

# Test Methods for Evaluating Aerial Drones Safety | Capabilities | Proficiency RobotTestMethods.nist.gov



## Aerial Drone Tests and Scorable Scenarios for Evaluating System Capabilities and Remote Pilot Proficiency in Level 3 Open, Level 4 Obstructed, and Level 5 Confined Environments

Developed by the National Institute of Standards and Technology



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



Sponsor:

Systems Engineering & Standards Division
Science and Technology Directorate
U.S. Department of Homeland Security

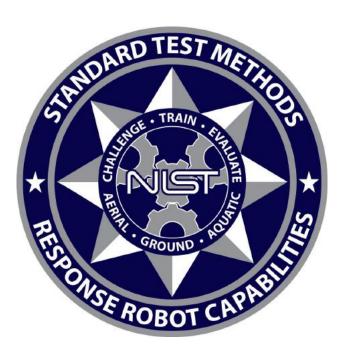






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## **Level 5 Confined Environments**

identify deviations from the intended path and encourage cor



### **CONFINED Test Lane**

**Payload Functionality Trials** 

Evaluate maneuvering in tight spaces, structed Scenario dealing with the drone's own turbulent air, while controlling zoom and exposure.

- 25 minutes (5 minutes each)
- 50 Alignment & 50 Acuity Points

objective: necessary

Sceniario S

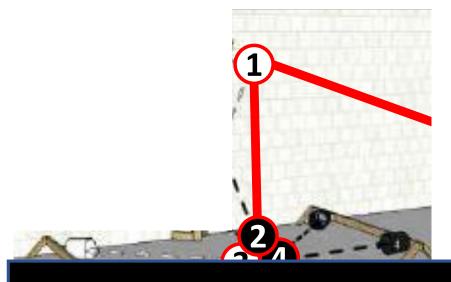
Figure 1 3 placed 5 a property of the room-to-

scenario also

## **Confined Scenario**

**Bus Interior** 





## Confin

**Confined Test Lanes and Scorable In** 

IDDLE INDOOR ALTITUDE 1 M (3 FT)

ASTM International Standards Comm Response Robots (E54.09) | W

## Confined Scenario: Struct Safety I Canabil



## MIDDLE INDOOR ALTITUDE 1 M (3 FT)

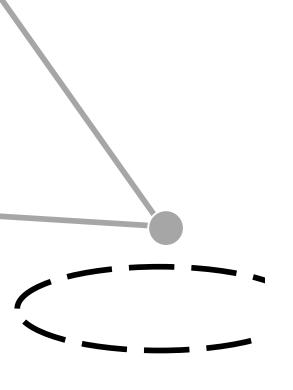
#### **Standard Test Methods for Sr**

ASTM International Standards Comm Response Robots (E54.09) | W

# Confined Scenario: Struct Safety | Capabil

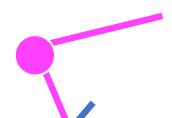
**OPEN** 





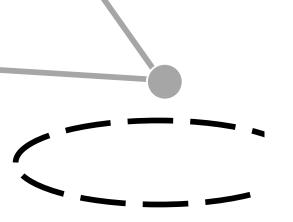


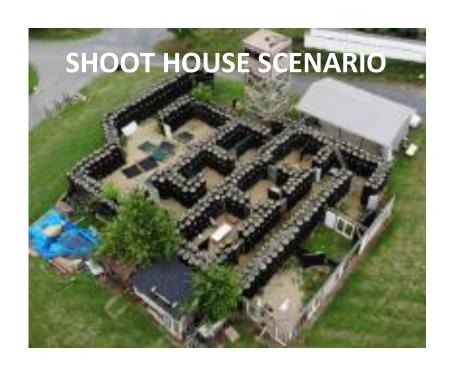
TOP INDOOR ALTITUDE 2 M (6 FT)



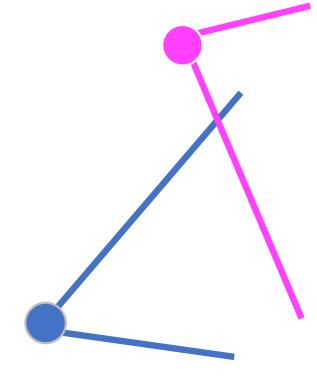
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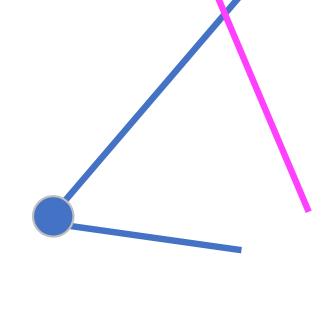
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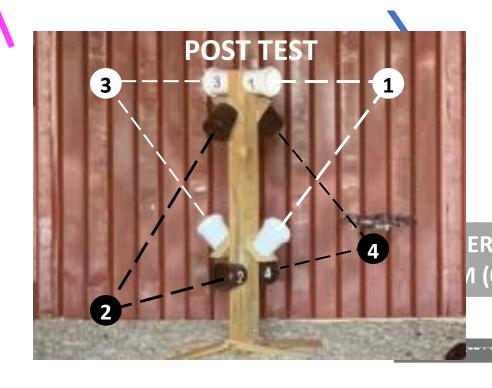
### MIDDLE INDOOR ALTITUDE 1 M (3 FT)



# MIDDLE INDOOR ALTITUDE 1 M (3 FT)



MIDDLE INDOOR ALTITUDE
1 M (3 FT)





or Evaluating Aerial Drones Safety [ Capabilities | Proficiency PROPORTESTMETHODS.nis.gov 4th SHIFT (15-20 minutes) ALL ARE OFF



### **Teams Rotate Through Each Role**

Each Pilot flies a 5-minute trial with help from othe A 3-4 person team completes all 5 tests in 2 hours.

**TEAM ROTATIONS** 





Four person teams always have one person getting their aircraft ready to launch right after the previous lands.

Three person teams work too, but require some time between each rotation to prepare the next after which produced distances and marks

- Maintain control of the aircraft.
- Call out each intention of movement before doing so
- Call out each bucket alignment and acuity target gap.

#### **PROCTOR**

- Fill in the form header.
- Read the test procedures to the Pilot.
- Confirm, record, and attest to scoring after the trial.

### VISUÄL OBSERVER (VO)

- Maintain sight with the aircraft and surroundings.
- Repeat the Pilot's intention of movement to confirm.
- Call out corrections and warnings as necessary.









**PILOTS** 

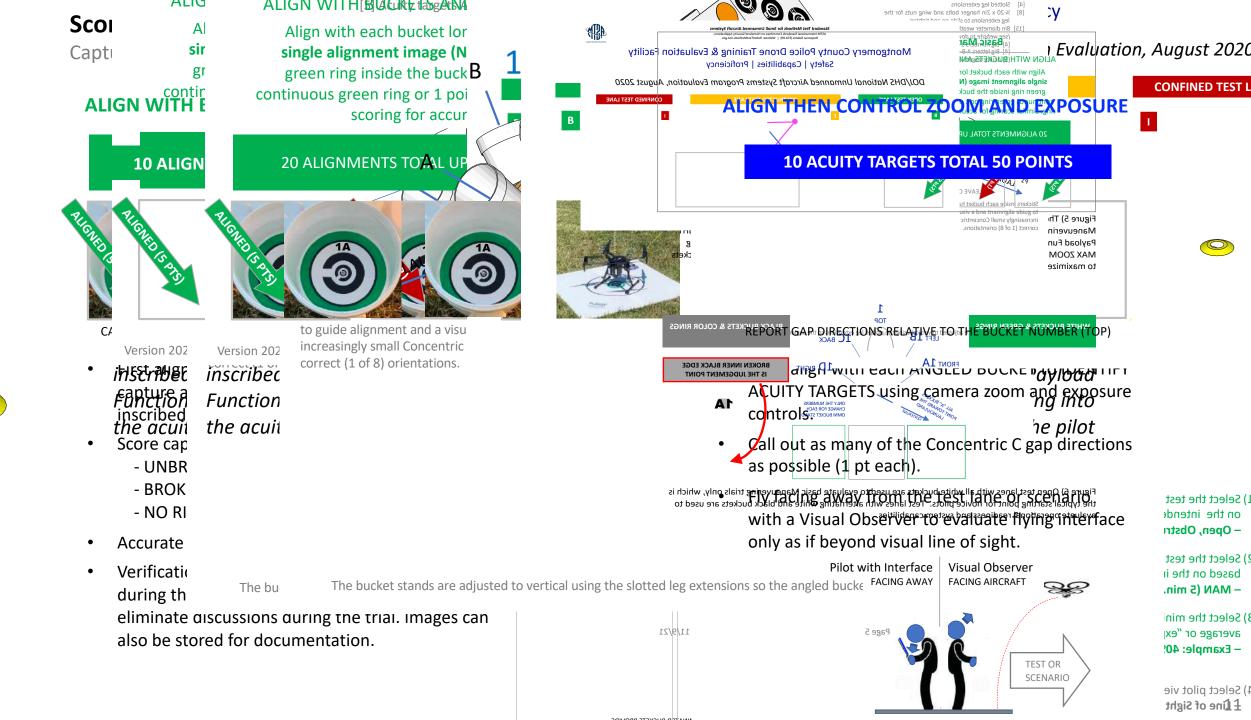


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# Level 5 Confined Lane Proctoring



the omni bucket stands to align with the designated buckets. The drone also lands centered on the platform with the chassis or any ground contact within a 30 cm (12 in) radius circle.

#### ORBIT (MAN/PAY 3)

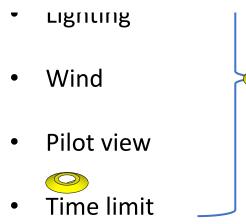
Evaluate drones flying circular flight paths at different altitudes around objects while looking inward to identify features on all four sides. The drone orbits at altitude 2(S) in both directions then altitude (S) in both directions to align with the designated buckets. Each orbit starts with an initial downward bucket alignment to check the radius before proceeding leftward and rightward. Accurate landings are not included.

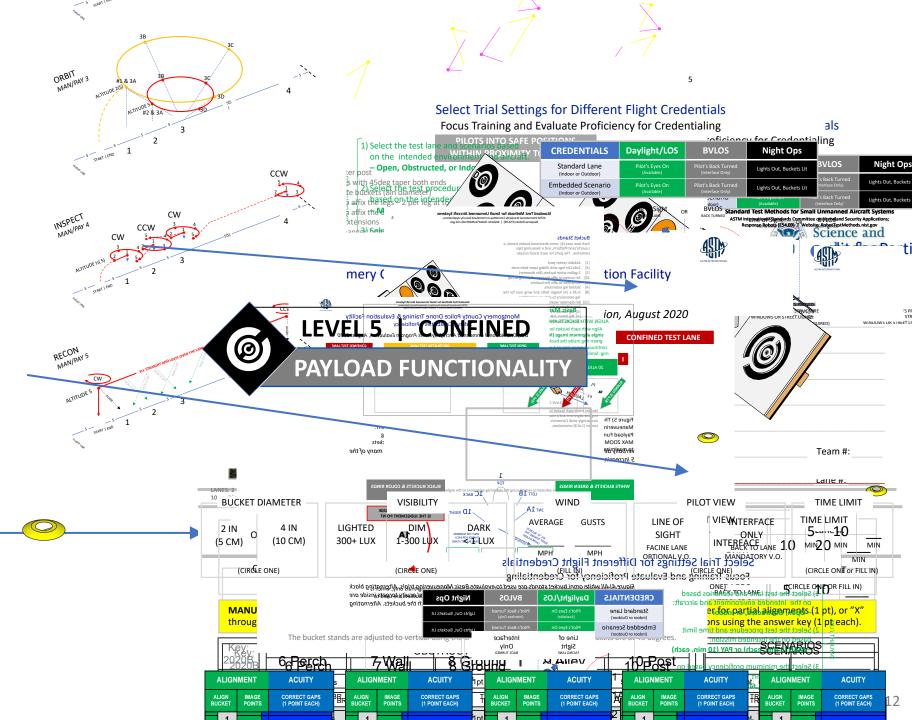
#### INSPECT (MAN/PAY 4)

Evaluate drones flying in closer proximity around objects to inspect detailed features on the top and all sides. The drone flies at altitude 1/2(S) all around each omni bucket stand to align with the designated buckets. Inspection tasks start on top then rotate around the objects in alternating clockwise and counter clockwise directions. Accurate landings are not included.

#### RECON (MAN/PAY 5)

Evaluate drones flying straight and level down range to establish stable hovers over objects in open space to perform reconnaissance tasks. The drone flies at altitude (S) at a sustainable speed directly over the lane centerline to align with designated buckets and the landing at each end of the lane. The down range reconnaissance tasks include looking straight down on the objects in different orientations and at an angle. A complete trial covers a total distance of 80(S) with moving (non-stop) alignments over the angled buckets along the centerline helping to identify deviations from the intended path and encourage consistency.







(S) the dug mout starting over the ality Trials

Capture a single image inside each bucket and the

Brief reminders and the trial.

Accurate landings are not included in this test.

A complete trial totals a distance of 80(S)

bucket alignments to score up to 100 alignment points.

Payload Functionality Trials (PAY): Same as Basic

Maneuvering (MAN) then is

Pilot with Interface | Visual Observer extensions so the angled buck Verify your score after the trial using captured video, although scores may yary due to

ng into ment by zooming into targets, all features. The pilot

ach).

(with a as if

raw a line through all incomplete.

**ALLEY** 

21 IMAGES TO CAPTURE 1 PRE-LAUNCH 20 ALIGNMENTS

21 IMAGES TO CAPTURE

(PAY 10)

1 PRE-LAUNCH

20 ALIGNMENTS

**POST** 

White and black bucket shading spessible to score up

SCORE WHILE PERCHED.

Circle alignment points when declared by the pilot with verification of images during or after the trial.

Separate totals for ALIGNMENT and ACUITY points (50 points each).

Any organization can select their own passing score.

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at different altitudes around atures on all four sides. The ions then altitude (S) in both cets. Each orbit starts with an check the radius before e landings are not included.

y around objects to inspect . The drone flies at altitude to align with the designated rotate around the objects in kwise directions. Accurate

own range to establish stable m reconnaissance tasks. The speed directly over the lane and the landing at each end sance tasks include looking rientations and at an angle. A 30(S) with moving (non-stop) g the centerline helping to and encourage consistency.



Science and Technology mall Unmanned Aircraft Systems ferent Flight Credentials oficiency for Credentialing v for Cradentialing Daylight/LOS **BVLOS Night Ops** VLOS Lights Out, Buckets Li enario Line of Sight **BVLOS** rcraft Systems Line of Sight **BVLOS** for Partial A tion Facility Recon (MAN/PAY 5) August 2020 Open Test Lane 10000St 2020 HTS CONFINED TEST LANE ONFINED TEST LANE Stickers inside each bucket ha CREPORT GAP DIRECTIONS RELATIVE TO THE BUCKET NUMBER TOPY SHOW Fly straight and level at a sustainable speed directly over the lane centerline to establish a stable hover over an นรูเบปัติ MARI DOOR! object and perform quick reconnaissance tasks. halfato ng into Function Maintain altitude (S) throughout starting over the targets ie bilot 19 NOTERFACE Iath Charlet to align with the designated buckets and Select Trial Settings for Different Flight Credentials the landing at each end of the lane. Focus Training and Evaluate Proficiency for Credentialing Capture a single image inside each bucket and the Figure AJAA white amni bucket stands are used to evaluate Basic Maneuvering tripls. Alternating bloc CINCERVUS

CHIEF POR PROPERTY OF THE CONTROL OF THE PROPERTY OF THE CONTROL OF TH landing target for scoring alignments after the trial. Night Ops Daylight/LOS CREDENTIALS

tial A

Test Methods for Small Unmanned Aircraft Systems

BACK 24

Perch (PAY 6)

**Obstructed Test Lane** 

L1

**L2** 

Land within 2-3 m (6-10 ft) of a wall in front of th aircraft with ground obstacles on both sides.

- While perched, inspect vertical and horizontal ob features upward, downward, leftward and rightw
- Launch and land repeatedly if necessary to score buckets in the sequence.
- Measure the field of view of the drone while per with independent pan-tilt-zoom cameras.

#### **Payload Functionality Trials (PAY):**

- Align with the PERPENDICULAR BUCKETS first and capture an image of the inscribed rings that can I to score up to 50 alignment points after the trial.
- Align with the ANGLED BUCKETS second to ident many acuity target gaps as possible to score up to acuity points. Call out the gap directions to the P

### BACK 24C opfine of Room-to-Room Labyrinth

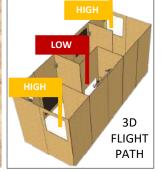
Searchtasks with 1 m (3ft) minimum clearances

#### **USE SETS OF 5 "INLINE" DUAL BUCKET RAILS**

HORIZONTALS FOR LEFTWARD/RIGHTWARD INSPECTIONS







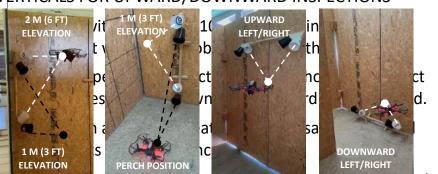
#### VERTICALS FOR UPWARD/DOWNWARD INSPECTIONS

**L2** 

L3

L4

L1



- Measure the field of view of the grone while perched Fabriciateid dependerropan-sidazdoscenario avith inspect
- tasks that can be replicated to track and compare scores. Payload Functionality Irials (PAY). Self-stamdinignpllywoodPcontoerwalls EdefineT1.2 not (4nft)

switchback halliwaysewith a blackbet tangschiling over toged at 2.4mg(8ft)u bits insidera 6mm(20ft) shippeing container.

Align with the ANGLED BUCKETS second to identify as square access "windows" measuring 1m (3ft) square provide entry/exit and interior high/low pass throughs. acuity points. Call out the gap directions to the Proctor.

#### **OBSTRUCTED**

PERPENDICULAR BUCKET:

ANGLED BUCKET: CALL OU

PERPENDICULAR BUCKET:

ANGLED BUCKET: CALL OU'

PERPENDICULAR BUCKET:

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PERPENDICULAR BUCKET:

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ANGLED BUCKET: CALL OU

PERPENDICULAR BUCKET:

O ANGLED BUCKET: CALL OU

**L3** 

L4

on the top and all sides. The drone flies at altitude ASTI Intelligibility Sizina Committee Of Honeland Security Applications;
Response Robbits (ESA.09) | Websile: Robbits estated and Security Applications;
Science and each omni bucket stand to align with the designated n tasks start on top then rotate around the objects in tial Alignments wise and counter clockwise directions. Accurate mery ( tion Facility icluded. PAY 5) ion, August 2020 Montgomery County Police Drone Training & Evaluation Facility ying straight and level down range to establish stable DOJ/DHS National Unmanned Aircraft Systems Program Evaluation, August 2020 CONFINED TEST LANE ts in open space to perform reconnaissance tasks. The tude (S) at a sustainable speed directly over the lane with designated buckets and the landing at each end down range reconnaissance tasks include looking the objects in different orientations and at an angle. A vers a total distance of 80(S) with moving (non-stop) the angled buckets along the centerline helping to Payload Fun MAX ZOOM from the intended path and encourage consistency. many of the 1erbetlyide Team #: Latte #: BU TIME LIMIT T VIEWNTERFACE TIME LIMIT 2 IN 5----10 0 (5 CM) INTERFACE ANE 10 MINO MIN MIN Select Trial Settings for Different Flight Credentials ( or FILL IN) Focus Training and Evaluate Proficiency for Credentialing Standard Test Methods for te.Basic.Maneuvering.tgipls...Alternating block CREDENTIALS Daylight/LOS Night Ops Response Robots (E54.09
Standard Test Methoda to C Standard Test Methods for Small Unmanned Aircraft Systems International Standards Committee for Homeland Security Applica Response Robots (E54.09) Website: RobotTestMethods.nist.gov Standard Lane PERCH TEST The bucket stands are adjusted to ve The perpertages 2 m (6 ft) from the PERCH TEST The drone lands 2 m (6 ft) from the wall guided by dual bucket alignments in various orientationse Asingle-penthros orientations. A single perch measures the field of view of an independent pan-tilt-zoom cameren Others Arangheed dome-laure the field of sind later the determination camera. Others may need to re-launch, rotate, and land to identify all the targets in order. camerap Others may need to re-lau WALL | FEN TOP VIEW TACLE
WALL | FENCE | OBSTACLE TOP VIEW 31 58 50 St TRodet 10 Positions = 20 Bucket 4100 Total Points LAUNCH FORWARD REVERSE FORWARD LAND LAUNCH 1 2 3 4 WALL TEST LAND The drone flies within 2-3 m (6-10 ft) of the wall align with buckets and identify features upward The drone files within 2-3 m (6-10 ft) of the wall at 45 de tasks inside elevated windows and doors. align with t TOP VIEW and identify features upward and downward. This approxima TOP VIEW WALL | FENCE | OBSTACLE task WALL | FENCE | OBSTACLE OWS and DOOR AR RUCKET - ALIGN AND CAPTURE IMAGE 明明有有限 BRT TELTE TER I ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS TO A BLBIR BL TR BE 10 5 1 0 WHILE PERCHED 5 1 0 WHILE PERCHEL PERPENDICULAR BUCKET: ALIGN AND CAPTURE IMAG ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS ANGLED BUCKET: CALL OUT ACUITY GAP DIRECTIONS STOP TIMER STOP TIMER RECORD SCORES AND ELAPSED TIME. RECORD SCORES AND ELAPSED TIME. ELAPSED TIME (MM:SS) ELAPSED TIME (MM:SS)

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Team with 3 people must take breaks together because all three roles are essential for safe trials, so such teams are vulnerable to hardwige amser Rota tent hoperough Each Role

#### 1st SHIFT (0-5 minutes)

Pilot Person 1 Proctor Person 2 VO Person 3

#### 2nd SHIFT (5-10 minutes)

Proctor Person 3
Proctor Person 1
Person 2

#### 3rd SHIFT (10-15 minutes)

Prilot Person 2
Proctor Person 3
VO Person 1

4th SHIFT (15-20 minutes)
ALL ARE OFF





nave one person getting their their Market one person getting their their Market one person getting their their Market one person of the perso

oo, but require some time repare the next aircraft.

PILOTS LAUNCH/

#### **PILOT**

Maintain control of the aircraft.

Call out each intention of movement bε ing sq

Call out each bucket alignment and acuity target gap.

#### **PROCTOR**

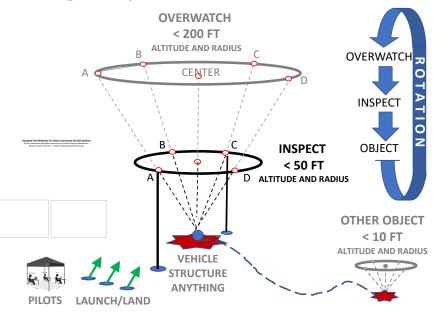
- Fill in the form header.
- Read the test procedures to the Pilot.
- Confirm, record, and attest to scoring after the trial.

#### **VISUAL OBSERVER (VO)**

- Maintain sight with the aircraft and surroundings.
- Repeat the Pilot's intention of movement to confirm.
- Call aut compations and warnings as passent

#### **Teams Sequence Through Scenarios**

Each Pilot flies a 15-minute scenario, sequencing through 3 objectives for 5 minutes each.



- This scenario mechanization enables embedded bucket scoring tasks to be performed similarly by all participating Pilots. So the results are comparable within the same scenario layout. Additional tactics can be overlayed onto these scenarios at your facility.
- Up to 3 teams concurrently fly different scenario objectives from safe distances and altitudes apart.
- Teams move as necessary to maintain sight lines with their aircraft and communications with other teams.
   The overwatch team leads communications.
- Scenarios restart every 20 minutes with a different rotation of Pilot, Proctor, and VO.



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## Level 5 Review

These test methods are primarily intended for vertical takeoff and landing systems with an

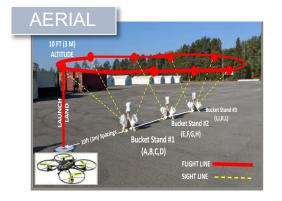
### Standards Enable Credentialing of Proctors and Remote Pilots

Safety | Capabilities | Proffice are extended to accommodate the orbit radius of forward flying systems.

### **NIST Develops and Validates Test Methods**

- Apparatus that can be reproducible by others.
- **Procedures** that are repeatable to conduct test trials.
- *Performance Metrics* that are quantitative and can be compared over time, across locations and internationally
- Evaluate Systems using expert pilots conducting complete trials
- *Operator proficiency* is compared with similar systems on the same lane spacing in similar environmental conditions with either complete or time limited trials

Compare time limited trials that are incomplete by total surfaces ensure the top bucket is points for similar elapsed times or calculate and compare the scoring rate as points per minute for different elapsed times







These test methods are primarily intended for vertical takeoff and landing systems with an

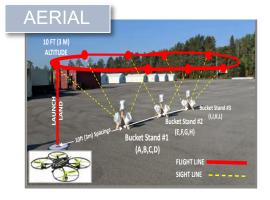
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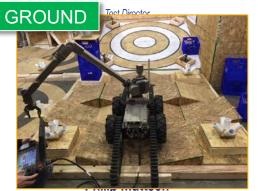
Safety | Capabilities | Profice per extended to accommodate the orbit radius of forward flying systems.

When conducting evaluations with these Test Methods the results should only be compared to similar environmental conditions.

Night or dark trials can be conducted with white or red headlamps illuminating the white buckets or only using the lights and sensors onboard the drone.

Bucket stands on a level surfaces ensure the top bucket is vertical and the angled buckets are 45 degrees.







These test methods are primarily intended for vertical takeoff and landing systems with an

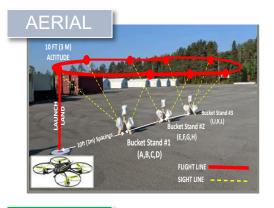
### Standards Enable Credentialing of Proctors and Remote Pilots

Safety | Capabilities | Profficiency are extended to accommodate the orbit radius of forward flying systems.

## When Credentialing operators an organization can;

- Set their own pass/fail scoring threshold
- Adopt a pass/fail scoring threshold set by a regional or national association with which the organization collaborates
- Adopt a pass/fail scoring threshold set by a similar organization

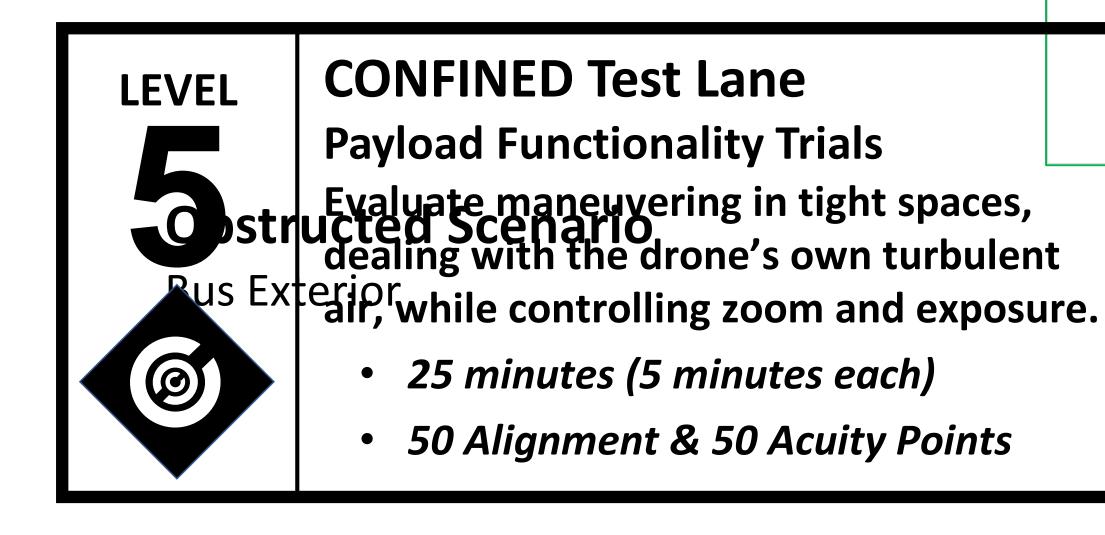
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alignmer the angled buckets along the centerline identify deviations from the intended path and encourage cor



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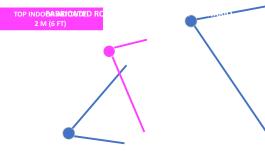
#### onfined Test Lanes and Scorable Indoor Scenarios

ASTM International Standards Committee on Homeland Security Applications;

Response Robots (E54.09) | Website: RobotTestMethods.nist.gov

#### Confined Scenario: Structure Interior Rooms (South) Safety | Capabilities | Proficiency







Response Robots (E54.09) | Website: RobotTestMethods.nist.gov

Standard Test Methods for Small Unmanned Aircraft Systems Confine Constant Repaired Flagger Committee on Homeland Security Applications in a

#### **Aerial Tests**







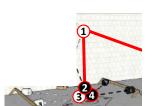
#### **Test Methods for Evaluating Aerial Drones** Safety | Capabilities | Proficiency

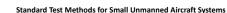
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MIDDLE INDOOR ALTITUDE

1 M (3 FT)





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Confined Scenario: Structure Interior Rooms (South) Safety | Capabilities | Proficiency

CONFINED



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



MIDDLE INDOOR ALTITUDE 1 M (3 FT)

Science and

Technology

Confined Scenario: Structure Interior Rooms (South) Safety | Capabilities | Proficiency

CONFINED









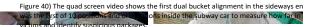






MIDDLE INDOOR ALTITUDE 1 M (3 FT)











## Aerial Drone Tests and Scorable Scenarios for Evaluating System Capabilities and Remote Pilot Proficiency in Level 3 Open, Level 4 Obstructed, and Level 5 Confined Environments

Developed by the National Institute of Standards and Technology



#### **Adam Jacoff**

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



Sponsor:

Systems Engineering & Standards Division Science and Technology Directorate U.S. Department of Homeland Security



