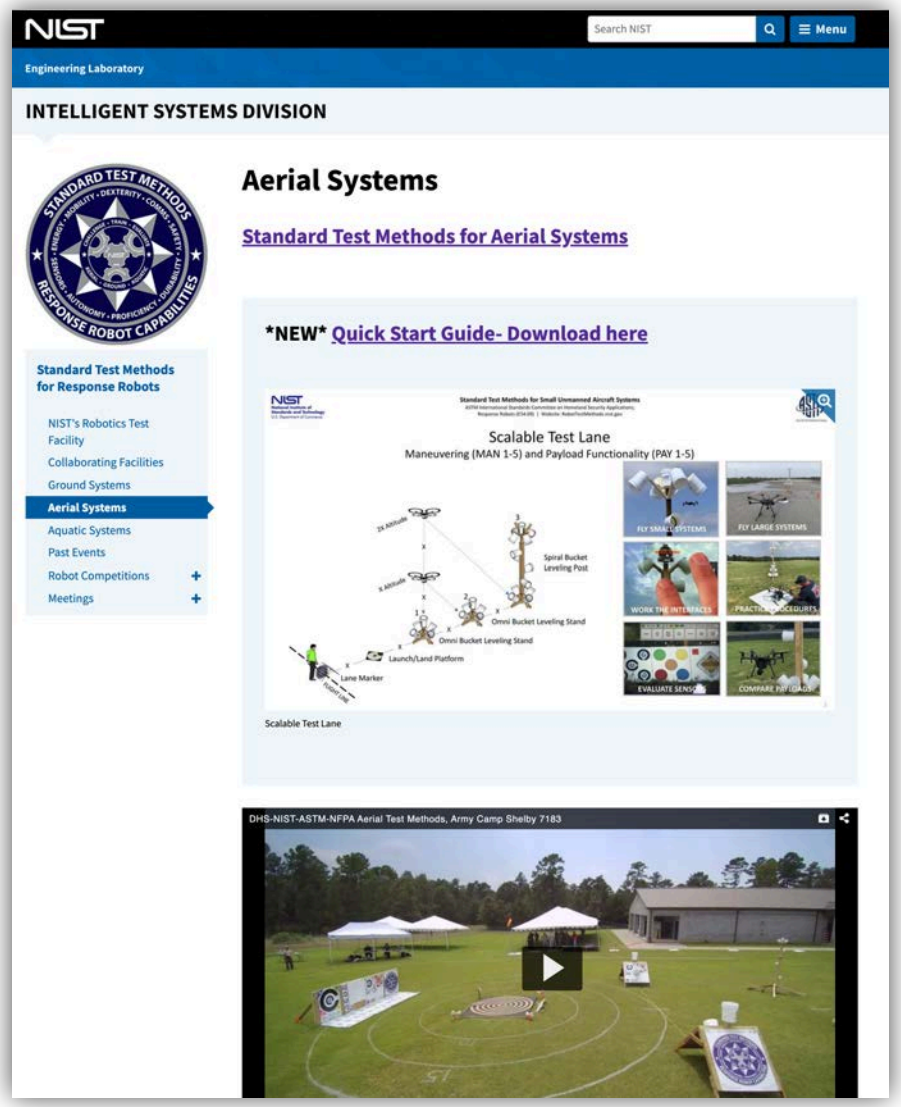


Fabrication Instructions & Test Procedures

https://RobotTestMethods.nist.gov

- Detailed fabrication guide including:
  - Bill of materials
  - Cut lists
  - Printable materials (stickers, posters, bucket inserts, etc.)
  - Fabrication and setup videos
- Detailed test procedures including:
  - Test guide
  - Printable test forms
  - Sample scoring videos

Or email: RobotTestMethods@nist.gov



Other UAS Test Methods

Scenarios with Directed Points of View

Safety | Capabilities | Proficiency

Vehicle Inspection

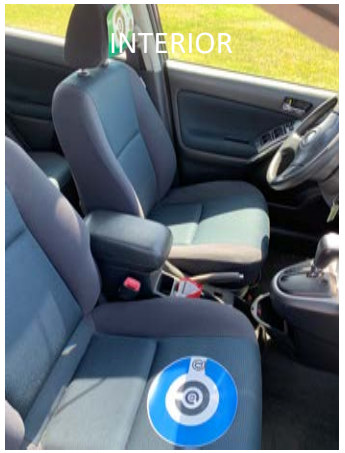
Training and Evaluation

Establish hover directly over top and orbit to identify all buckets on the roof stand (#, A, B, C, D).

Determine if further inspection is warranted (could be 20 vehicles).

Spiral inspect all sides and interior.

Perch to identity underbody targets (and maintain view if necessary for ground robots coming down range).



Canadian Police College, London, Ontario, Canada

Box Truck Inspection

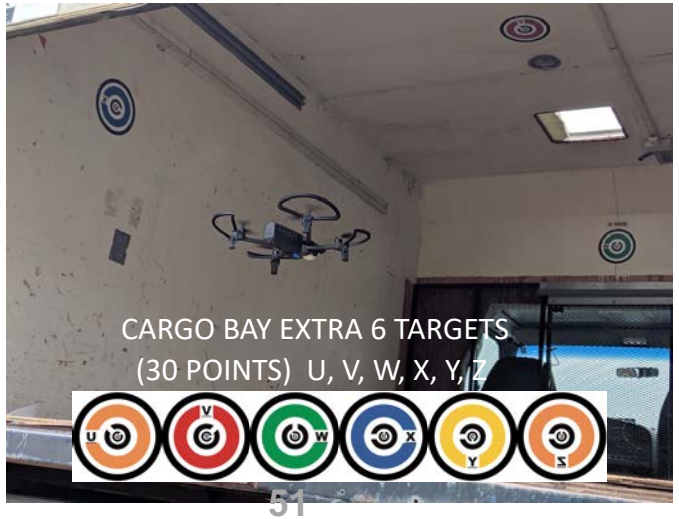
Training and Evaluation

Establish hover directly over top and orbit to identify all buckets on the roof stand (#, A, B, C, D).

Determine if further inspection is warranted (could be 20 vehicles).

Spiral inspect all sides and interior.

Perch to identity underbody targets (and maintain view if necessary for ground robots coming down range).



NIST, Gaithersburg, MD

Fuel Truck / Rail Car Inspection

Training and Evaluation

Establish hover directly over top and orbit to identify all buckets on the roof stand (#, A, B, C, D).

Determine if further inspection is warranted (could be 20 vehicles).

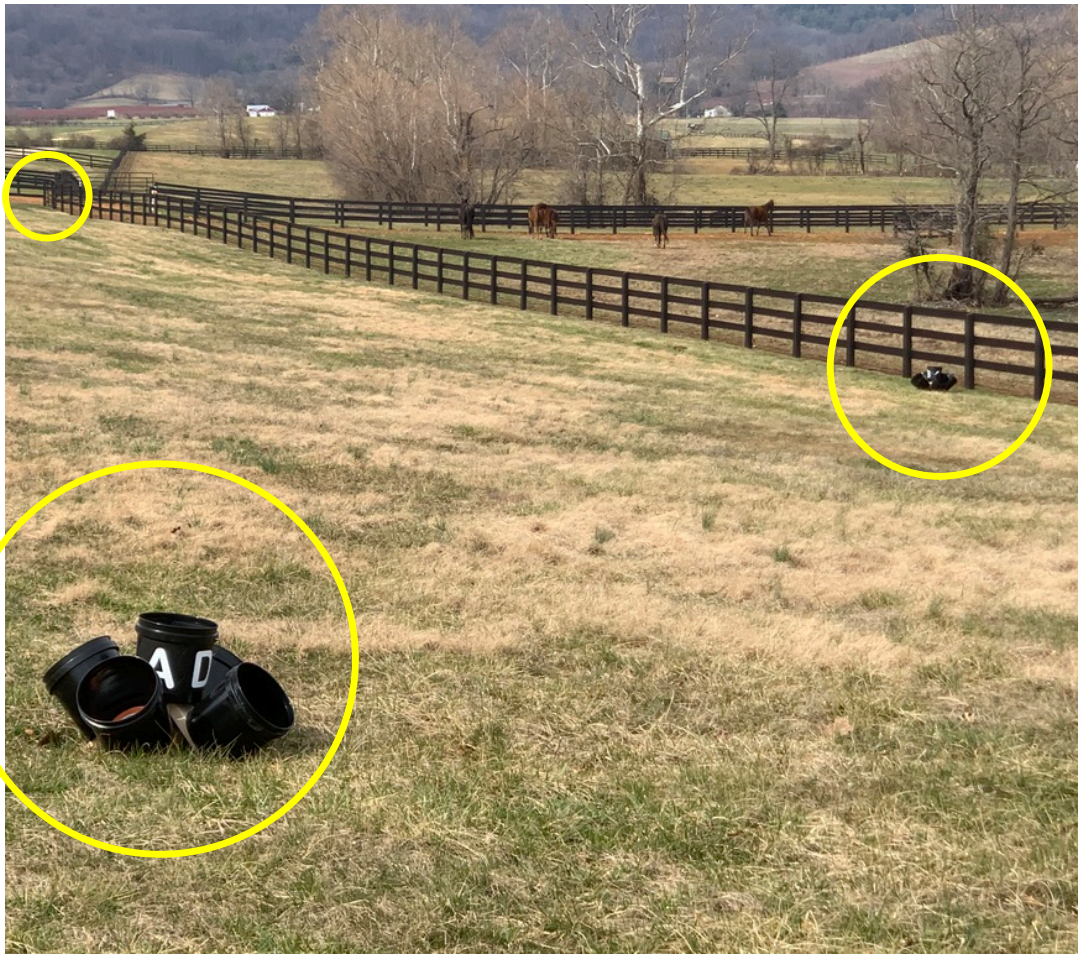
Spiral inspect all sides and interior.

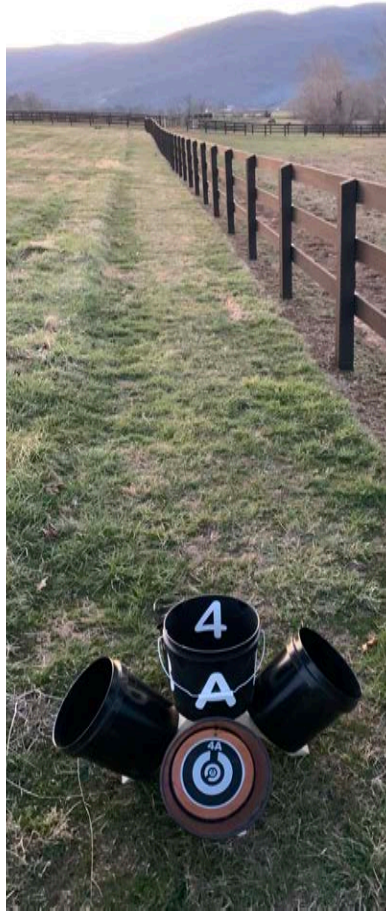
Perch to identity underbody targets (and maintain view if necessary for ground robots coming down range).

Safety and Emergency Response Training Center (SERTC), Pueblo, CO

Wide Area Search

Training and Evaluation

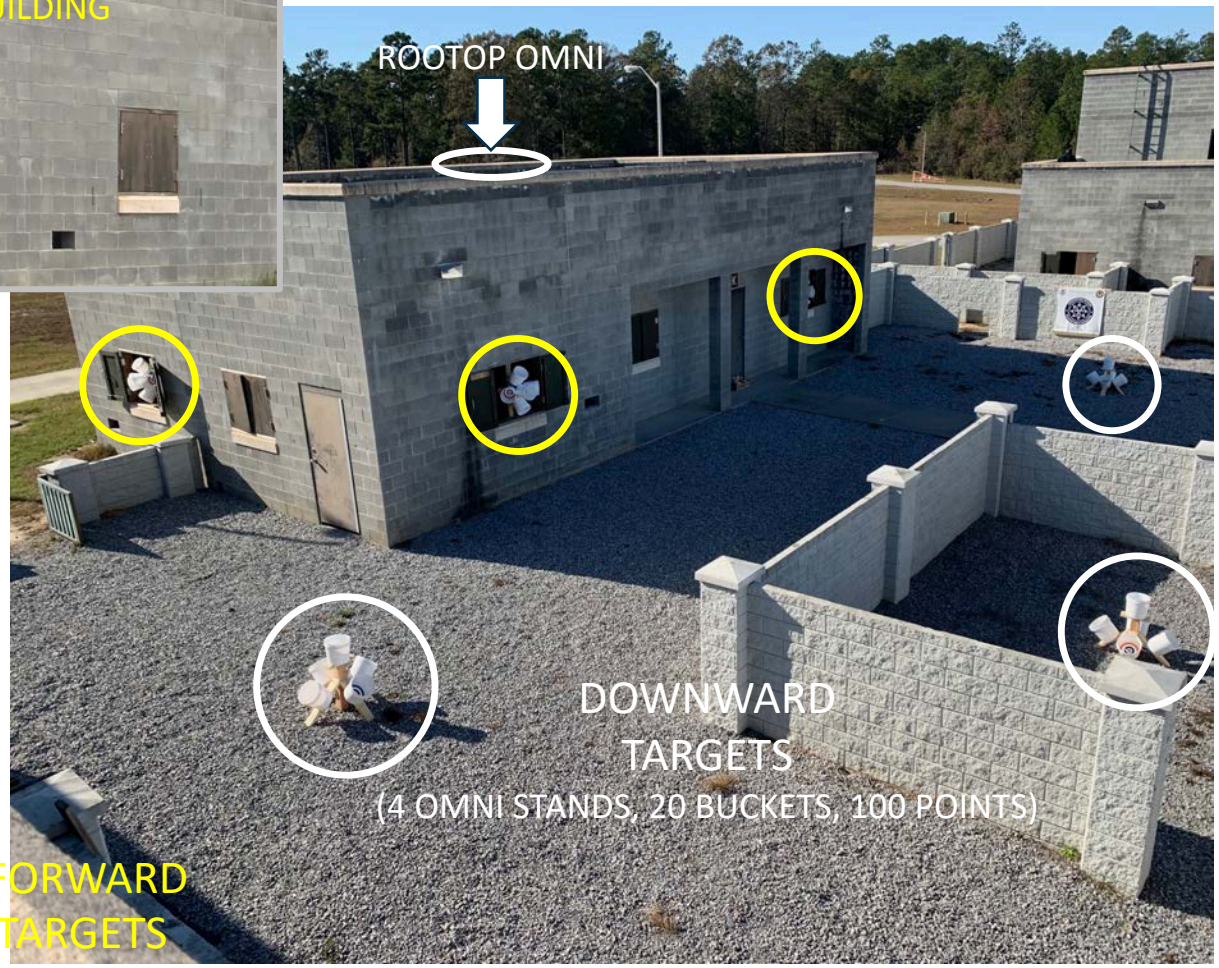




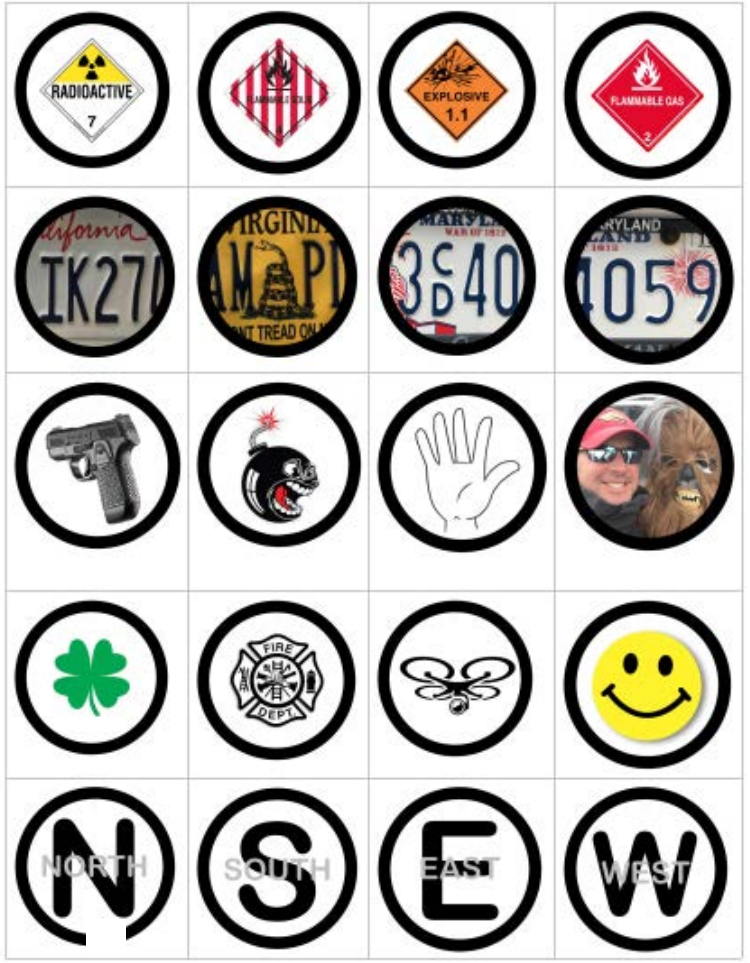
Various Locations

Building Exterior Search

Training and Evaluation



FORWARD
TARGETS
(4 OMNI STANDS, 20 BUCKETS, 100 POINTS)



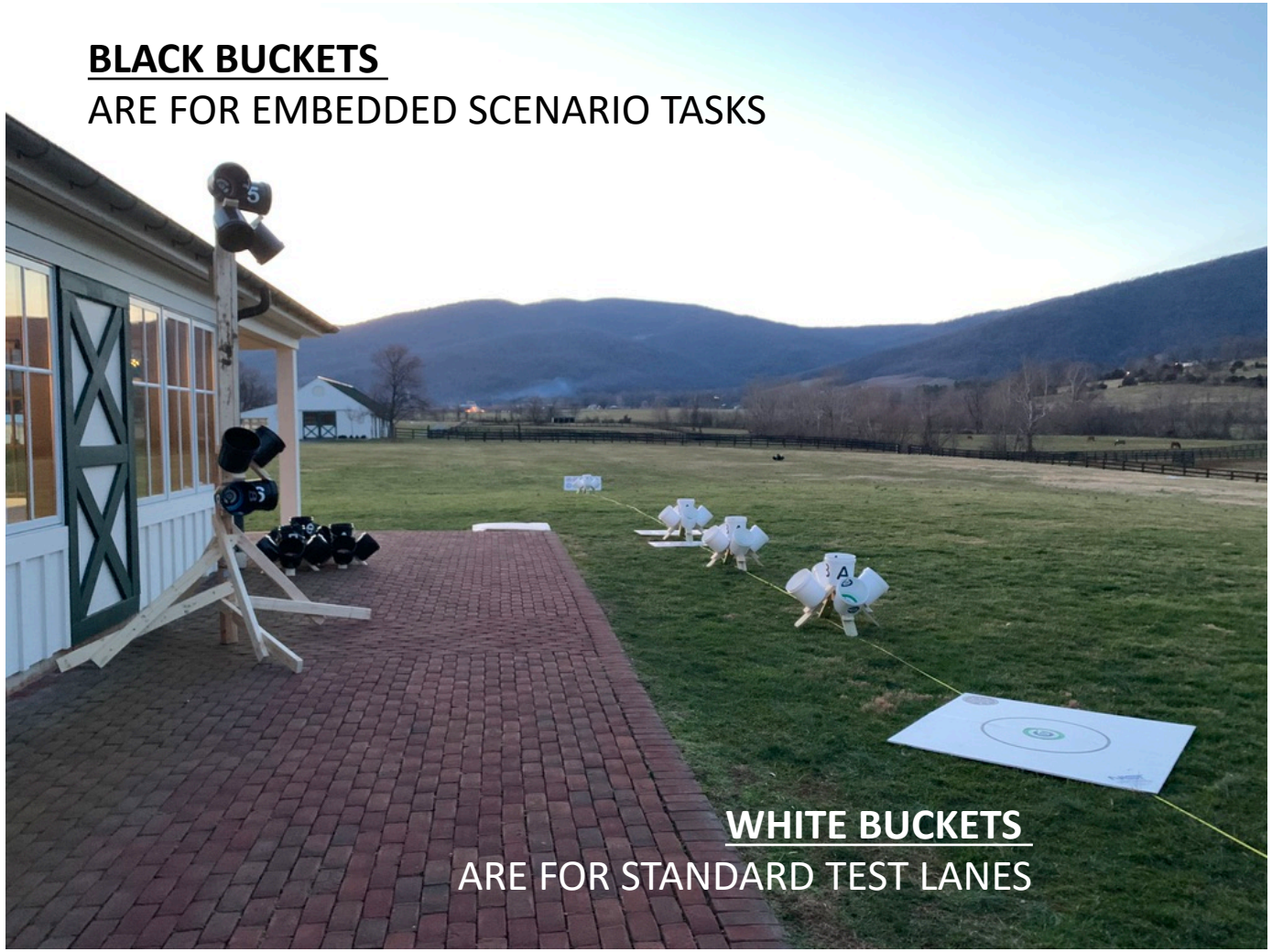
Indoor/Outdoor

Training and Evaluation

INDOOR VERSIONS
(1qt/4in diameter)

OUTDOOR VERSIONS
(2gal/8in diameter)

BLACK BUCKETS
ARE FOR EMBEDDED SCENARIO TASKS



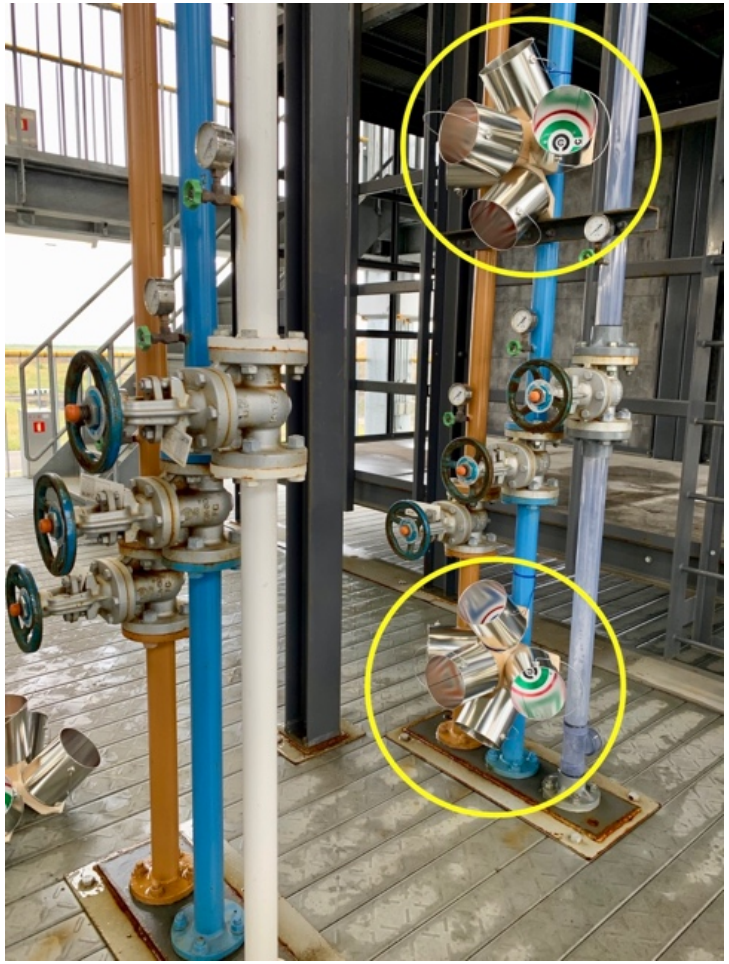
WHITE BUCKETS
ARE FOR STANDARD TEST LANES

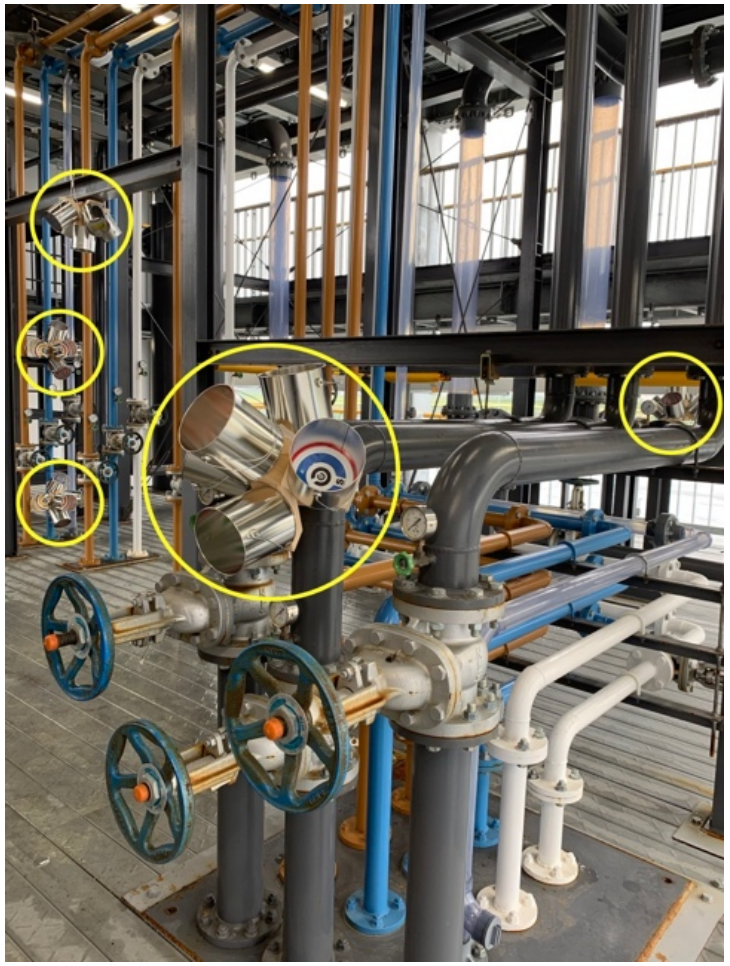
Indoor Search

Training and Evaluation

METAL BUCKETS

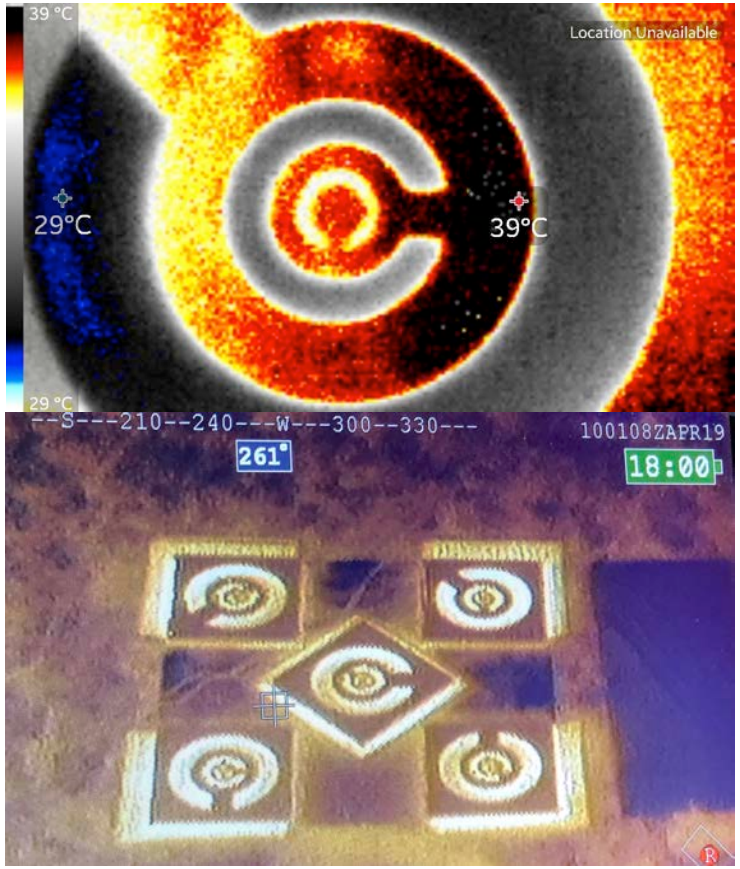
BLEND INTO THE ENVIRONMENT





Thermal Targets

Training and Evaluation



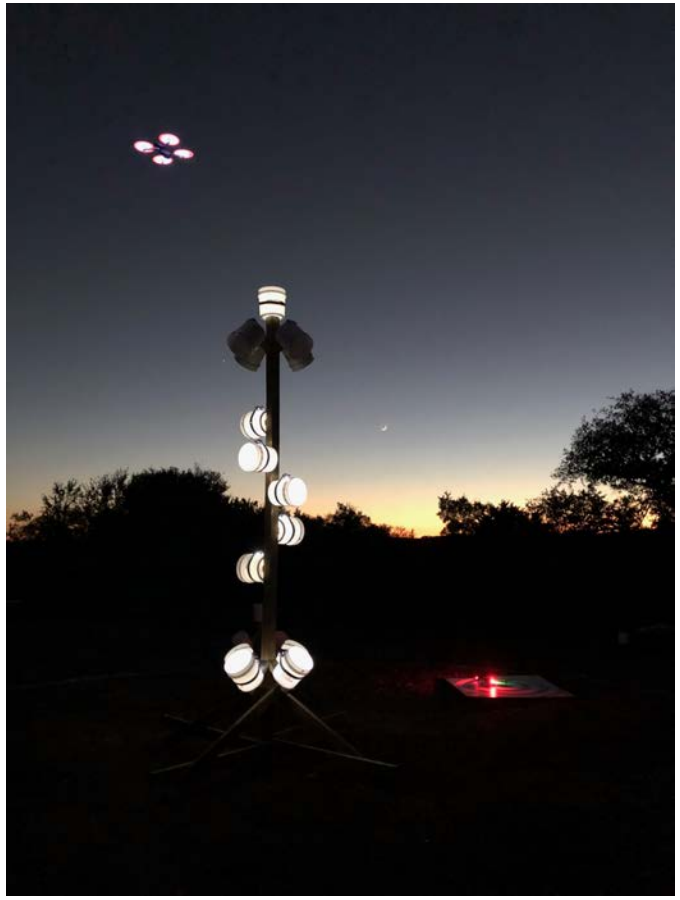
NIST and Reveille Peak Ranch, Burnet, TX

Night Operations

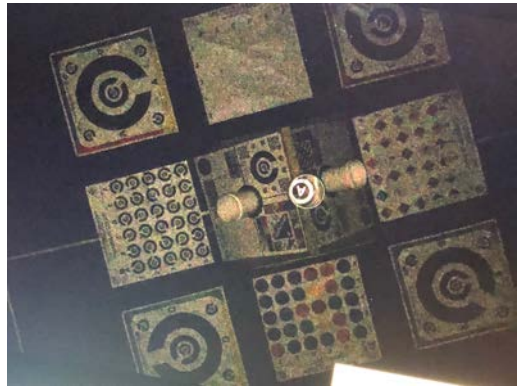
Training and Evaluation

White or red headlamps wrapped around the buckets pointed inward!

Position guidance for range to target using lighted buckets (red or white)



Inspect objects of interest using lighted buckets (red or white)



Identify objects lighted from the aircraft

Thermal Targets

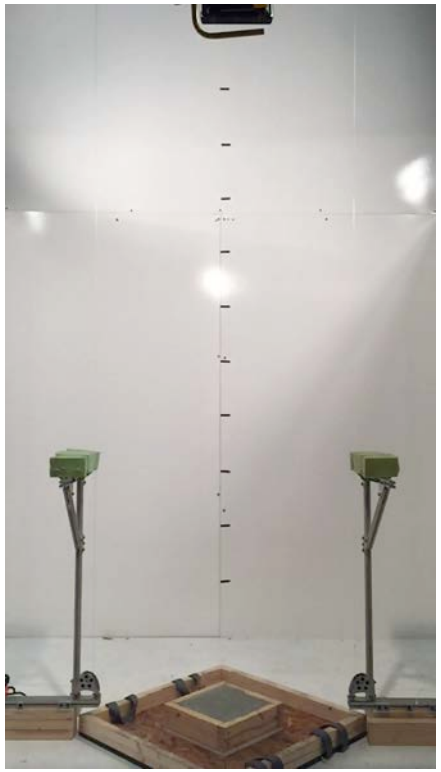
Measure additional sensor capabilities

NIST and Reveille Peak Ranch, Burnet, TX

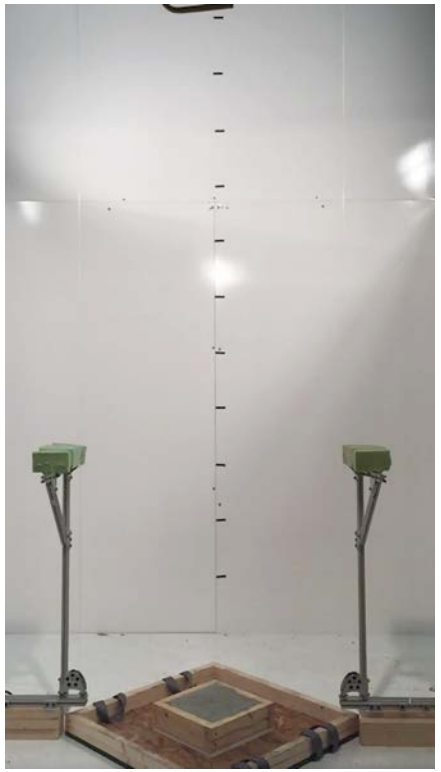
Deliver Payload

Inspect Object

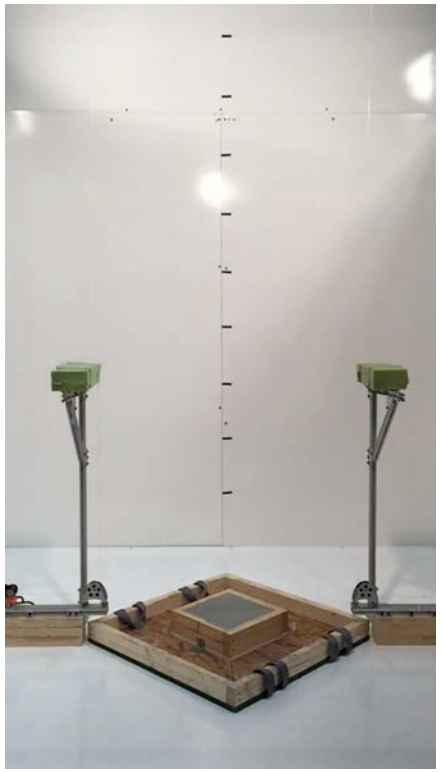
Measurement Science Approach



Wooden Ball



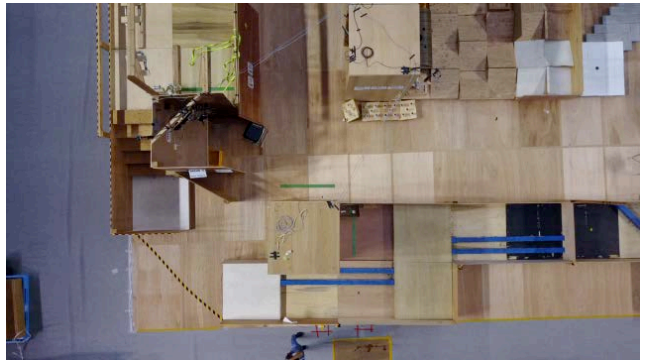
Steel Ball



Toy UAS

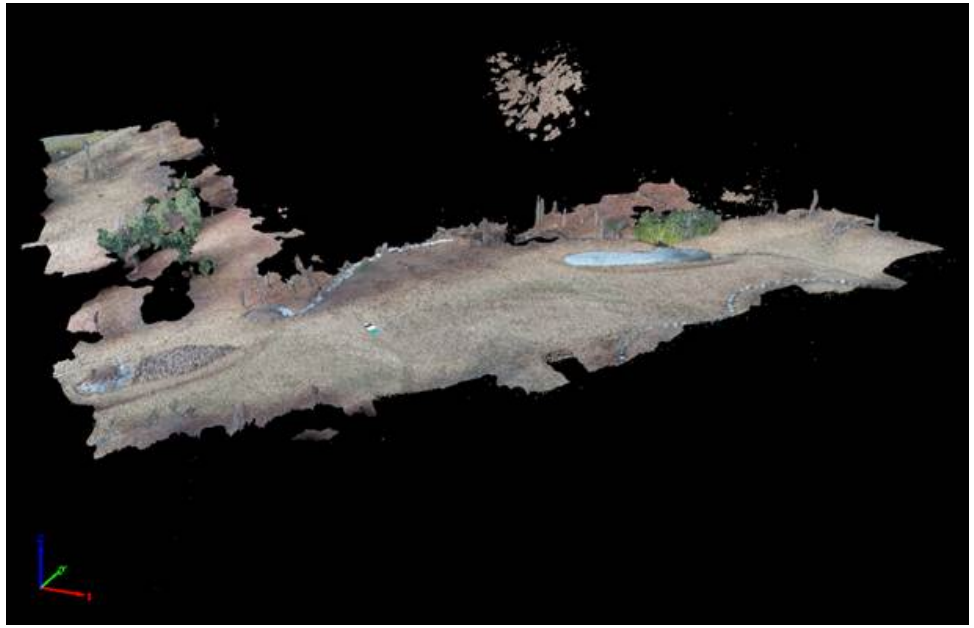
UAS Surrogate

Map Wide Areas



Indoor

Outdoor



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FUTURISTIC DESIGN
UI ELEMENTS
HUD VISUALIZATION
PROFILE
BLOCK - 1
A 001
A 002
A 003
42%
75%
59%
0035,4
0082,7
0073,8
345729.56
ON
POLICIE
THANK
YOU
#PSCR2020
NIST
PSCR