

# 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



#### **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





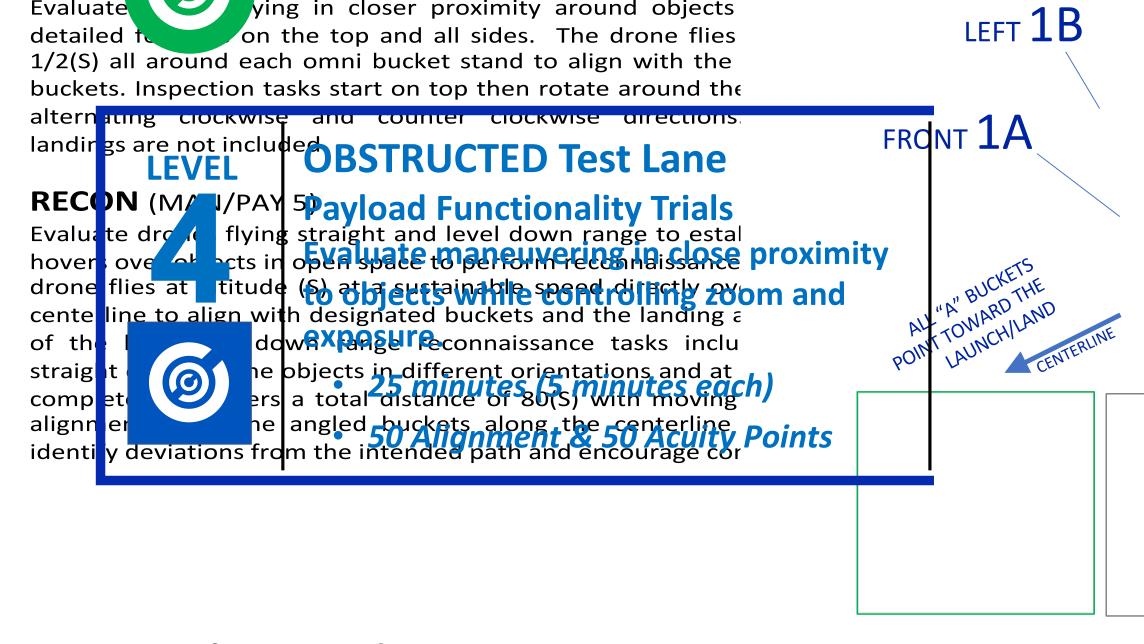


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## Level 4 Obstructed Environments



### **Obstructed Scenario**

**Aus Exterior** 

NE

objectives f

ASTM International Standards Committee for Homeland Security Applications:

NATIONAL INSTITUTE OF STANDARDS AND RESPONSEY Robots (E54.09) Website: Robot I est Methods nist gov U.S. DEPARTMENT OF COMMERCE Safety | Capabilities | Proficiency

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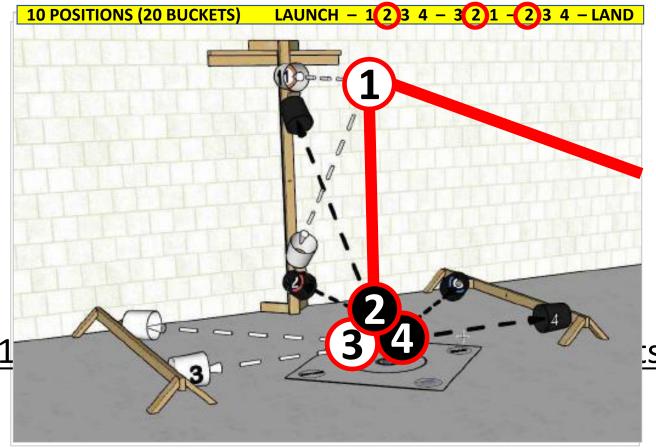
CH TEST

# BACK 24 | Pereh (PAY 6)

drone lands 2 m (6 ft) from the wall guided by dual bucket alignments in various ntations. A single perch measures the sigld of view of arangependent pan-tilt-zoom

era. Others may need to re-launch, rotate, and land to identify2alltontongets/incorderched

**TOP VIEW** FENCE | OBSTACLE



#### **PERCH TEST**

The drone lands 2 m (6 ft) orientations. A single per camera. Others may need **TOP VIEW** 



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## BACK 24

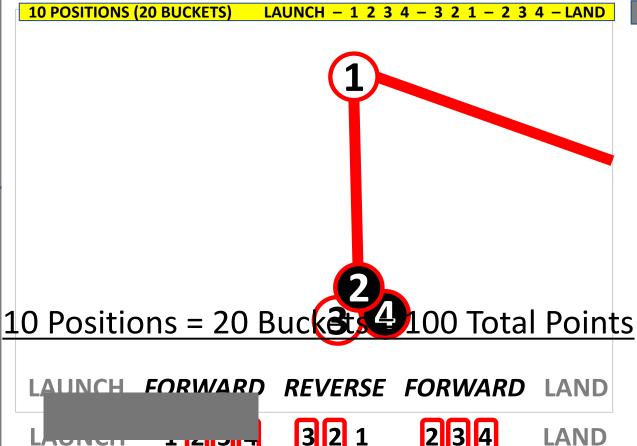
# Perch (PAY 6)

ne drone lands 2 m (6 ft) from the wall guided by dual bucket alignments in various rientations. A single perch measures in Sield of the family and the targets in order.

TOP VIEW

WALL | FENCE | OBSTACLE

L1



#### **PERCH TEST**

The drone lands 2 m (6 ft) from orientations. A single perch recamera. Others may need to

VALL | FENCE | OBSTACLE



ALL TEST

**ERCH TEST** 





### BACK 24

KHWUIIU (PAT O)

he drone lands 2 m (6 ft) from the wall guigeα by quai pucket alignments in various rientations. A single perch measure chose du com a consepence pan-tilt-zoom amera. Others may need to re-launch, rotate, and land to identify all the targets in order.

TOP VIEW

LICH TEST

WALL | FENCE | OBSTACLE



**10 POSITIONS (20 BUCKETS)** LAUNCH - 1 2 3 4 - 3 2 1 - 2 3 4 - LAND **10 POSITIONS (20 BUCKETS)** LAUNCH - 1 2 3 4 - 3 2 1 - 2 3 4 - LAND



#### **PERCH TEST**

The drone lands 2 m (6 ft) from orientations. A single perch m camera. Others may need to r **TOP VIEW** 

#### FENCE | OBSTACLE WALL



L TEST





## BACK 24

# **Peley** (PAY 9)

he drone lands 2 m (6 ft) from the wall guided by dual bucket alignments in various rientations. A single perch measure of the state of a state of the pan-tilt-zoom amera. Others may need to re-launch, rotate, and land to identify all the targets in order.

TOP VIEW

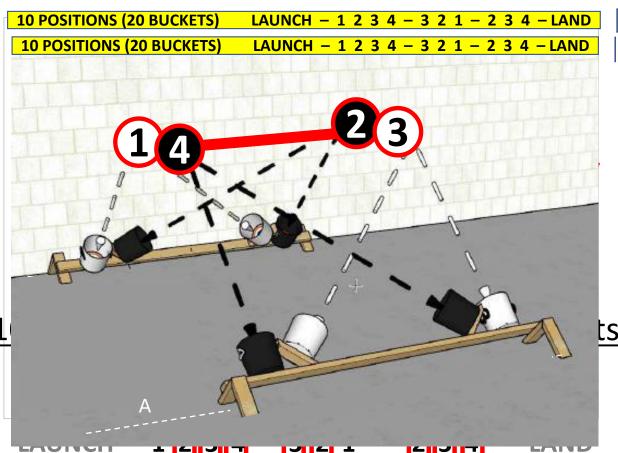
**ERCH TEST** 

**VALL TEST** 

WALL | FENCE | OBSTACLE

3221

L1



#### **PERCH TEST**

The drone lands 2 m (6 ft) from orientations. A single perch recamera. Others may need to

WALL | FENCE | OBSTACLE



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**RCH TEST** 

**TOP VIEW** 

FENCE | OBSTACLE

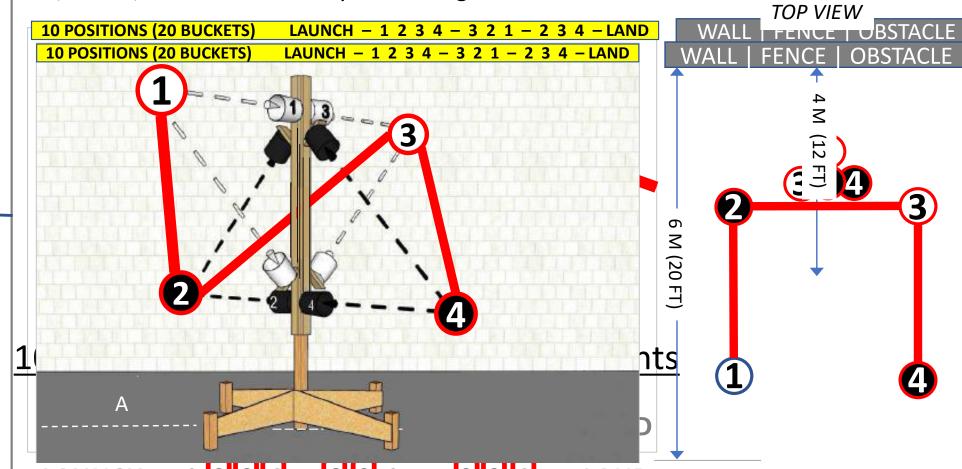
# BACK 24 | **Post** (PAY 10)

drone lands 2 m (6 ft) from the wall guided by dual bucket alignments in various entations. A single perch measure commentations. A single perch measure comments and a single perchange of the single perchang

nera. Others may need to re-launch, rotate, and land to identify all the targets in order.

#### **PERCH TEST**

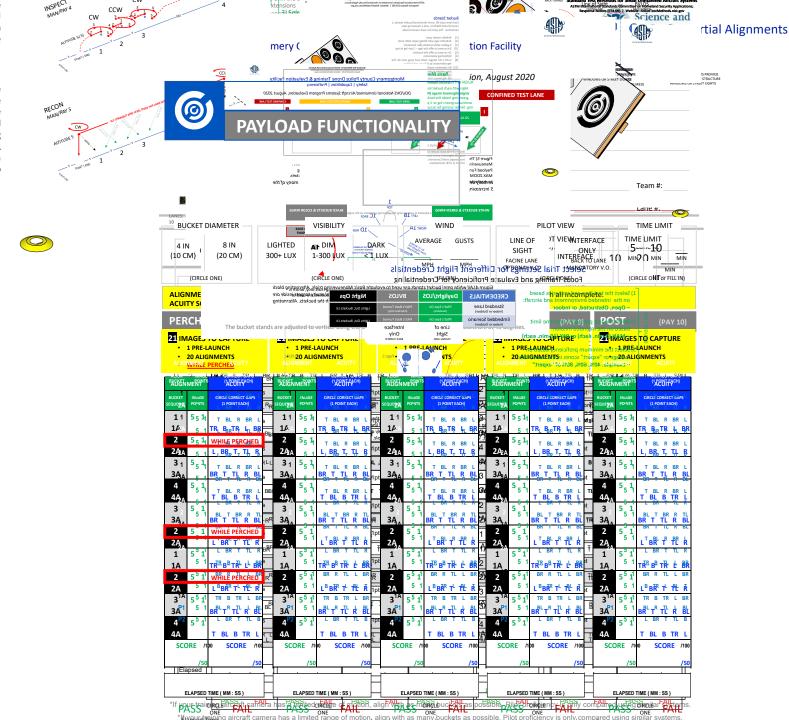
The drone lands 2 m (6 f orientations. A single per camera. Others may nee



on the top and all sides. The drone flies at altitude each omni bucket stand to align with the designated in tasks start on top then rotate around the objects in wise and counter clockwise directions. Accurate cluded.

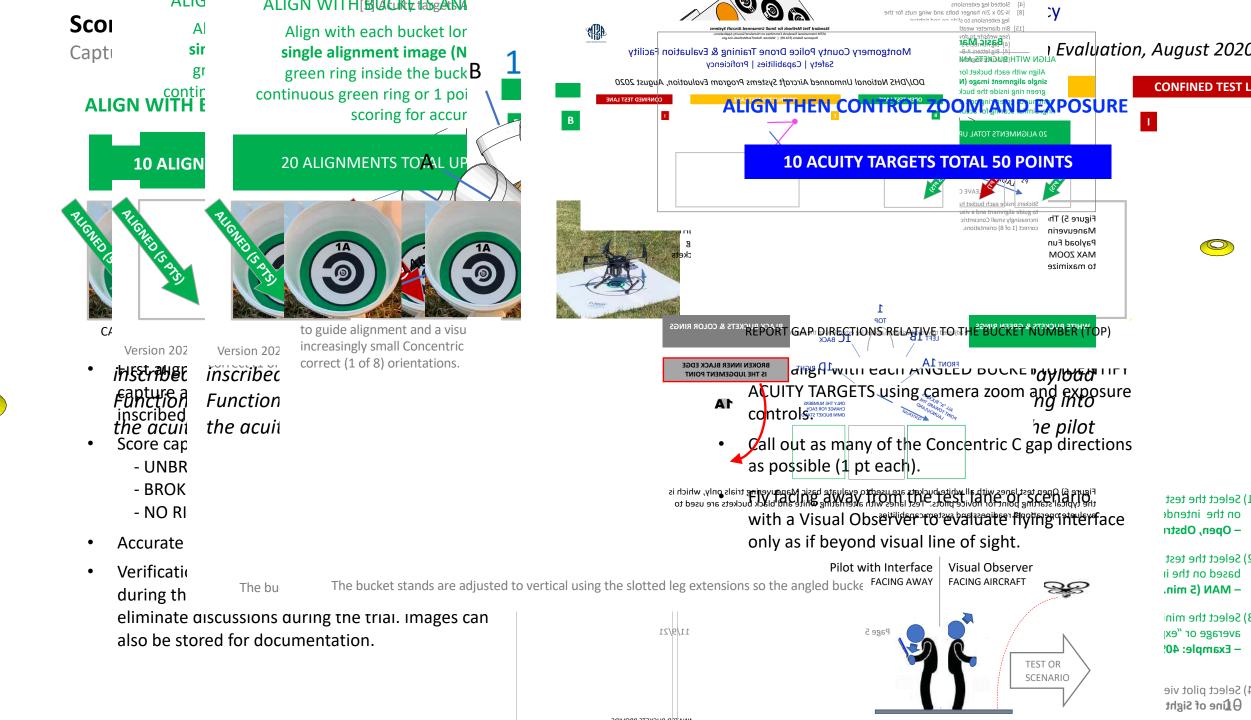
#### PAY 5)

ying straight and level down range to establish stable is in open space to perform reconnaissance tasks. The ude (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 ters a total distance of 80(S) with moving (non-stop) the angled buckets along the centerline helping to from the intended path and encourage consistency.





0



**ALIGNMENT ACUI ALIGNMENT ACUITY** d Functionality Trials (PA vering (MAN) then iden **ALIGN IMAGE CORRECT GAPS ALIGN IMAGE CORRECT BUCKET POINTS** (1 POINT EACH) **BUCKET** (1 POINT E **POINTS** possible to score up to CIRCLE CORREC **IMAGE** CIRCLE CORRECT GAPS **IMAGE** BU BU **POINTS POINTS** (1 POINT EACH) R<sub>R</sub> SEQI (1 POINT E SEQ **2A 2A** 5<sub>5</sub> 4 554 BR BL TL BR BB **2A 2A** BRTR VHILE PERCHED 2 2A 2 2A BB<sub>R</sub> T BR T BR BL BL **3A 3A** B₿I BR 4 2A BL **2A** 5aks 1nt 1Ants



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** 



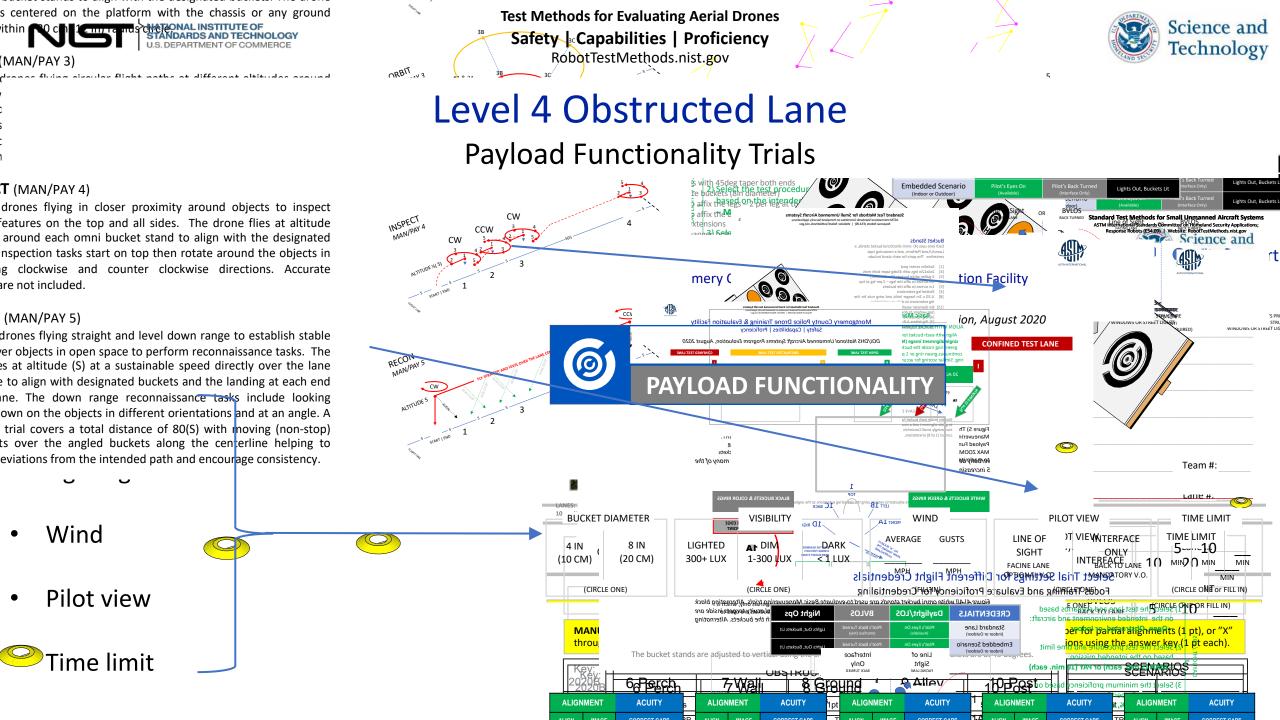
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# Level 4 Obstructed Lane Proctoring









ONLY FOR SCORING Science and TRIALS ON DAY 3. Technology DECLARE EACH CONCENTRIC C FOR YOUR PROCTOR TO SCORE DURING

NIST OF LAND REPORT APPRICATIONS RELATIVE CONTRACTIONS RELATIVE CO iteland ' Jocuses on Payloaa

Hude (S) the lug mout starting over the color lity 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

extensions so the angled buck Verify your score afte the trial using captured

video, although scores

as if ilot with Interface | Visual Observer

ach).

(with a

21 IMAGES TO CAPTURE 1 PRE-LAUNCH 20 ALIGNMENTS

raw a line through all incomplete.

USE INTERFACE

THE TRIAL

ng into ment by zooming into

targets, all features. The pilot

**ALLEY** 

**POST** 

21 IMAGES TO CAPTURE

(PAY 10)

1 PRE-LAUNCH

20 ALIGNMENTS

Maneuvering (MAN) then ident White and black bucket shading spossible 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.

o ti	0	ALIGNMENT		ACUITY		ALIGNMENT		ACUITY		ALIGNMENT			ACUITY				ALIGNI	MENT	ACUITY		ALIGNMENT		ACUITY			
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Standard Test Methods for Small Unmanned Aircraft System

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

Obstructed Test Lane and Related Ope

Standard Test Methods for Small Unmanned Aircraft Systems

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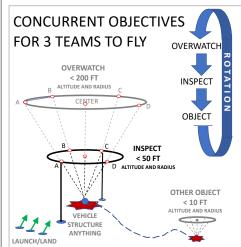


#### **Obstructed Vehicle Inspection Scenarios**

Day and Night Trials

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

DISTRIBUTED THROUGHOUT THE SCENARIO













#### **Obstructed Search Scenarios**

Day and Night Trials

START TIMER (CAPTURE CLOC

PERPENDICULAR BUCKET

ANGLED BUCKET: CALL OL

ANGLED BUCKET: CALL OL

PERPENDICULAR BUCKET

10 ANGLED BUCKET: CALL OL

11 PERPENDICULAR BUCKET

2 ANGLED BUCKET: CALL OL

13 PERPENDICULAR BUCKET

4 ANGLED BUCKET: CALL OU

5 PERPENDICULAR BUCKET

16 ANGLED BUCKET: CALL OU

17 PERPENDICULAR BUCKET:

18 ANGLED BUCKET: CALL OU

19 PERPENDICULAR BUCKET

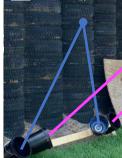
20 ANGLED BUCKET: CALL OU

STOP TIMER (CAPTURE CLOCK

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

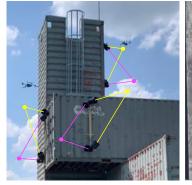
HORIZONTALS DISTRIBUTED WITH OBJECTS OF INTEREST







#### **VERTICALS IN ELEVATED WINDOWS AND ON STRUCTURES**







- Teams concurrently fly separate objectives set up at safe distances and/or altitudes apart (with a clearly designated and safe return path).
- Each pilot flies for 15 minutes across 3 different objectives for 5 minutes each. Teams move as necessary to maintain sight lines and communication.
- Scenarios restart with a different rotation of Pilot, Proctor, and VO.

START TIMER (CAPTO

1 PERPENDICULAR

2 ANGLED BUCKET

PERPENDICULAR

4 ANGLED BUCKET

5 PERPENDICULAR

6 ANGLED BUCKET

7 PERPENDICULAR

8 ANGLED BUCKET

9 **PERPENDICULAR** 

10 ANGLED BUCKET

1 PERPENDICULAR

12 ANGLED BUCKET

13 PERPENDICULAR

4 ANGLED BUCKET

L5 PERPENDICULAR

15 / 2/11 2/15/002

ANGLED BUCKET

17 PERPENDICULAR

18 ANGLED BUCKET

19 PERPENDICULAR

ANGLED BUCKET

STOP TIMER (CAPTU

n the top and all sides. The drone flies at altitude ASTM Information Standard Committee on Formation Security Applications;
Response Robots (E44,09) | Website: RobotTestMethods nist gov
Science and ach omni bucket stand to align with the designated tasks start on top then rotate around the objects in ırtial Alignments rise and counter clockwise directions. Accurate mery ( tion Facility luded. Pilot LAST Name S PROVIDE STRUCTURE T LIGHTS Pilot FIRST Name ing straight and level down range to establish stable in open space to perform reconnaissance tasks. The (P) Pilot Organization de (S) at a sustainable speed directly over the lane with designated buckets and the landing at each end **SCORABLE SCENARIOS** Drone Make down range reconnaissance tasks include looking ne objects in different orientations and at an angle. A Drone Model ers a total distance of 80(S) with moving (non-stop) **Facility Location** ne angled buckets along the centerline helping to from the intended path and encourage consistency. Date (YYYY/MM/DD) Team #: PROCTOR NAME цапе #: BUCKET DIAMETER TIME LIMIT A l' TMORS OT VIEWNTERFACE TIME LIMIT AVERAGE GUSTS LINE OF 4 IN LIGHTED AT DIM 5----10 SIGHT (10 CM) (20 CM) 300+ LUX 1-300 LUX 1 LUX INTEREACE AND 10 MIN MIN MIN FACINE LANE .o.vynota@ellect Trial.Sete(Mgg9for Different Flight Credentials (CIRCLE ONE) (CIRCLE ONE) (CIRCLE WILL OF FILL IN) Folks Traffiling and Evaluate Proficiently Folk Credentialing Standard Test Methods to ate Basic Maneuvering tripls. Afternating black Night Ops CREDENTIALS Daylight/LOS Response Robots (E54
Standard Test Methods (W) 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 ver The perent lands 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 Ausingle-genthro orientations. A single perch measures the field of view of an independent pan-tilt-zoom camerienOthers Analygheed domedauras camera. Others may need to re-launch, rotate, and land to identify all the targets in order camera<sub>P</sub> Others may need to re-lau WALL | FEN TOP VIEW TACLE
WALL | FENCE | OBSTACLE TOP VIEW 2 50 s 50 s tTPo 10t 1<sub>1</sub> 10 Positions = 20 Bucket 4100 Total Points LAUNCH FORWARD REVERSE FORWARD LAND LAUNCH WALL TEST LAND The drone flies within 2-3 m (6-10 ft) of the wall align with buckets and identify features upward tasks inside elevated windows and doors. align with t TOP VIEW and identify features upward and downward. This approxima WALL | FENCE | OBSTACLE task WALL | FENCE | OBSTACLE OWS and 明明有有限即 WART 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 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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Robot Test Methods. nist. gov





# Level 4 Review

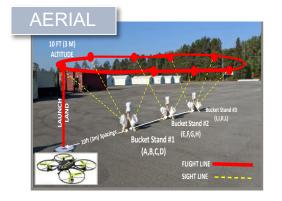
### Standards Enable Credentialing of Proctors and Remote Pilots

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

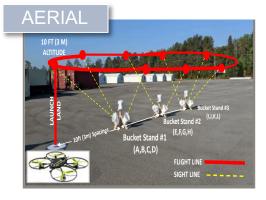
### Standards Enable Credentialing of Proctors and Remote Pilots

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

vertical and the angled buckets are 45 degrees.

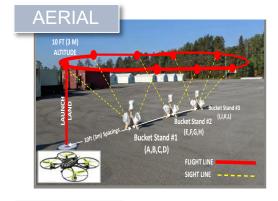
### Standards Enable Credentialing of Proctors and Remote Pilots

Safety | Capabilities | Profficiency 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

  Bucket stands on a level surfaces ensure the top bucket is







on the top and all sides. The drone flies detailed to 1/2(S) all around each omni bucket stand to align with the buckets. Inspection tasks start on top then rotate around the alternum gung ciockwise and counter ciockwise directions. landings are not include OBSTRUCTED Test Lane RECON (M/PAY 5payload Functionality Trials Evaluate dro (Flying straight and level down range to estal hover ove the cts in of the light to the control of the control of the cts in of the c drone flies at titude (%) objects in the scondroiffing wom and cente line to align with designated buckets and the landing a ddwaxaasure tasks inclu of th he objects in different orientations and at ers a total distance of 80(S) with moving straig t comp et alignment angled buckets along the centerline lidentify deviations from the intended path and encourage cor

LEFI

FRONT 1/

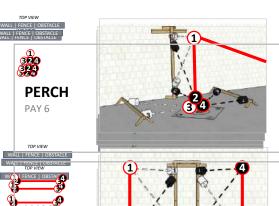
"A" BUCK "TOWARD



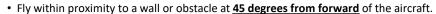
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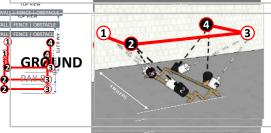




- Land or hover just above the ground within proximity to a wall or obstacle with additional ground obstacles on both sides. Launch and land repeatedly if necessary to score all buckets in the sequence of perch tasks.
- Inspect vertical and horizontal object features all around the aircraft.
- Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.

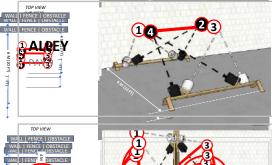


- Inspect vertical object features upward and downward.
- Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.

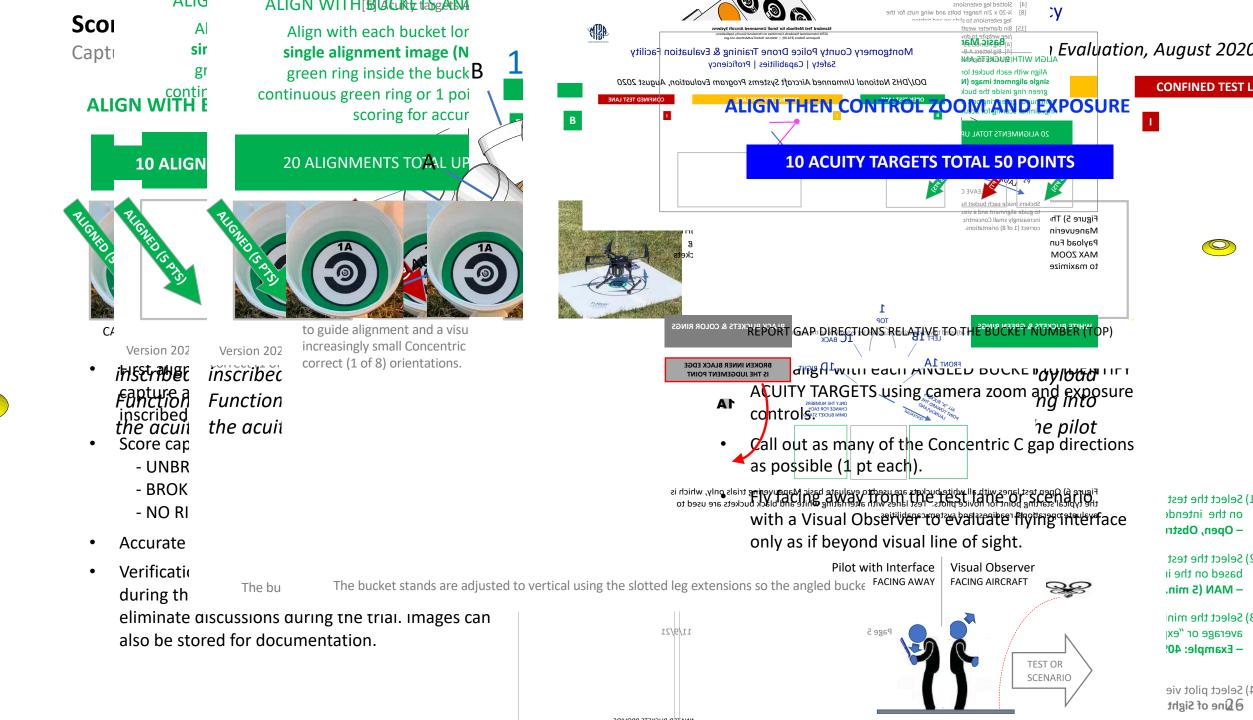


PAY 7

- Fly within proximity to a wall or obstacles at **90 degrees from forward** of the aircraft.
- Inspect <u>horizontal</u> object features <u>leftward</u> and <u>rightward</u>.
- Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.



- Fly within proximity to a wall or obstacle in <u>front of the aircraft (0 degrees)</u> and <u>behind the aircraft (180 degrees)</u>.
- Inspect <u>horizontal</u> object features <u>leftward</u> and <u>rightward</u>.
- Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.
- Fly within proximity to a post and wall or obstacle and pass between the post and the wall.
- Inspect <u>vertical</u> object features <u>upward</u> and <u>downward</u> all around the post.
- Complete 10 positions to score up to 50 Alignment points and 50 Acuity points.





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Developed by the National Institute of Standards and Technology



Test Director

#### **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



