Measuring and Comparing Small Unmanned Aircraft System Capabilities and Remote Pilot Proficiency

Version 2020B1

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Acknowledgements

Acknowledgements

This work was sponsored by **Philip Mattson** and **Kai-Dee Chu** from the Department of Homeland Security, Science and Technology Directorate, through an interagency agreement with the National Institute of Standards and Technology (NIST).

The NIST Team includes:
Adam Jacoff, Raymond Sheh, Kamel Saidi,
Kenny Kimble, and Ann Virts.

Dozens more people have contributed to the development and validation of these test methods. They include FEMA urban search and rescue task force teams, firefighters, law enforcement, collaborating test facilities, other civilian and military organizations, and commercial manufacturers. There are far too many to mention, but some of the ongoing (non-commercial) collaborators are listed below, roughly in order of their involvement:

Disclaimer

Commercial equipment shown in this document are for illustrative purposes only. This does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products identified are necessarily the best available for the purpose.

Measurement Units

The International System of Units (a.k.a. SI Units) and U.S. Customary Units (a.k.a. Imperial Units) are used throughout this document. Approximate equivalents in each system of units enable use of readily available materials in different countries. This avoids excessive purchasing and fabrication costs. The differences between the stated unit dimensions are insignificant for comparison of test method results, so each set of units are considered standard for the purposes of these test methods.

Collaborators

Tom Haus, Los Angeles Fire Dept. & CA-TF1, CA

Parry Boogard, Valley Regional Fire Authority & WA-TF1, WA

Clint Arnett, TEEX/Disaster City & TX-TF1, TX

George Hough, Fire Dept. of New York City & NY-TF1, NY

Jim Ingledue, Virginia Beach Fire Dept. & VA-TF2, VA

Mark Hundley, Virginia Beach Fire Dept. & VA-TF2, WA

Michael O'Shea, FAA UAS Integration Office (formerly U.S. DOJ)

Martin Hutchings, Sacramento Sheriff & IAB, CA

John Delaney, Arlington County Fire, Dept., & IAB, VA

Mike Marino, Prince George's County Fire Dept. & IAB, MD

Coitt Kessler, Austin Fire Dept., TX

Chris Sadler, York County Fire Dept., VA

Andy Moore, Southwest Research Institute, San Antonio, TX

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Tony Galladora, Montgomery County Police, MD

Satoshi Tadokoro, Tohoku University, Sendai, Japan

Tetsuya Kimura, Nagoaka Univ. of Technology, Nagoaka, Japan

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Andy Olesen, Canadian Explosives Technicians Assoc., Canada

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Oliver Huke, RACE Test Facility, UKAEA, Oxfordshire, United Kingdom

Table of Contents

Test Method Introduction

Open Test Lane Usage

Open Test Lane Fabrication

Project Overview

Safety | Capabilities | Proficiency

Objectives:

Develop the measurements and standards infrastructure necessary to quantitatively evaluate robotic system capabilities and remote pilot proficiency.

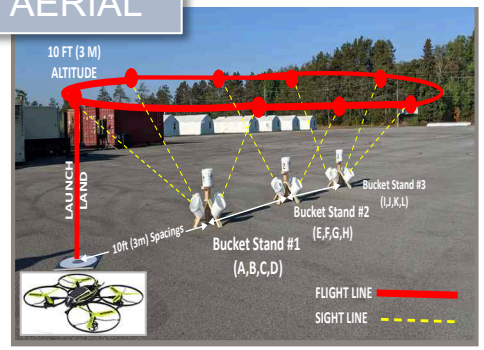
Outcomes:

Test methods, performance metrics, and data collection tools to facilitate integration of emerging technologies for hazardous and essential missions.

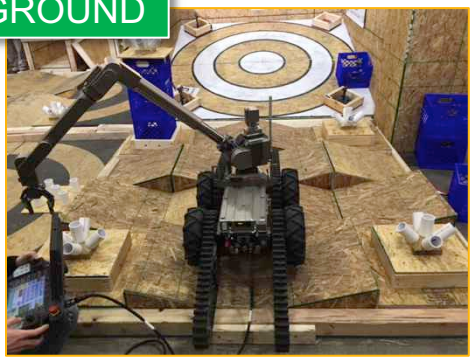
Impacts:

- Objective test methods help researchers and manufacturers push the state of the science by measuring progress and highlighting breakthroughs.
- Resulting quantitative performance data helps compare systems, specify purchases, and train with measures of remote operator/pilot proficiency.

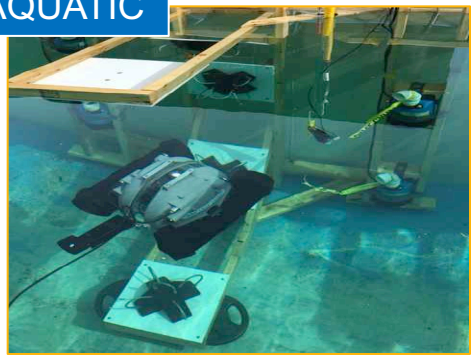
AERIAL



GROUND



AQUATIC



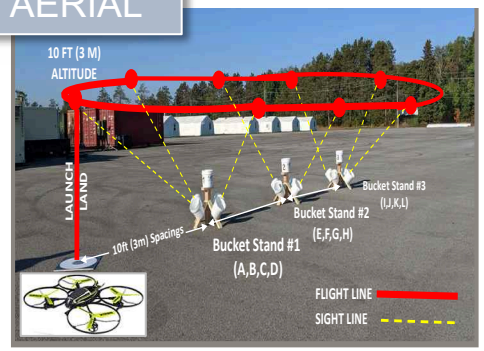
Project Approach

Safety | Capabilities | Proficiency

REPEAT

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

AERIAL



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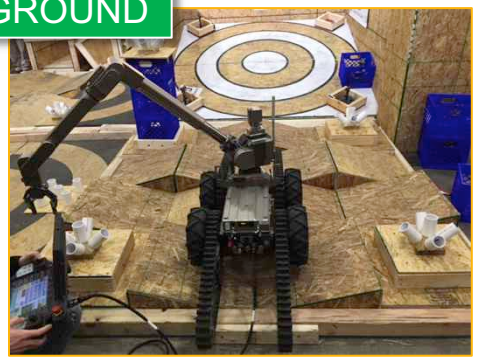

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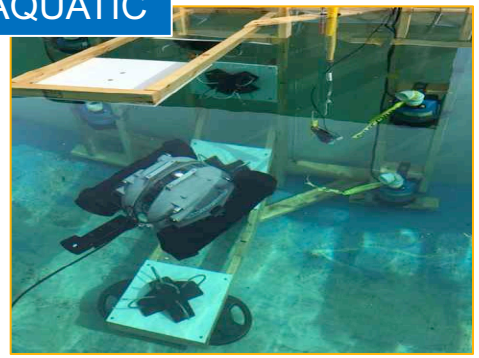


Comprehensive Suites of Standard Test Methods

Safety | Capabilities | Proficiency

- Mobility
- Dexterity
- Endurance
- Sensors
- Radio Comms
- Durability
- Logistics
- Safety
- Autonomy
- Proficiency

Standard Test Lanes

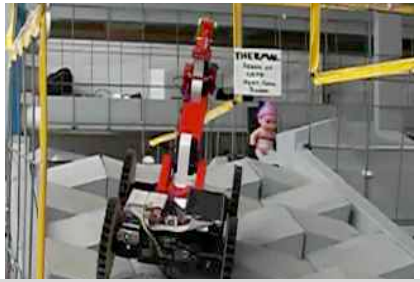
Scorable Scenarios

Repeatable Tasks

Competitions

120cm (48in) Scale

60cm (24in) Scale

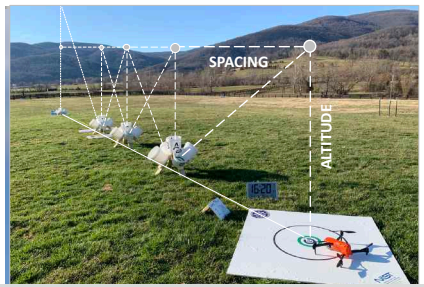


30cm (12in) Scale

Confined Access

Aerial (netted)

Aerial (hangar)

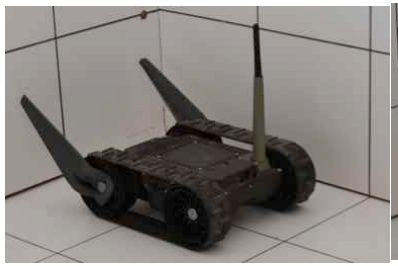


Aerial (outdoor)

Underwater (tank)

Spectrum of Ground Robots Tested

Safety | Capabilities | Proficiency



iRobot 110 FirstLook
2.4kg (5.2lbs)

Qinetiq Dragon Runner 10
4.5kg (10lbs)

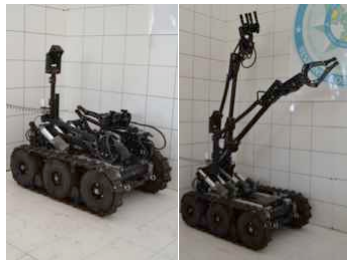
iRobot 310 SUGV
13.2kg (29lbs)

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)

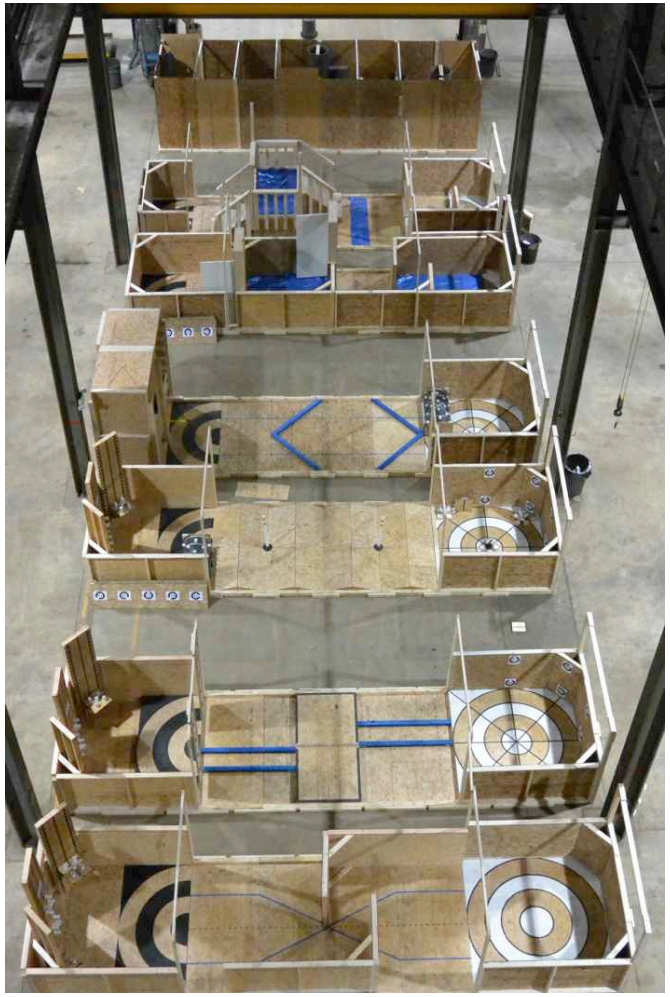
WM Robotics Knight
249kg (550lbs)

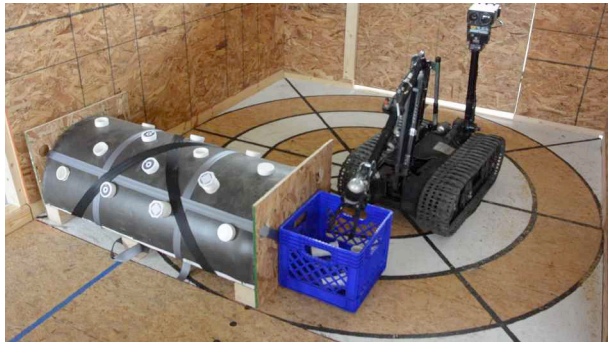
Remotec Mark 5-A1
358kg (790lbs)

Remotec Wolverine
367kg (810lbs)

120cm (4ft) Lateral Clearance Apparatuses

Safety | Capabilities | Proficiency





60cm (24in) Lateral Clearance for Confined Environments

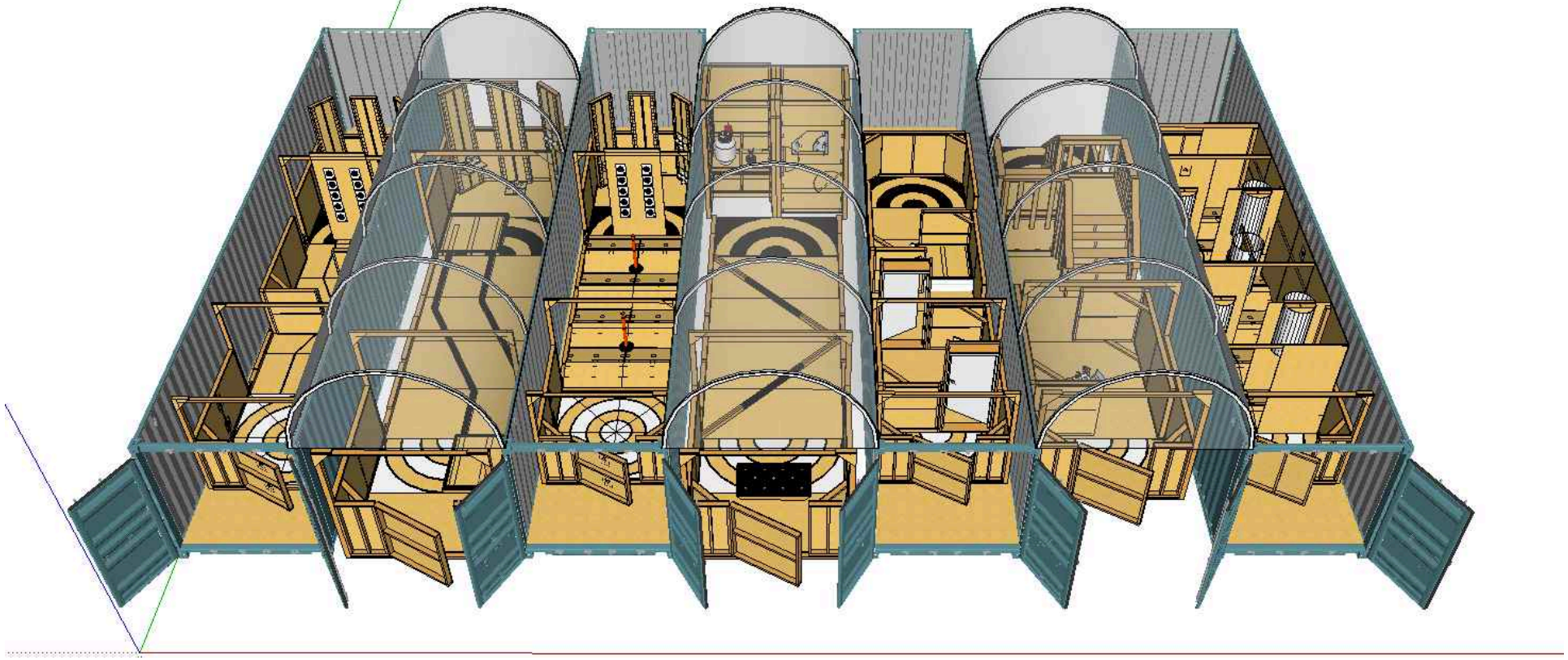
Safety | Capabilities | Proficiency

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

Parking Lot ISO Container Facilities (Rent or Buy)

Safety | Capabilities | Proficiency

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



Parking Lot ISO Container Facilities (Rent or Buy)

Safety | Capabilities | Proficiency

- ISOs have easy lights out testing, radio attenuated, all weather.
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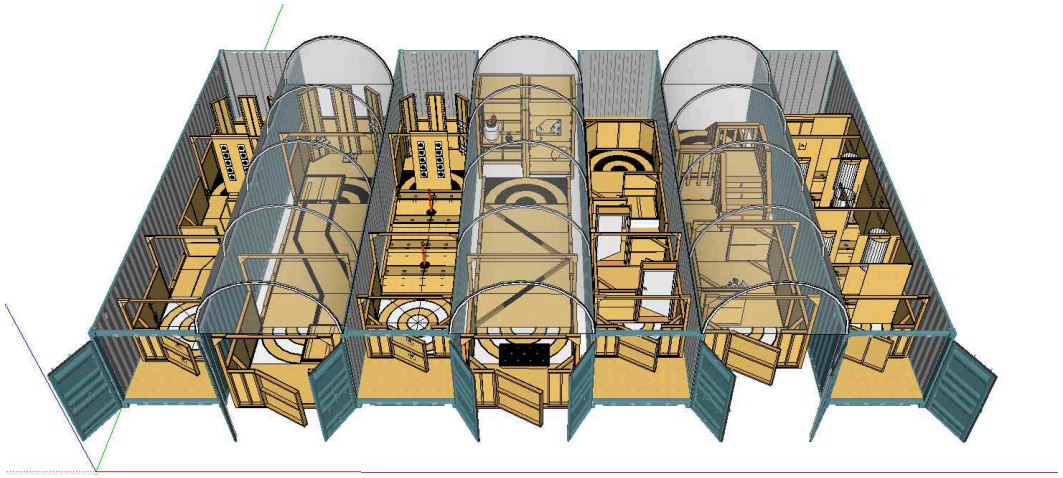
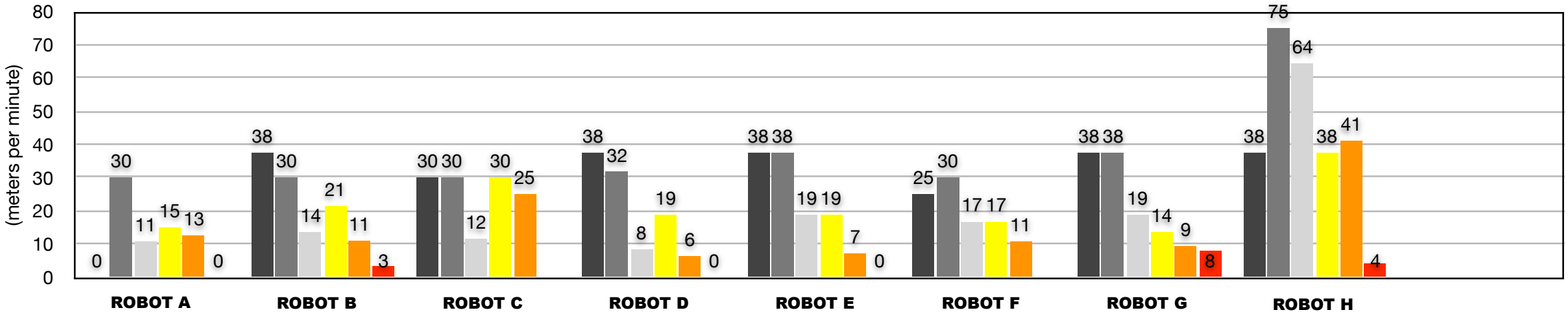


Compare Capabilities and Proficiency

Safety | Capabilities | Proficiency

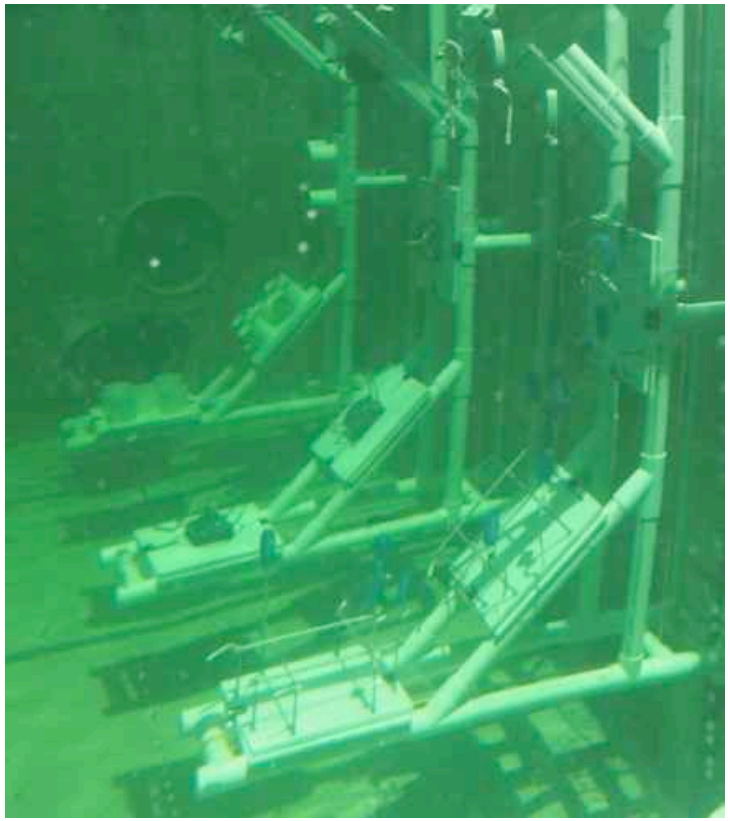
Sand | Gravel | Flat Line Following | Continuous Ramps | Crossing Ramps | Stepfields



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

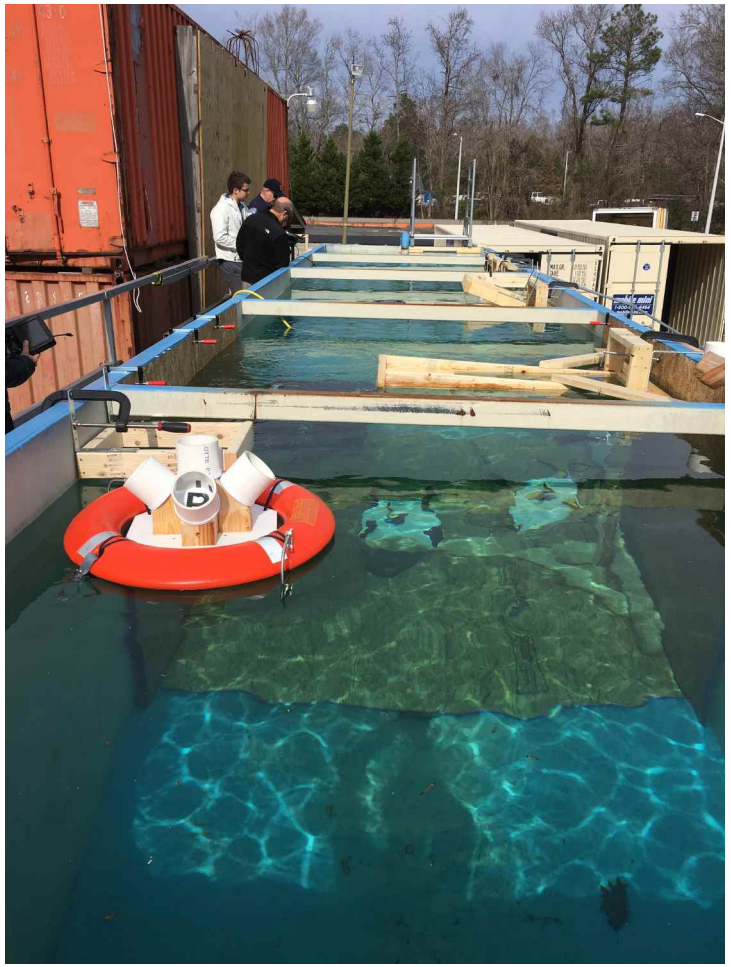
Underwater ROV Test Methods

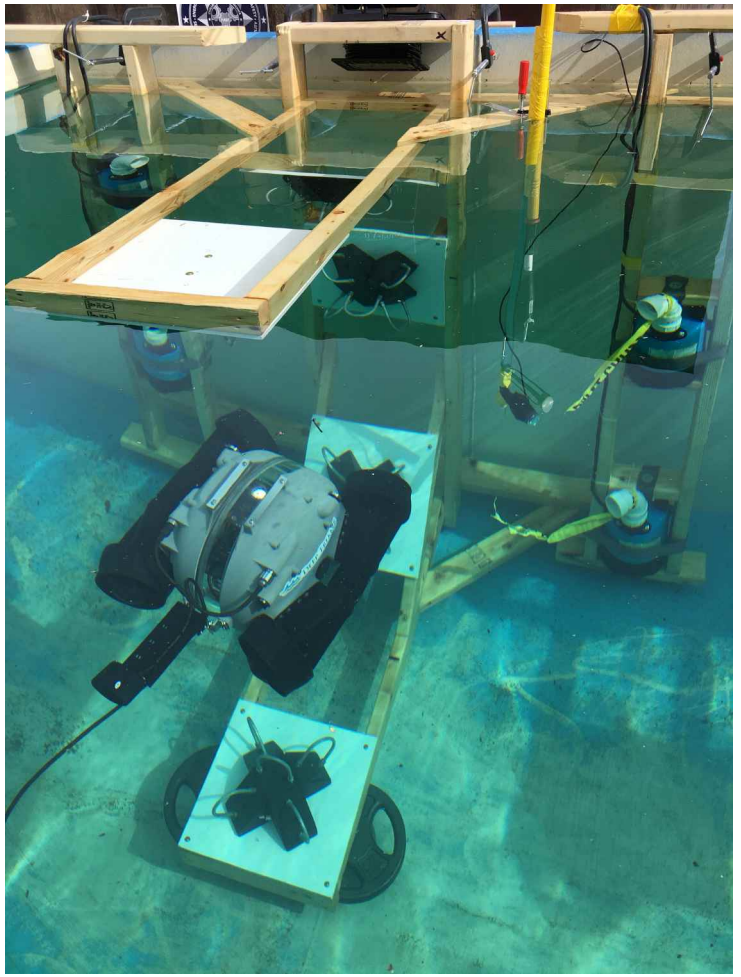
Safety | Capabilities | Proficiency



Underwater ROV Test Methods

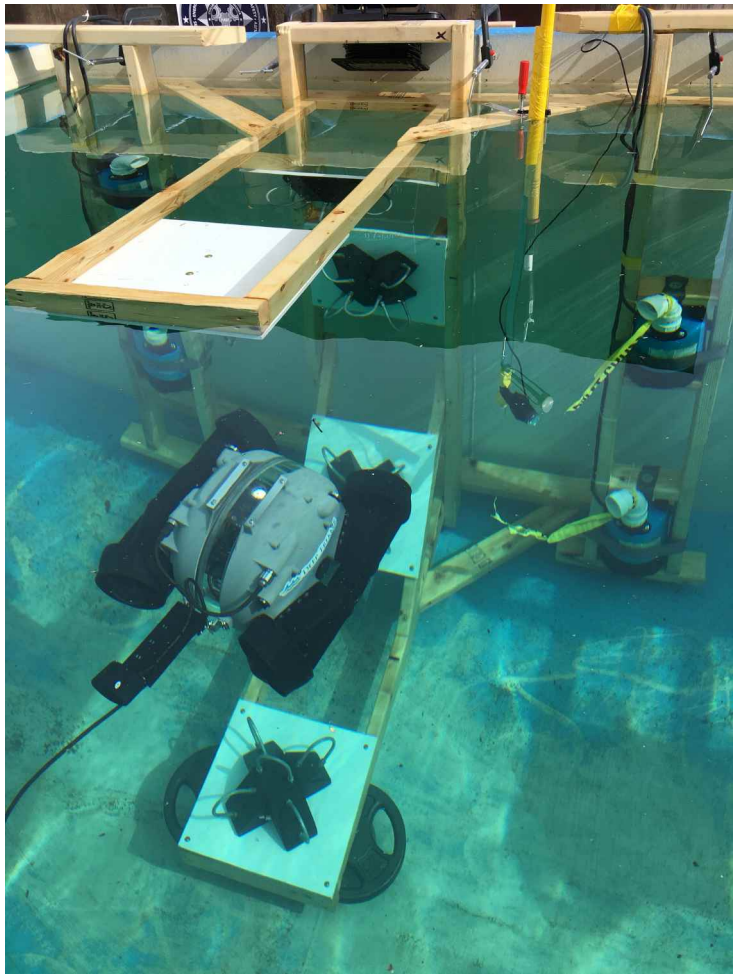
Safety | Capabilities | Proficiency





Underwater ROV Test Methods

Safety | Capabilities | Proficiency



Related Awards

Project Recognition

Our same process originally applied to ground robots will work similarly for sUAS and remote pilots.

2020 Presidential Gears of Government Award

Recognizing people across the Federal workforce whose dedication supports exceptional delivery of key outcomes for the American people, specifically around mission results, customer service, and accountable stewardship.

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.

2019 Secretary Ron Brown Excellence in Innovation Award, U.S. Department of Commerce

The most prestigious singular honor given by the Department, chosen from among the Gold Medal Awards each year.

2019 Gold Medal Award, U.S. Department of Commerce

The highest award given by the Department for extraordinary contributions that impact key mission objectives.

Test Methods for sUAS

Safety | Capabilities | Proficiency

Small Unmanned Aircraft Systems (sUAS)











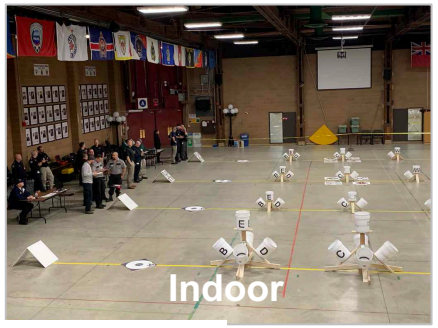
Initial focus is VTOL, but some tests apply to forward flying aircraft when scaled up to the appropriate orbit radius.

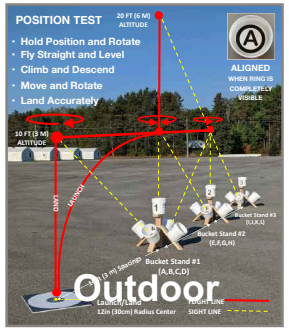
Test Methods Being Developed

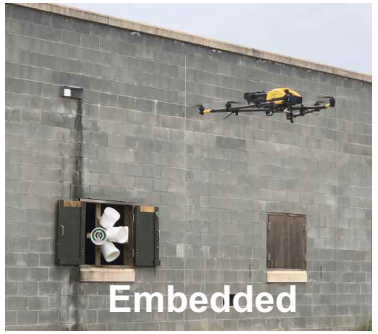
Safety | Capabilities | Proficiency

Sensing

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







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

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. (cont.)

- Avoid Obstacles
- Ground, Post, Wall Tasks
- Pass Through Doors and Windows
- Map Wide Areas (Stitched Images)
- Survey Acuity
- Deliver Payload

Energy/Power

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

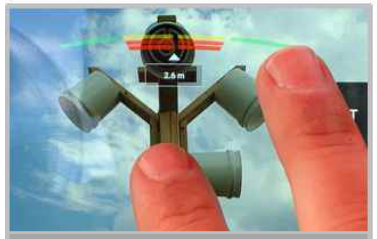
Repeatable Maneuvering and Payload Functionality Tests

Safety | Capabilities | Proficiency

MEASURE & COMPARE


SMALL SYSTEMS


LARGE SYSTEMS

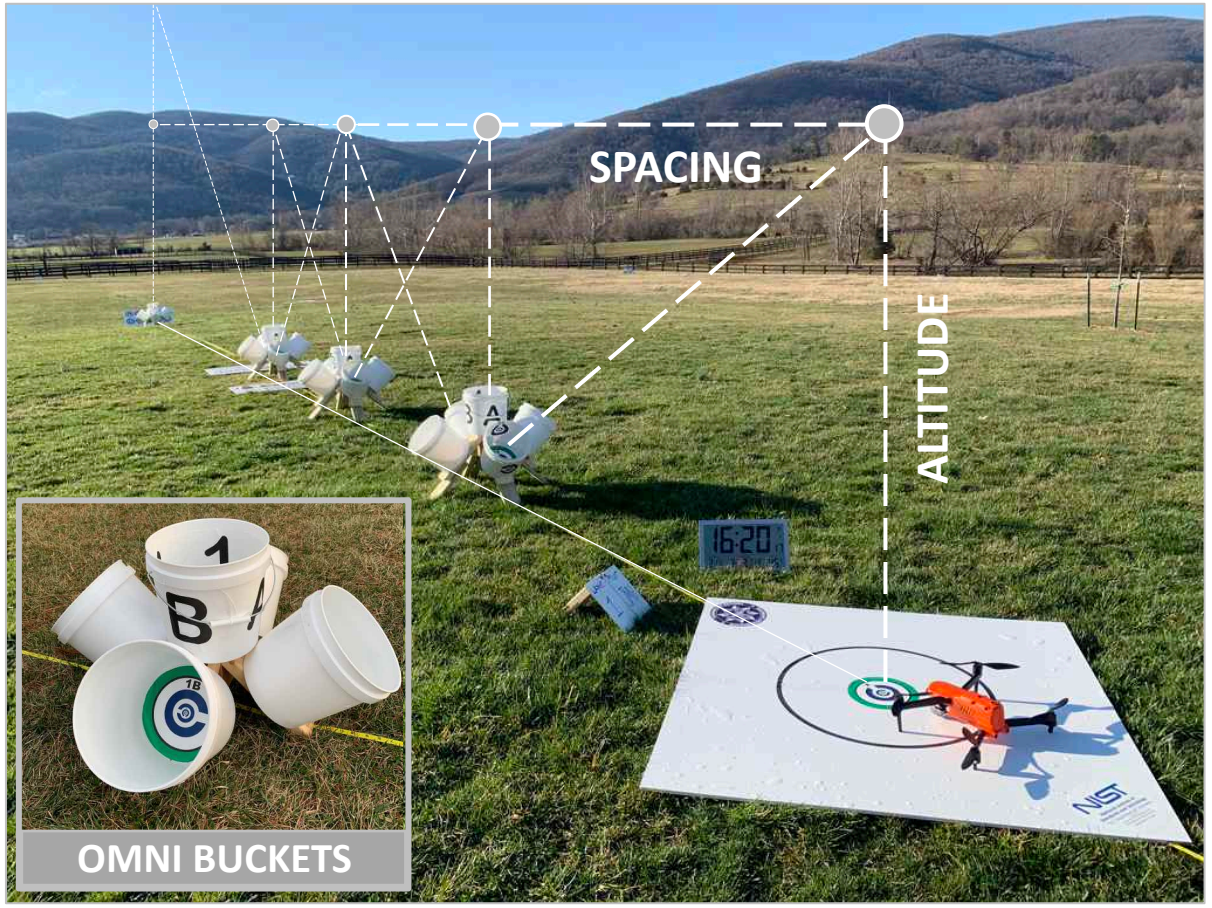

INTERFACES


PROCEDURES

SENSORS


MANEUVERING

SCALABLE TEST LANES (ALTITUDE = SPACING)

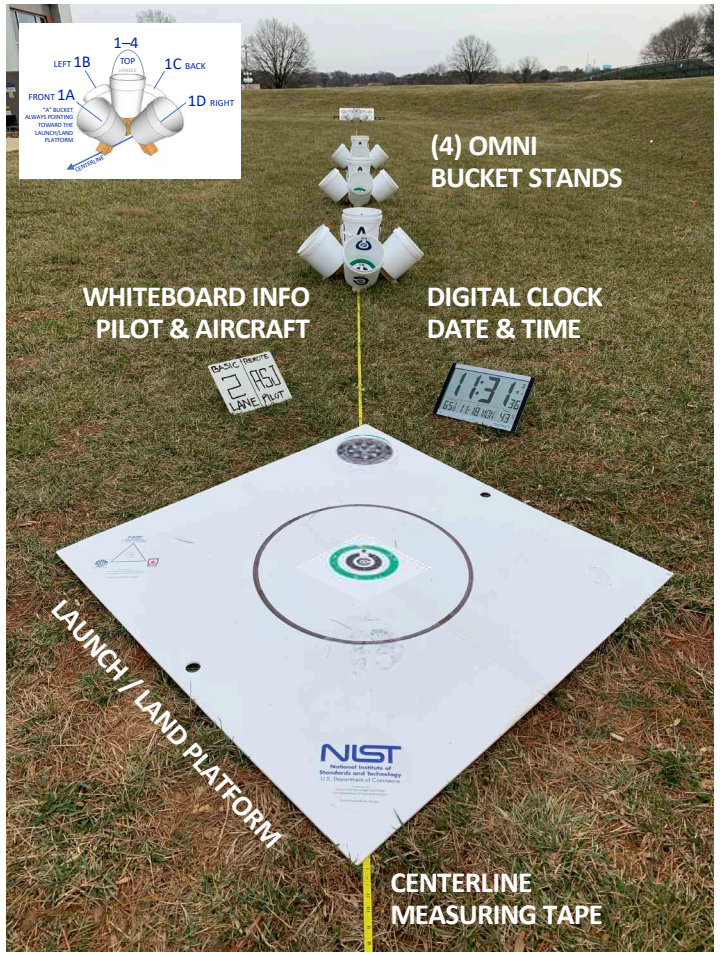


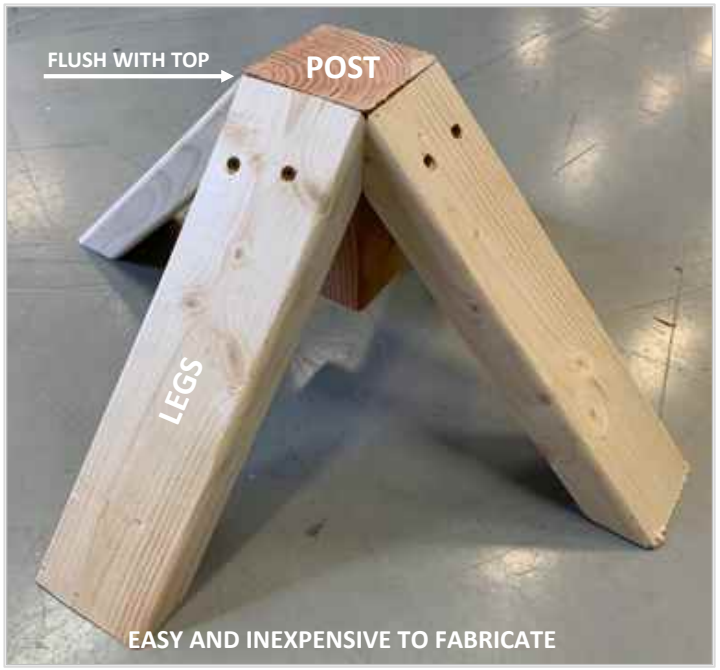
OMNI BUCKETS

Easy Fabrication and Stowing

Open Test Lane

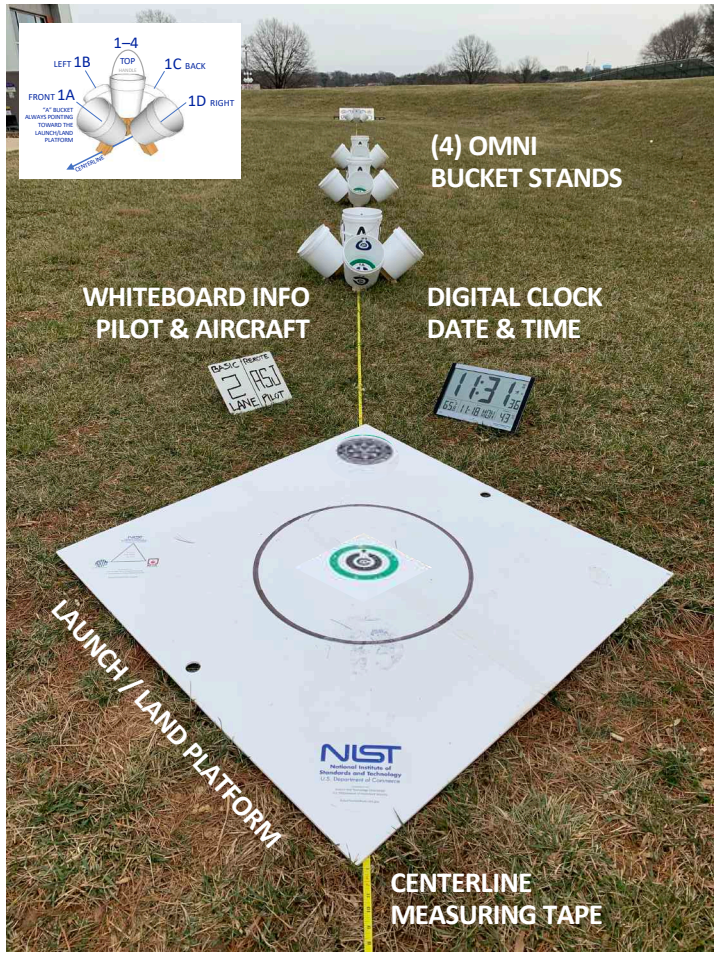
2 Gallon Buckets – Printed Stickers – Transportable



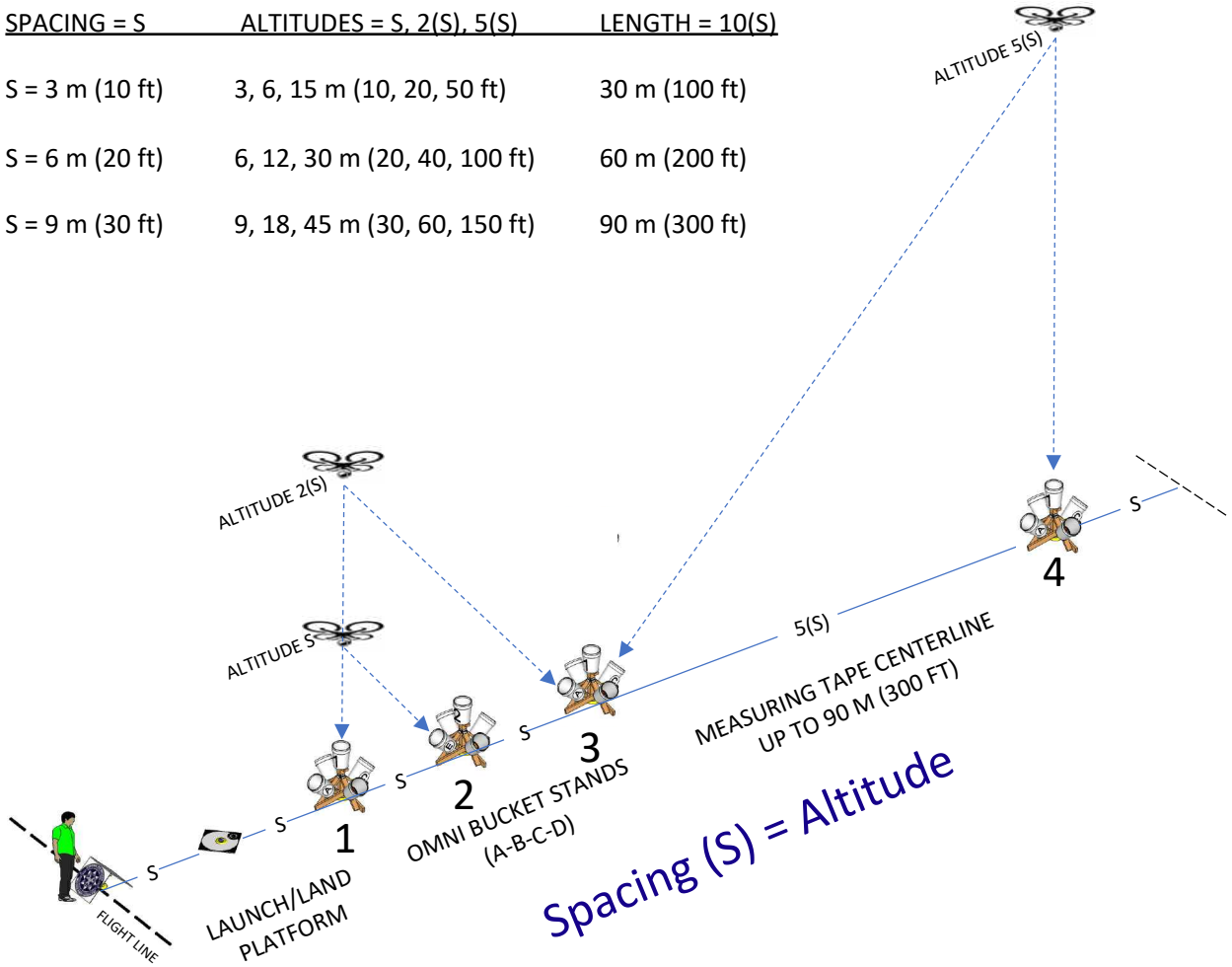


Scalable for Indoor/Outdoor Venues

Open Test Lane

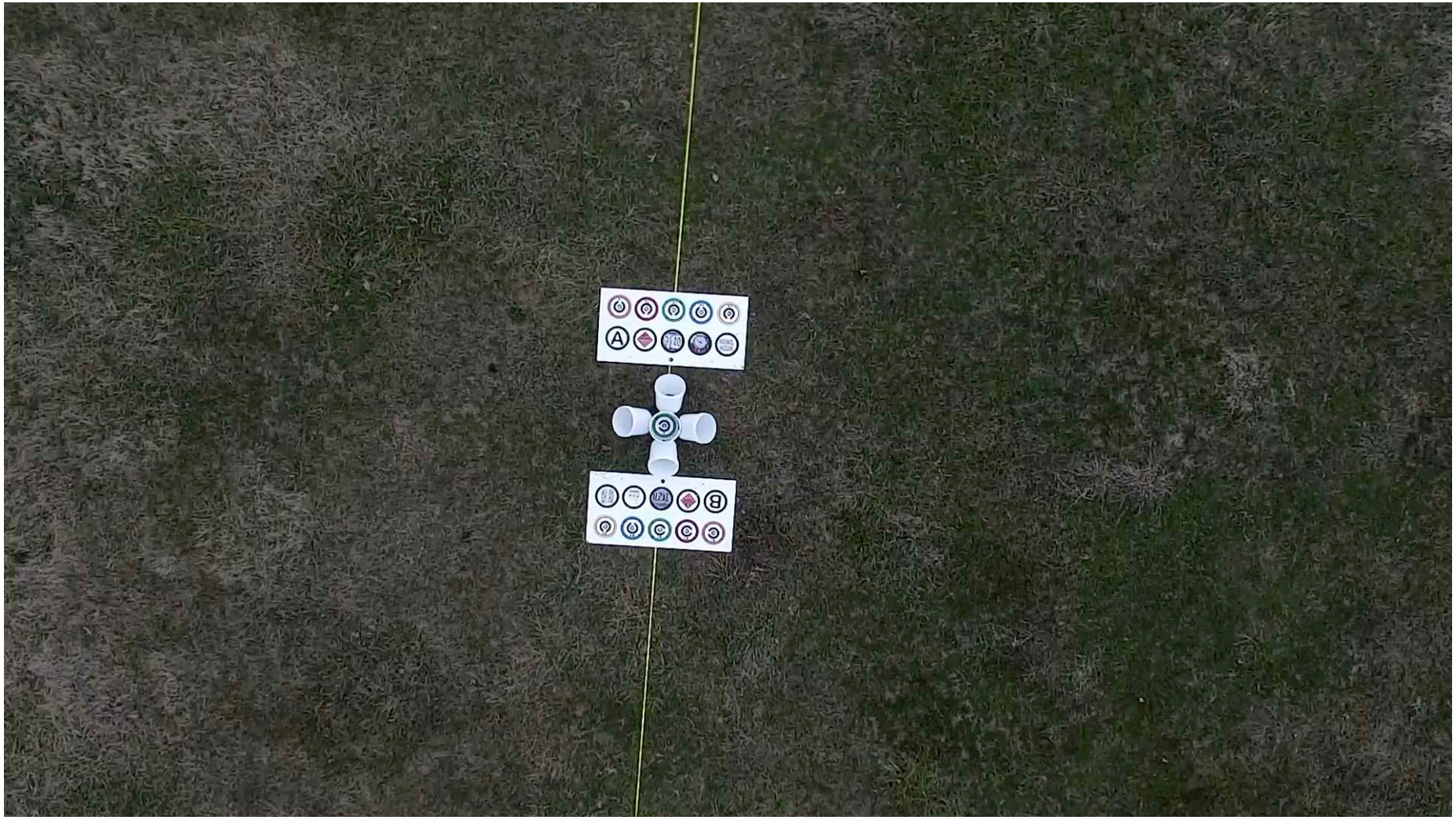


SPACING = S	ALTITUDES = S, 2(S), 5(S)	LENGTH = 10(S)
S = 3 m (10 ft)	3, 6, 15 m (10, 20, 50 ft)	30 m (100 ft)
S = 6 m (20 ft)	6, 12, 30 m (20, 40, 100 ft)	60 m (200 ft)
S = 9 m (30 ft)	9, 18, 45 m (30, 60, 150 ft)	90 m (300 ft)



Evaluate Sensors

Precise Distance to Targets

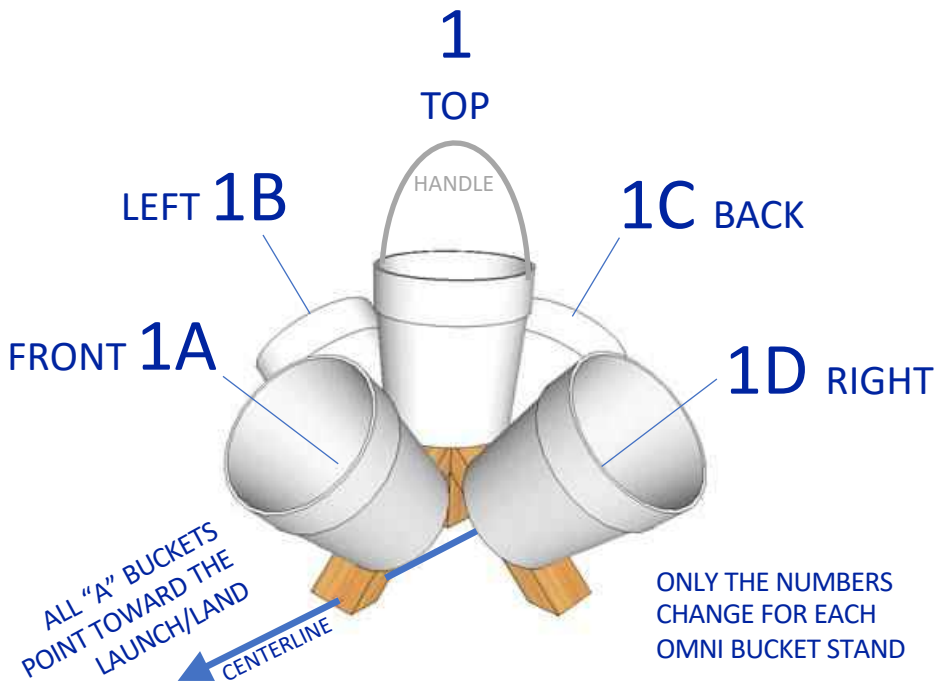


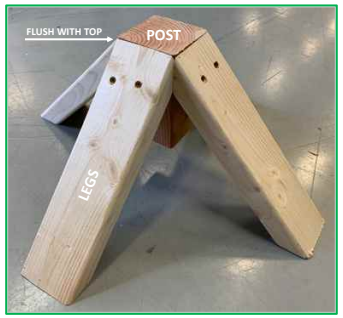
Omni Bucket Stands

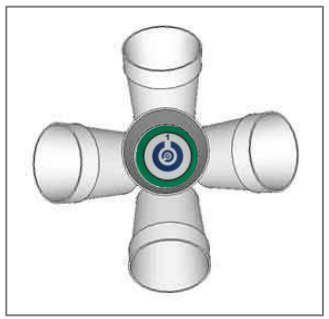
Open Test Lane

WHITE BUCKETS & GREEN RINGS IN STANDARD TEST LANES

SHOWN NOT ALIGNED







BLACK BUCKETS & COLOR RINGS EMBEDDED INTO SCENARIOS

SHOWN ALIGNED

Conduct Tests Two Ways

Open Test Lane

Basic Maneuvering (MAN)

ALIGN WITH BUCKETS

Align with the 20 designated buckets long enough to capture a single image (**NO ZOOM**) showing a continuous green ring inside each bucket. The numbers and letters are bucket identifiers.

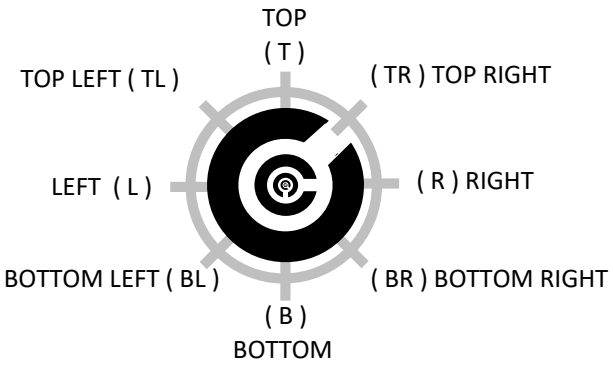
1 point per successfully aligned image
SCORE UP TO 20 POINTS

Payload Functionality (PAY)

ALIGN AND IDENTIFY TARGETS

Align with the 20 designated buckets long enough to capture a single image (**FULL ZOOM**) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep.

1 point per correct gap shown in the image
SCORE UP TO 100 POINTS



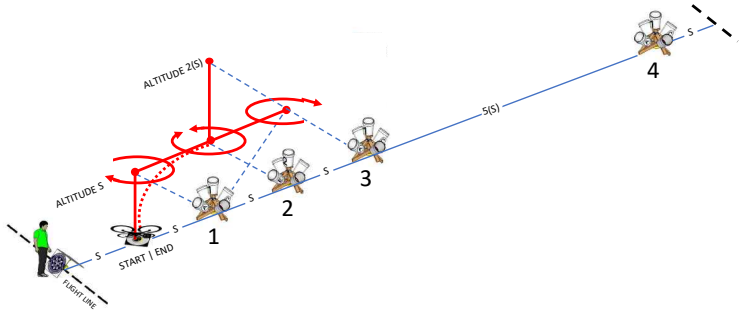
Positive Aircraft Control (Part 107 Skills Test?)

Open Test Lane

Position

MAN/PAY 1

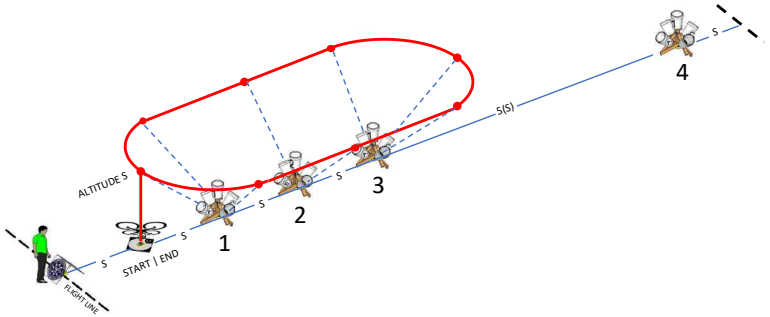
- Hover stably
- Basic maneuvers
- Land accurately
- 20 Buckets in 1 lap



Traverse

MAN /PAY 2

- Fly sideways along a line
- Left and right directions
- Land accurately
- 20 Buckets in 2 laps



Circuit Training with Scores

Open Test Lane

BASIC MANEUVERING MAN 1-5

ALIGN WITH BUCKETS

Align with 20 buckets long enough to capture a single image (NO ZOOM) showing a continuous green ring inside to determine successful alignment. The numbers/letters are bucket identifiers.

NOT ALIGNED

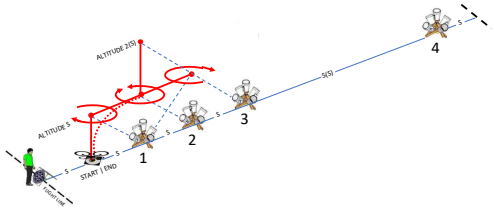
BARELY ALIGNED

ALIGNED

PAY 1-5 PAYLOAD FUNCTIONALITY

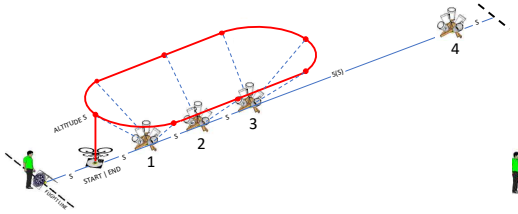
IDENTIFY VISUAL ACUITY TARGETS

Align with 20 buckets long enough to capture a single image (FULL ZOOM) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep in 8 different orientations.



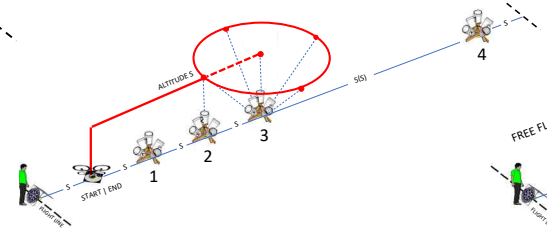
Position
MAN/PAY 1

- Hover stably
- Basic maneuvers
- Landing accuracy
- 20 Buckets in 1 lap



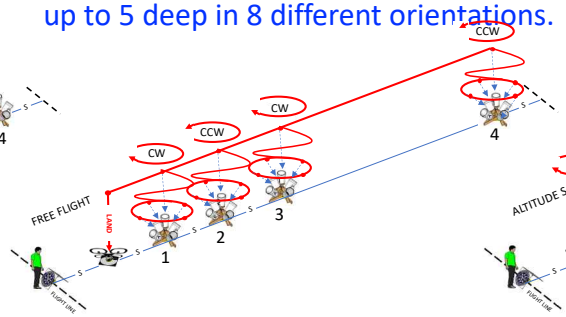
Traverse
MAN/PAY 2

- Fly sideways along a line
- Left and right directions
- Landing accuracy
- 20 Buckets in 2 laps



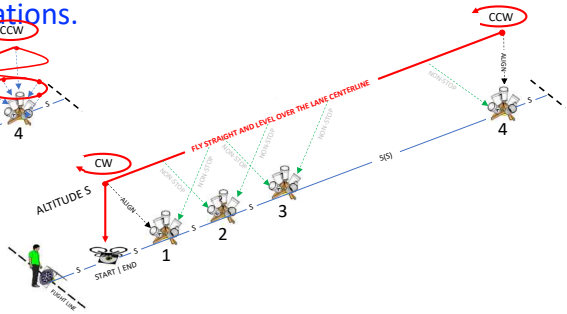
Orbit
MAN/PAY 3

- Orbit to identify objects
- Left and right directions
- S and 2(S) altitudes
- 20 Buckets in 4 laps



Spiral
MAN/PAY 4

- Fly freely to inspect objects
- Any proximity (use zooms)
- Any altitude
- 20 Buckets in 1 lap



Recon
MAN/PAY 5

- Sustain speed over a line
- Establish hovers over objects
- S altitude, 160(S) distance
- 20 buckets in 10 laps

MAN: Align only 5 minutes / 20 points	MAN: Align only 5 minutes / 20 points	MAN: Align only 5 minutes / 20 points	MAN: Align only 5 minutes / 20 points	MAN: Align only 5 minutes / 20 points	100 PTS
PAY: Align and Identify 10 minutes / 100 points	PAY: Align and Identify 10 minutes / 100 points	PAY: Align and Identify 10 minutes / 100 points	PAY: Align and Identify 10 minutes / 100 points	PAY: Align and Identify 10 minutes / 100 points	500 PTS

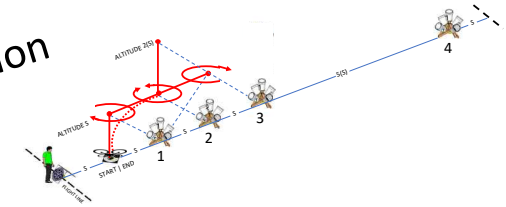
*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Proficiency is compared using similar aircraft.

Circuit Training with Scores

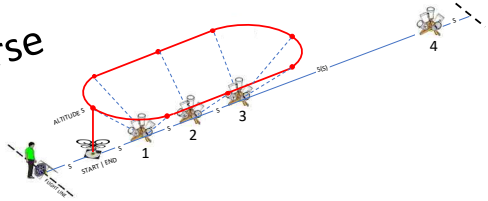
Open Test Lane

- Test lanes are inexpensive and easy to replicate. Conduct alone or in groups with concurrent lanes. Compare results on similar aircraft in similar size lanes.
- Maneuvering and Payload functionality tests are all conducted in the same lane.
- *Maneuvering Tests (MAN):* Align with 20 buckets along the flight paths. 5 minutes per test in 30 minutes total time. Score up to 20 points each, 100 points total.
- *Payload Functionality Tests (PAY):* Align with 20 buckets and identify up to 5 increasingly small Concentric C visual acuity gaps. 10 minutes per test in 60 minutes total time. Score up to 100 points each, 500 points total.
- Twenty tests are being standardized through ASTM International (E54.09). They've been adopted in the NFPA 2400 Standards to evaluate Job Performance Requirements and the ASTM F38 Standard for Remote Pilot Endorsement.
- Replicated internationally to support training and evaluations. Currently being validated as a quantitative scoring basis for remote pilot credentialing.

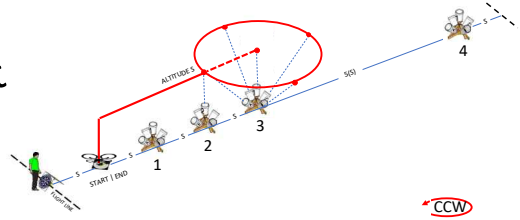
Position



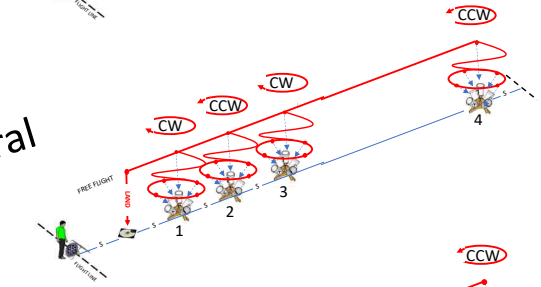
Traverse



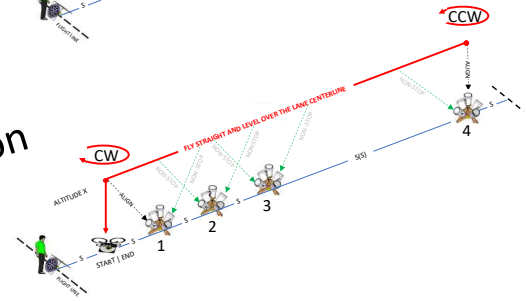
Orbit



Spiral



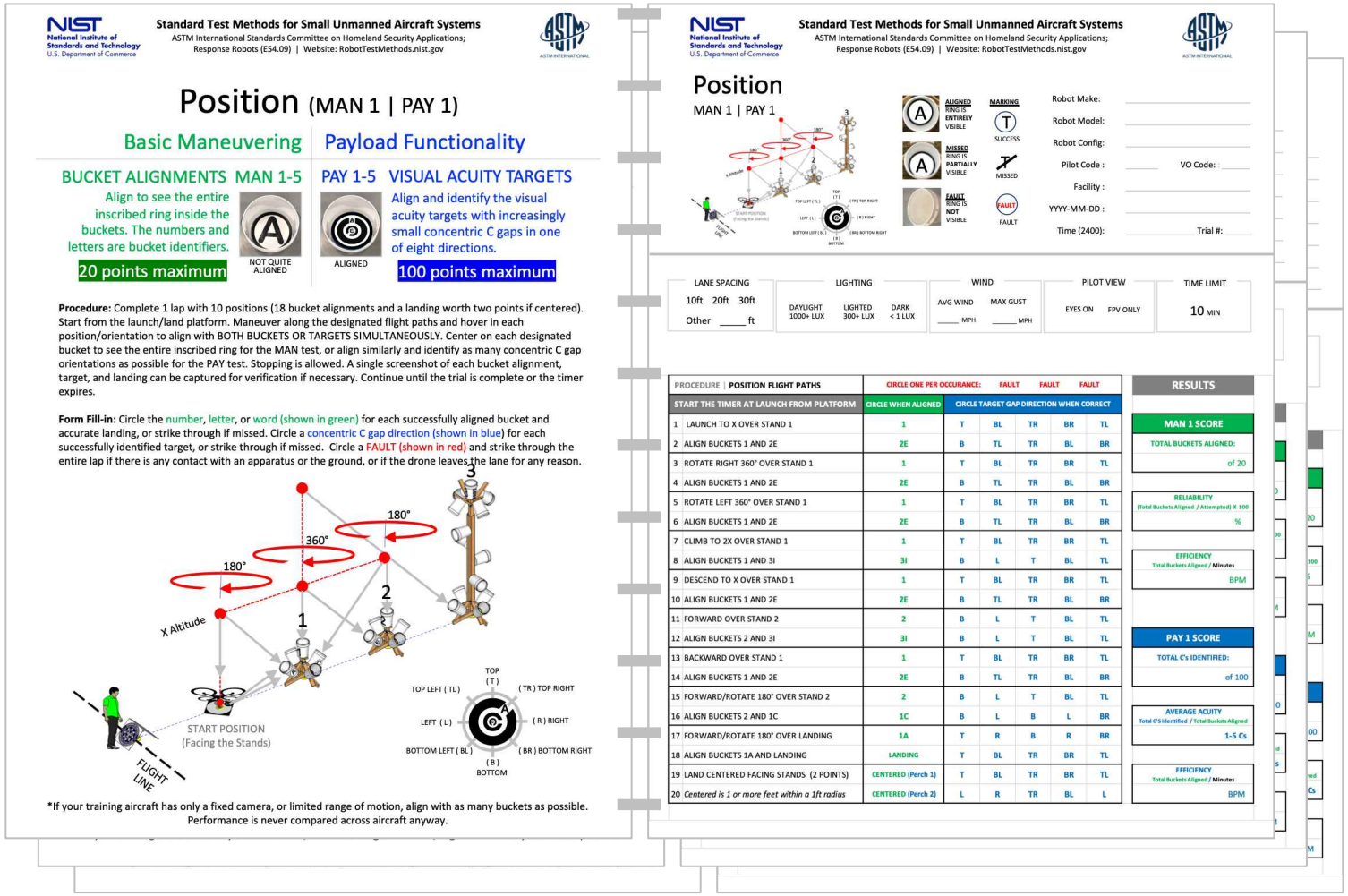
Recon



Track Scores Over Time

Open Test Lane

[Download Forms Books Here]



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

Position (MAN 1 | PAY 1)

Basic Maneuvering	Payload Functionality
BUCKET ALIGNMENTS MAN 1-5	PAY 1-5 VISUAL ACUITY TARGETS
Align to see the entire inscribed ring inside the buckets. The numbers and letters are bucket identifiers.	Align and identify the visual acuity targets with increasingly small concentric C gaps in one of eight directions.
20 points maximum	100 points maximum

NOT QUITE ALIGNED — 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.

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

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

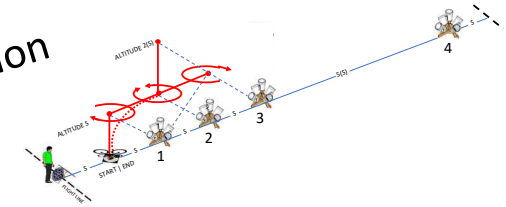
PROCEDURE | POSITION FLIGHT PATHS	CIRCLE ONE PER OCCURANCE:	FAULT	FAULT	FAULT		
START THE TIMER AT LAUNCH FROM PLATFORM	CIRCLE WHEN ALIGNED	CIRCLE TARGET GAP DIRECTION WHEN CORRECT				
1 LAUNCH TO X OVER STAND 1	1	T	BL	TR	BR	TL
2 ALIGN BUCKETS 1 AND 2E	2E	B	TL	TR	BL	BR
3 ROTATE RIGHT 360° OVER STAND 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

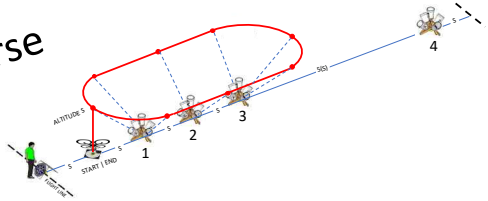
MAN 1 SCORE
TOTAL BUCKETS ALIGNED: of 20
RELIABILITY (Total Buckets Aligned / Attempted) X 100 %
EFFICIENCY Total Buckets Aligned / Minutes BPM

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

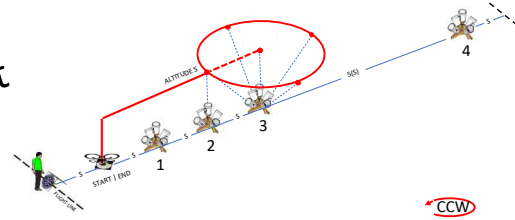
Position



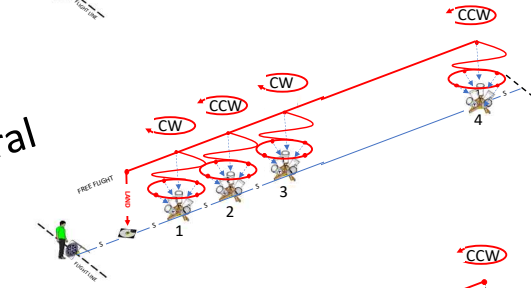
Traverse



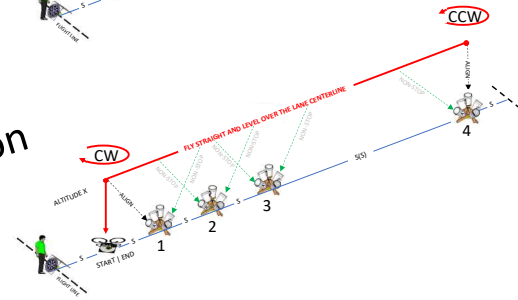
Orbit



Spiral



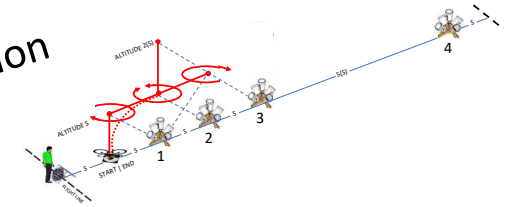
Recon



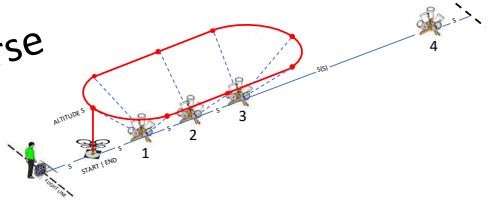
Indoor Layout –Basketball/Tennis Courts

Open Test Lane

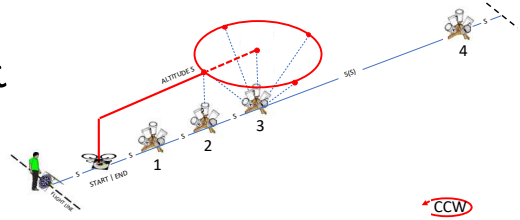
Position



Traverse



Orbit



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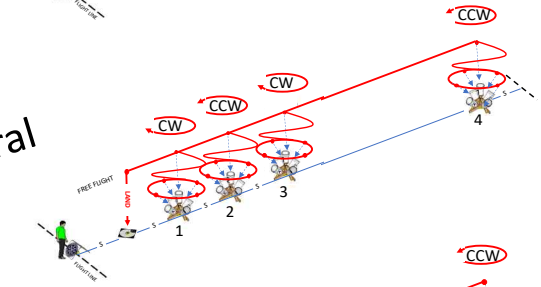
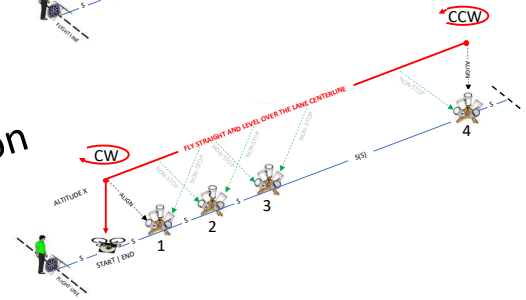
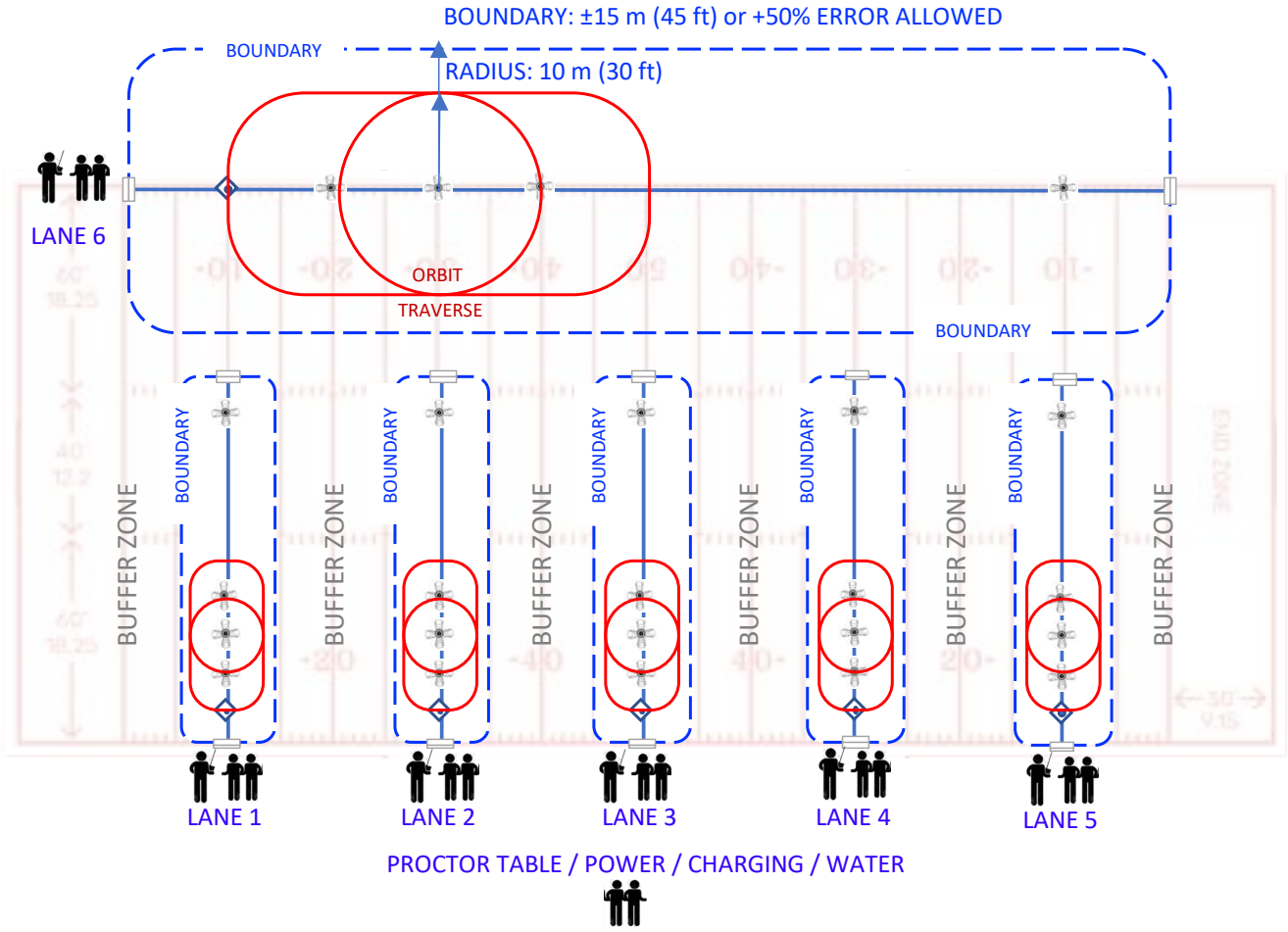


Recon



Football Field Layout

Open Test Lane



LANE SPACING
10 m (30 ft)

BOUNDARY (+50%)
± 15 m (45 ft)

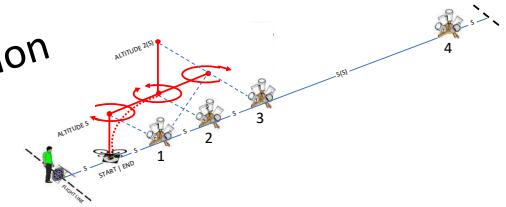
LANE LENGTH
100 m (300 ft)

LANE SPACING
3 m (10 ft)

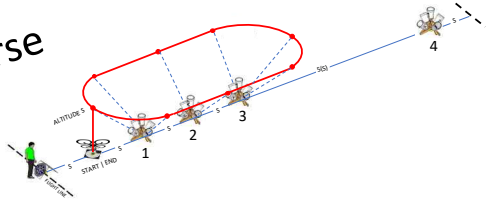
BOUDARY (+50%)
±5 m (15 ft)

LANE LENGTH
30 m (100 ft)

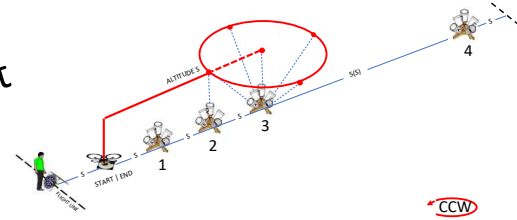
Position



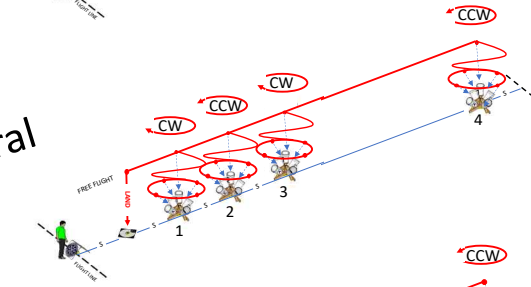
Traverse



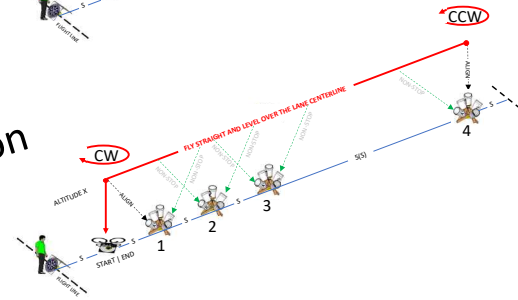
Orbit



Spiral



Recon



SENSOR PANELS & FLIGHT LINES

LAUNCH/LAND PLATFORM

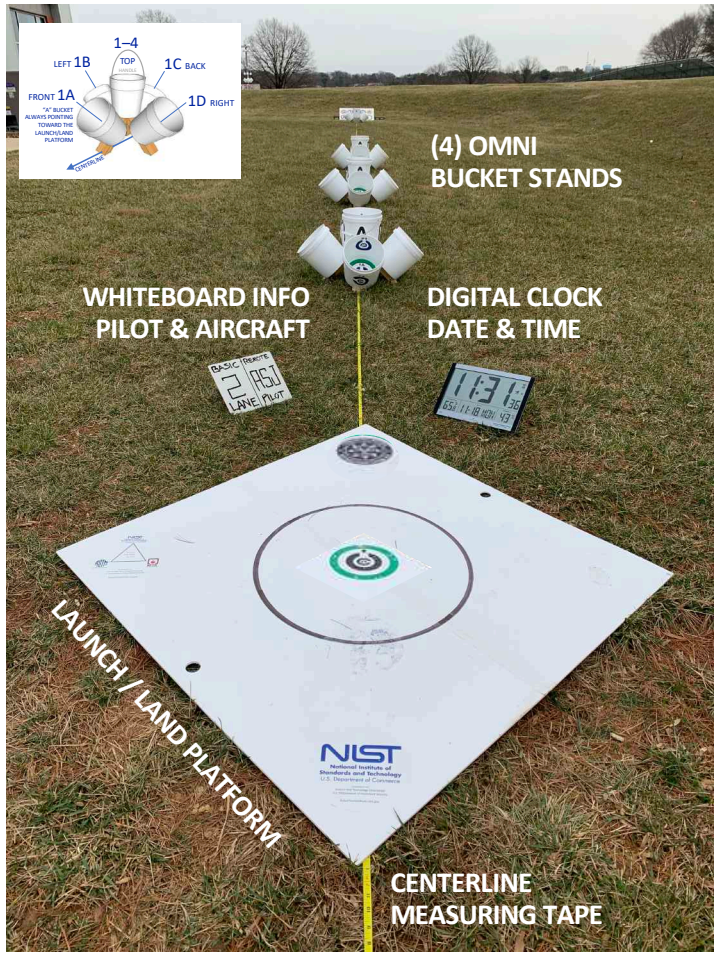
OMNI BUCKET STANDS #1, #2, #3, #4

ORBIT PATH AND TRAVERSE PATH

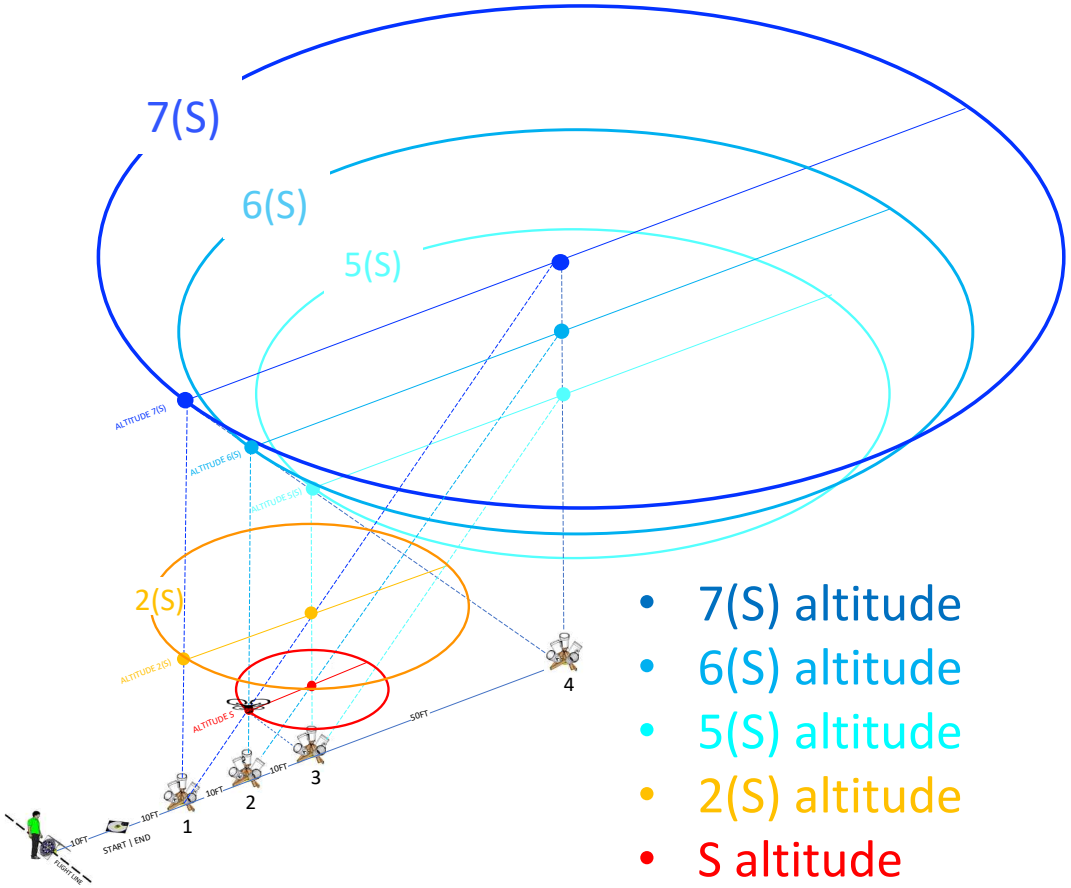
PILOT, VISUAL OBSERVER, AND FORM FILLER

Evaluate Various Flight Paths and Sensors

Open Test Lane

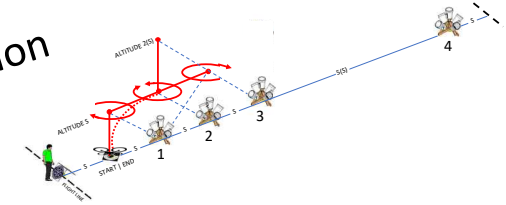


5 Different Orbits in Every Lane Spacing
(S) = 10ft, 20ft, 30ft, or other

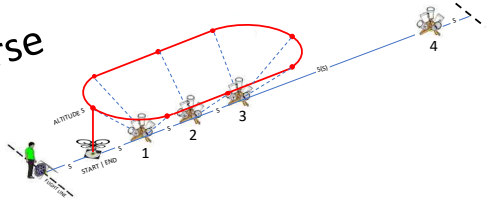


- 7(S) altitude
- 6(S) altitude
- 5(S) altitude
- 2(S) altitude
- S altitude

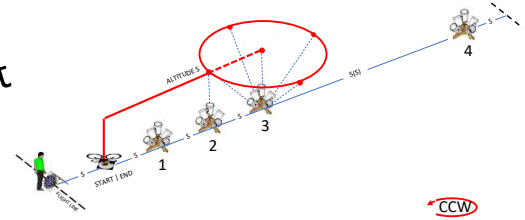
Position



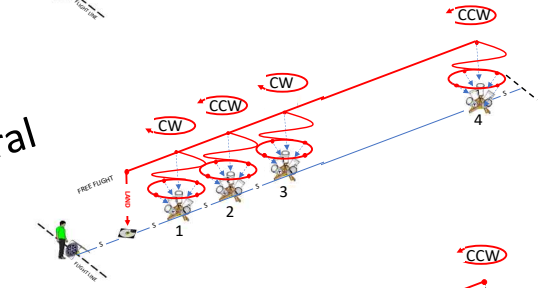
Traverse



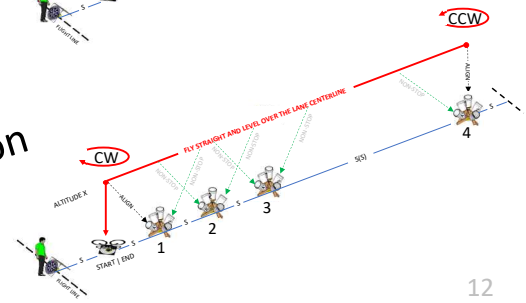
Orbit



Spiral



Recon



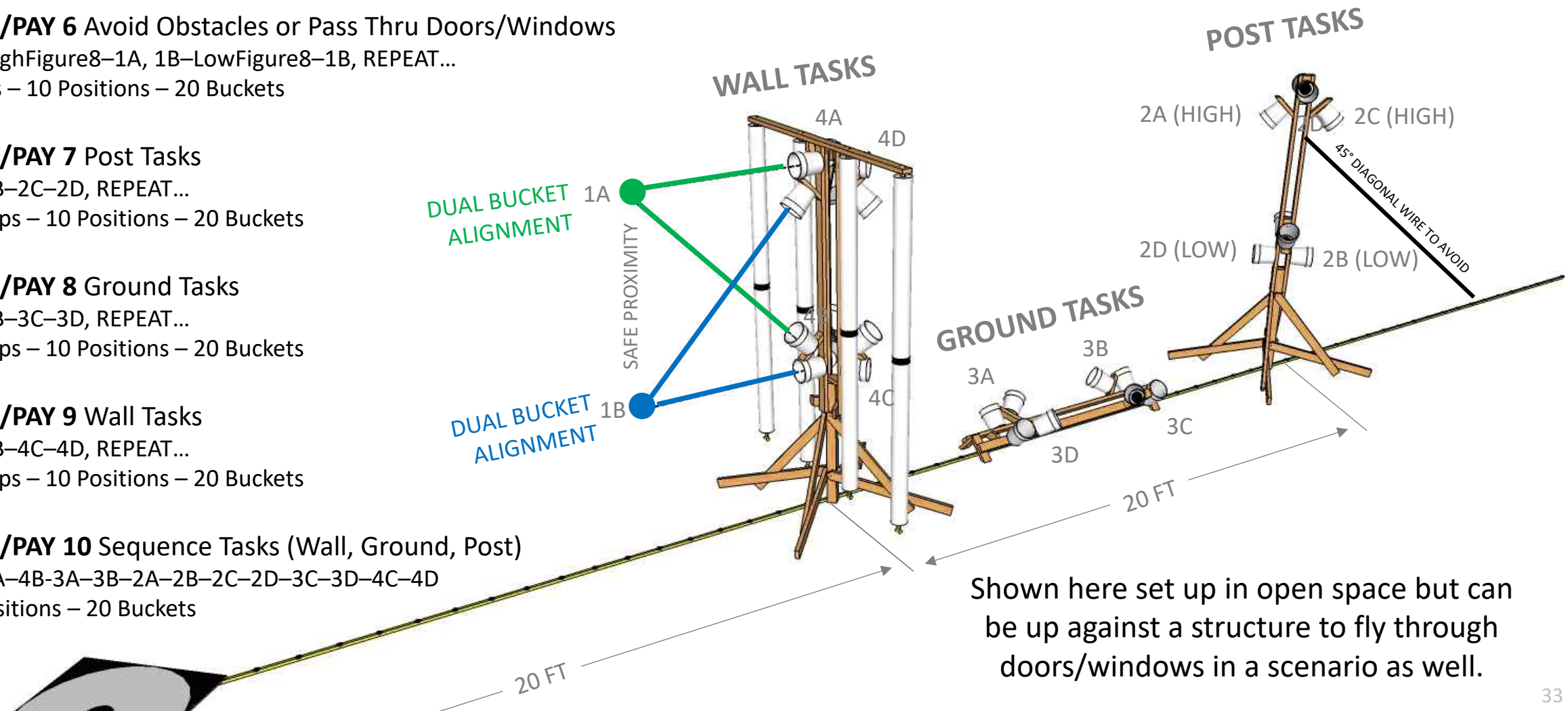
Evaluate Tasks in Proximity to Obstacles

Obstructed Test Lane

Evaluate Tasks in Proximity to Obstacles

Obstructed Test Lane

- **MAN/PAY 6** Avoid Obstacles or Pass Thru Doors/Windows
  1A–HighFigure8–1A, 1B–LowFigure8–1B, REPEAT…
  5 Laps – 10 Positions – 20 Buckets
- **MAN/PAY 7** Post Tasks
  2A–2B–2C–2D, REPEAT…
  2.5 Laps – 10 Positions – 20 Buckets
- **MAN/PAY 8** Ground Tasks
  3A–3B–3C–3D, REPEAT…
  2.5 Laps – 10 Positions – 20 Buckets
- **MAN/PAY 9** Wall Tasks
  4A–4B–4C–4D, REPEAT…
  2.5 Laps – 10 Positions – 20 Buckets
- **MAN/PAY 10** Sequence Tasks (Wall, Ground, Post)
  1A–4A–4B-3A–3B–2A–2B–2C–2D–3C–3D–4C–4D
  10 Positions – 20 Buckets



Shown here set up in open space but can be up against a structure to fly through doors/windows in a scenario as well.


LANE
PILOT
3
MAX
ADVANCED
CODE
15:49

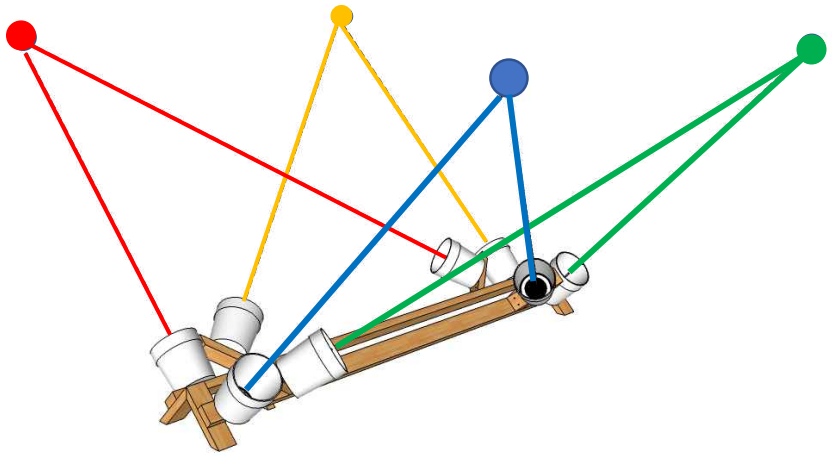
Ground Task Apparatus

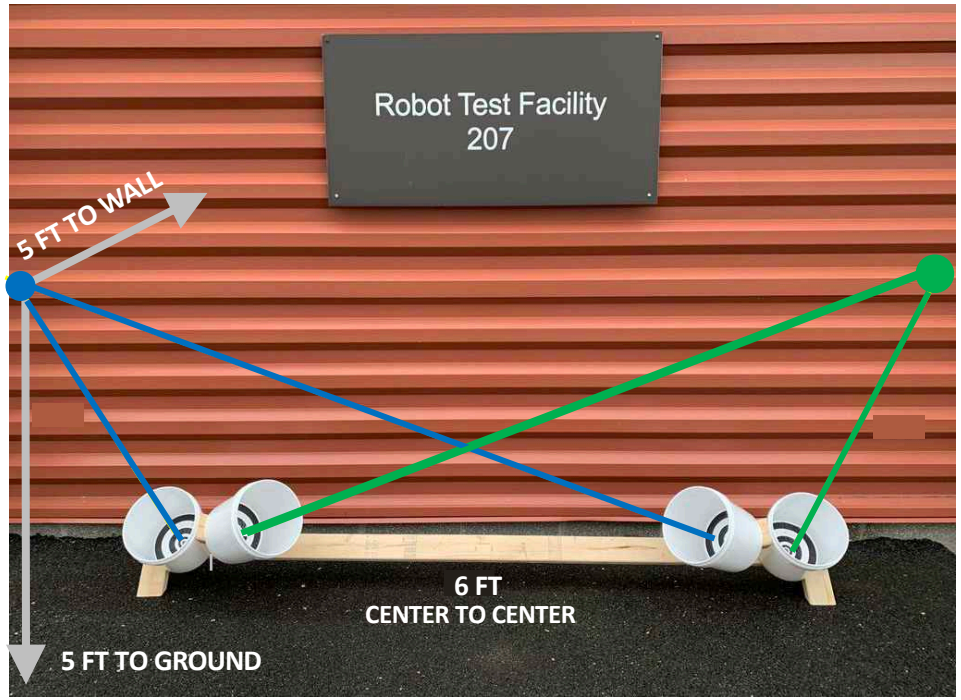
Obstructed Test Lane

- Performing detailed inspection tasks near obstacles requires precision movements at low altitude.
- The DUAL BUCKET ALIGNMENTS guide the aircraft to safe positions around the obstacles that the pilot can trust.
- These apparatuses are used as objects of interest or to evaluate degradation of maneuvering and payload functionality in proximity to structures due to latency, loss of radio comms, fewer GPS satellites, etc.

DUAL BUCKET ALIGNMENTS:

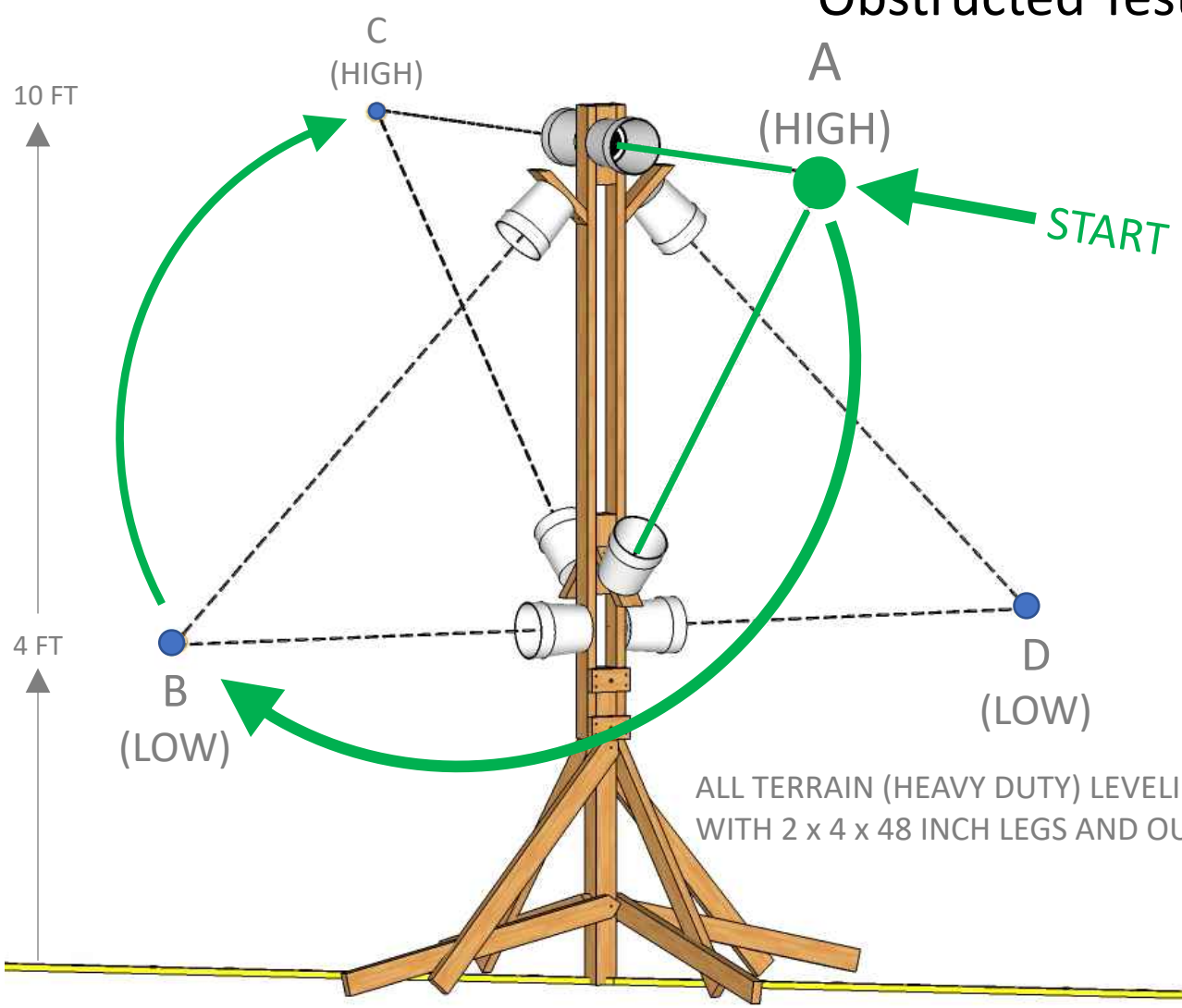
- Simultaneous alignment of perpendicular and angled bucket pairs.
- Both point to a 2m (6ft) stand-off from apparatus.



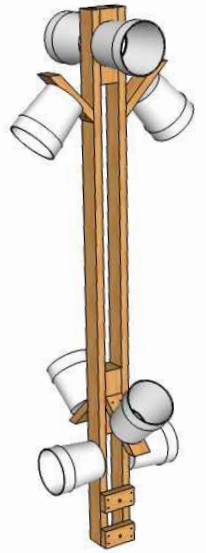


Post Task Apparatus

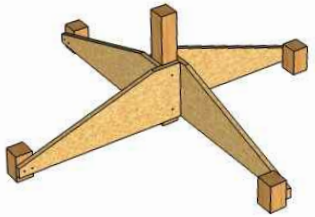
Obstructed Test Lane



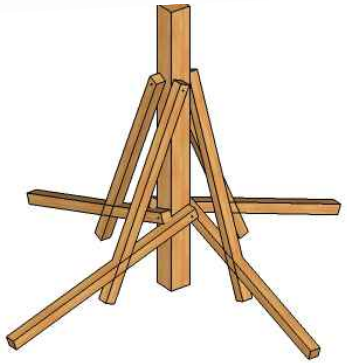
ALL TERRAIN (HEAVY DUTY) LEVELING BASE WITH 2 x 4 x 48 INCH LEGS AND OUTRIGGERS



MODULAR POST WITH DUAL BUCKET ALIGNMENTS ALTERNATING HIGH AND LOW



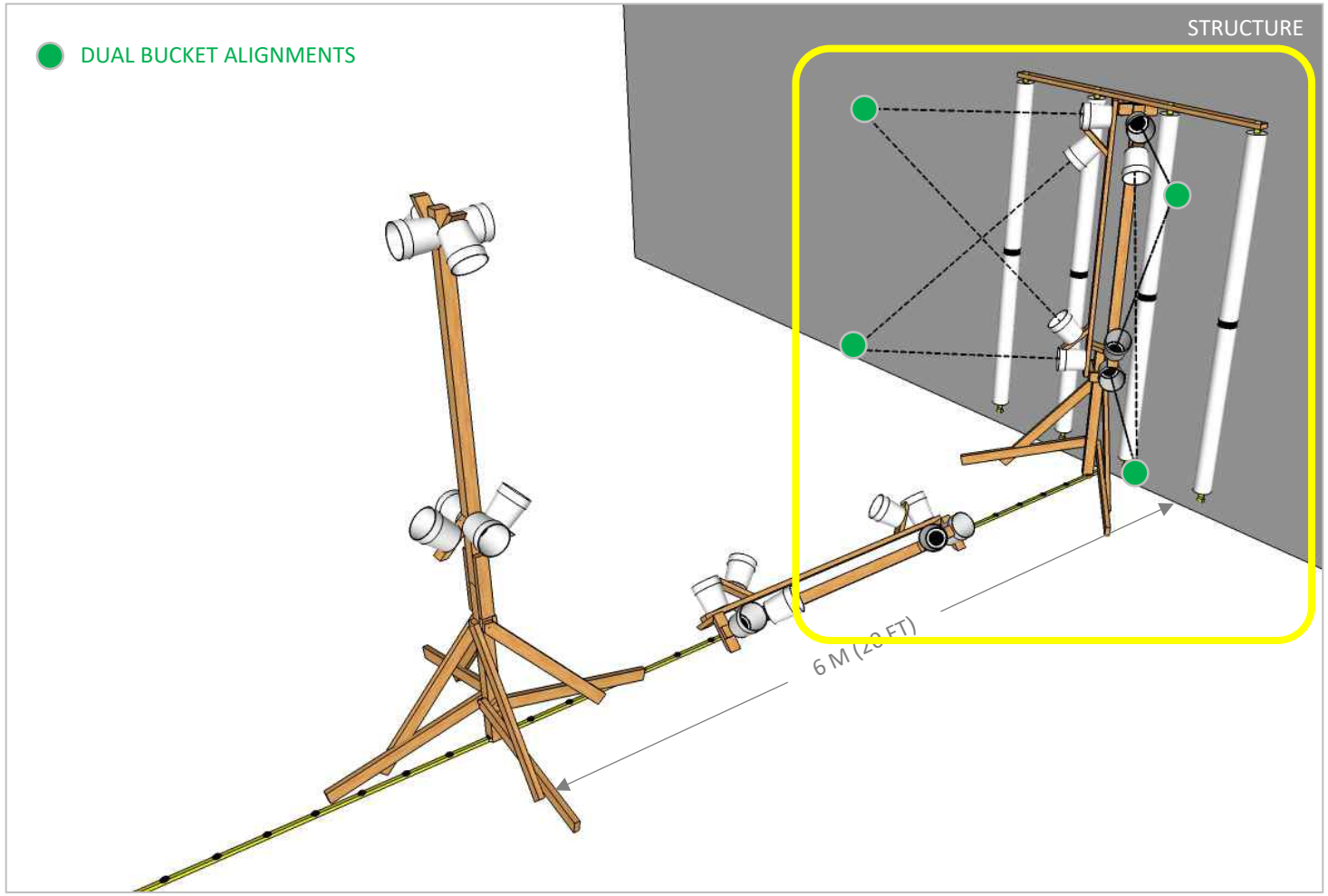
SHORT (24 INCH) LEVELING STAND FOR INDOOR OR RELATIVELY FLAT GROUND AND SMALL sUAS. LOWER HOVERS AT 2 FT AGL.



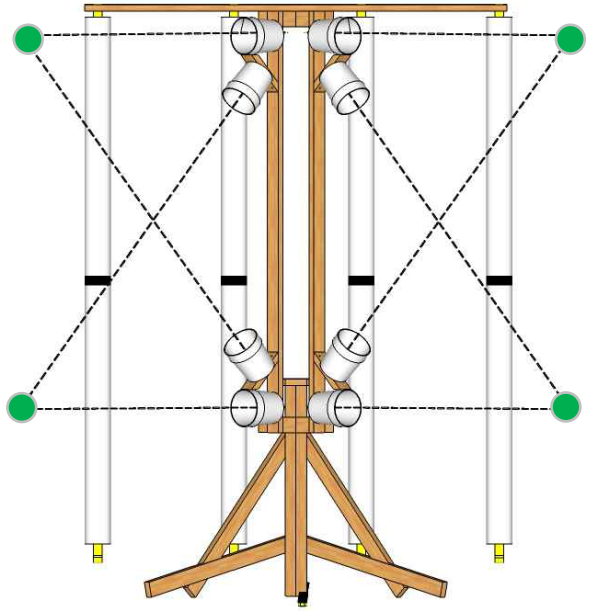
ALL TERRAIN (LIGHTWEIGHT) LEVELING BASE WITH 2 x 2 x 36-48 INCH LEGS AND OUTRIGGERS

Wall Task Apparatus

Obstructed Test Lane

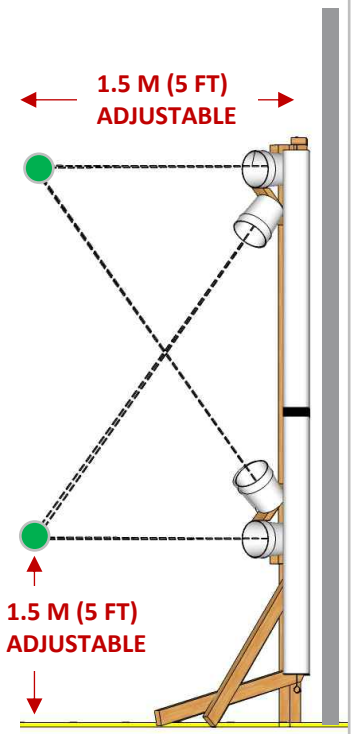


FRONT VIEW



POOL NOODLES ADD CONTRAST/BUMBERS TO WALL AND REQUIRE SIMILAR OBSTACLE AVOIDANCE WHEN SET UP IN A FIELD.

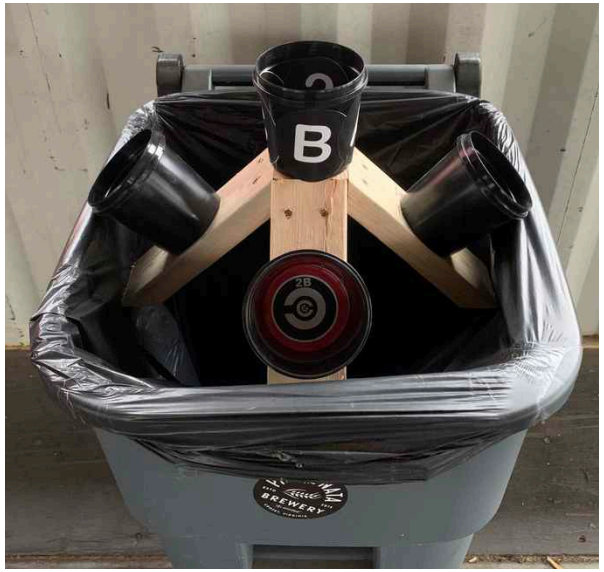
SIDE VIEW

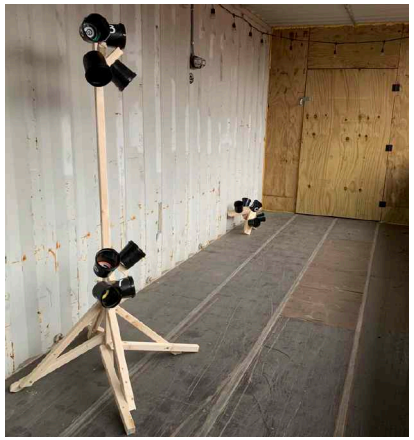


Indoor Environments

Confined Test Lane

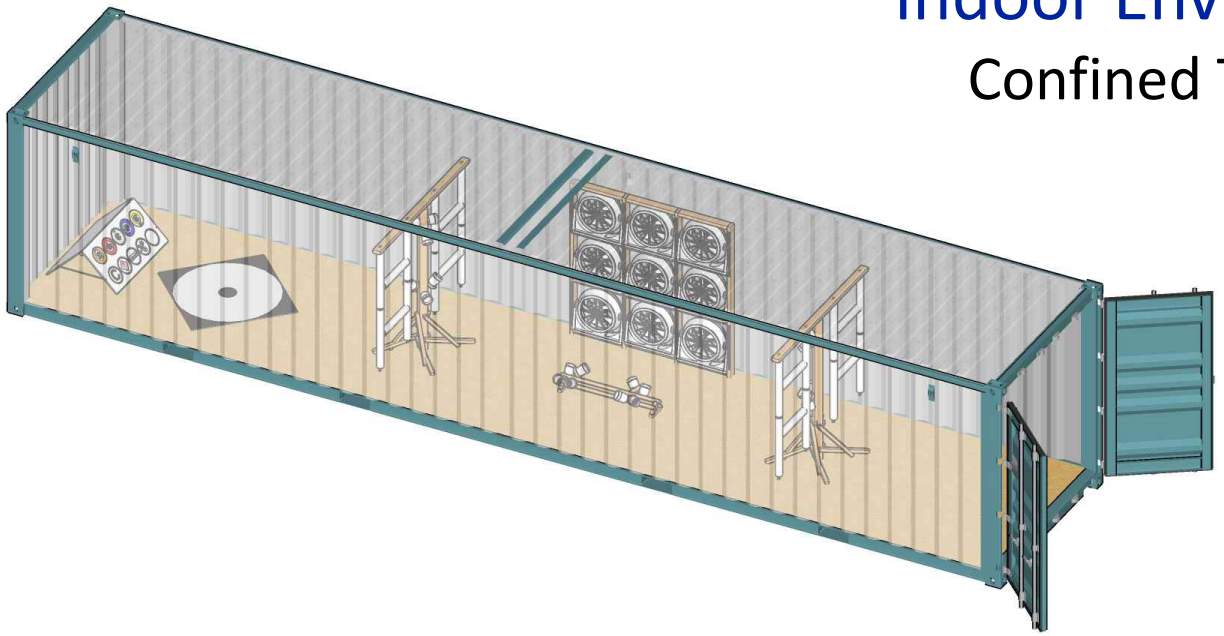
- Exact same Obstructed Test Lane at half scale. Uses 10 cm (4 in) diameter, 1-quart cups fitted with stickers.
- The DUAL BUCKET ALIGNMENTS provide half the stand-off distance at 1 m (3 ft) from the apparatus.
- They lead pilots to safe proximities from walls, ceiling, and floor to help understand distortions in their views, prop wash effects, and generally get comfortable operating in confined spaces.
- Practice in open areas, evaluate **inside shipping containers** within defined 2.4 m (8 ft) rooms.

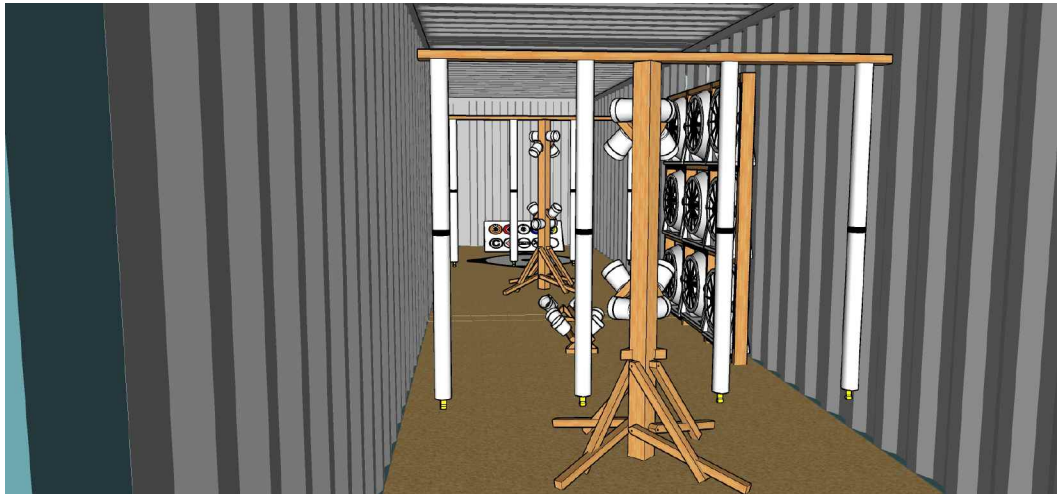




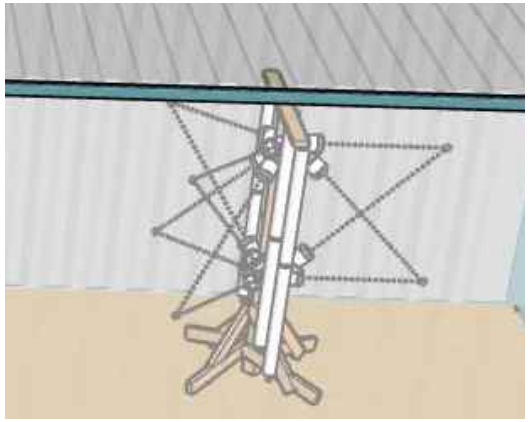
Indoor Environments

Confined Test Lane

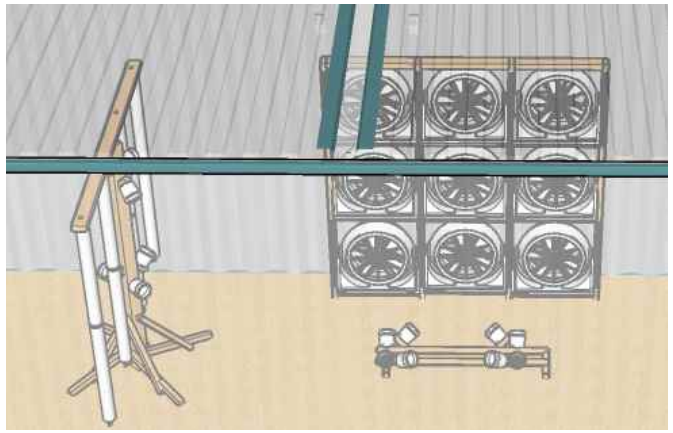


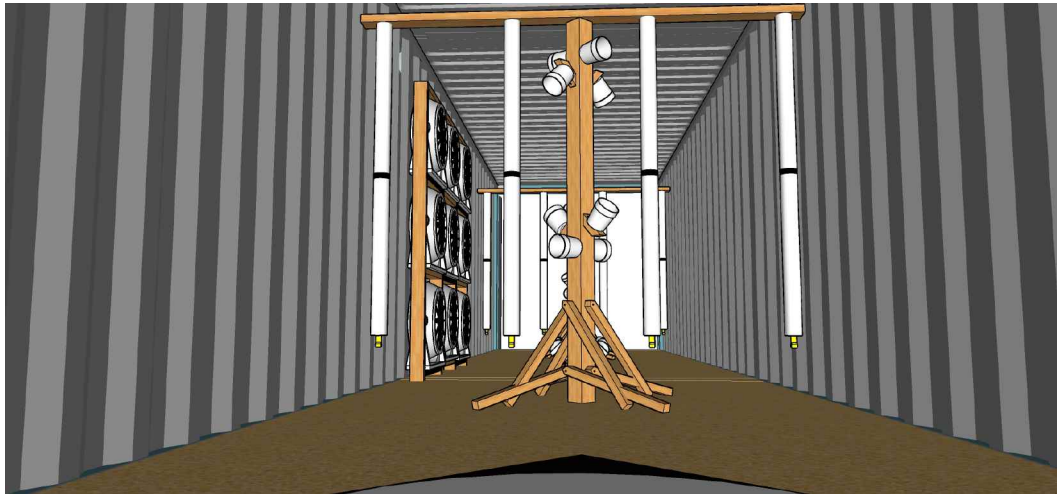


SAFE DUAL BUCKET ALIGNMENT POSITIONS



GPS DENIED DOOR/WINDOWS PASS THROUGHS (POOL NOODLES)

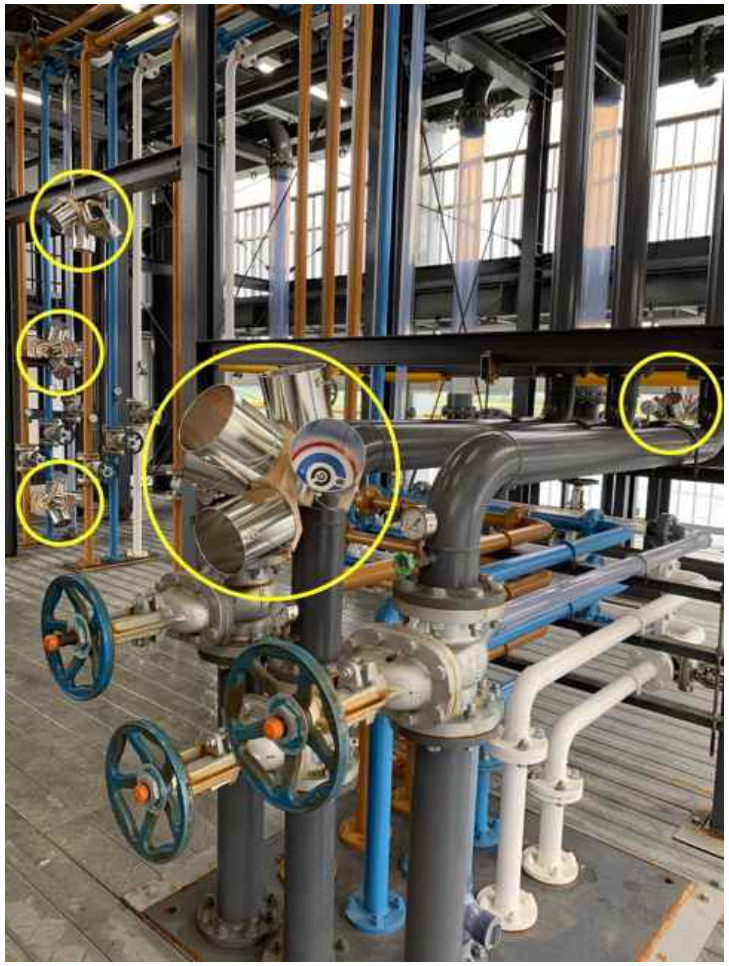




Indoor Environments

Confined Test Lane

METAL BUCKETS
BLEND INTO THE ENVIRONMENT



Standard Disaster Response Robot Challenge and Plant Disaster Prevention Challenge, World Robot Summit, Japan

Evaluate Sensors

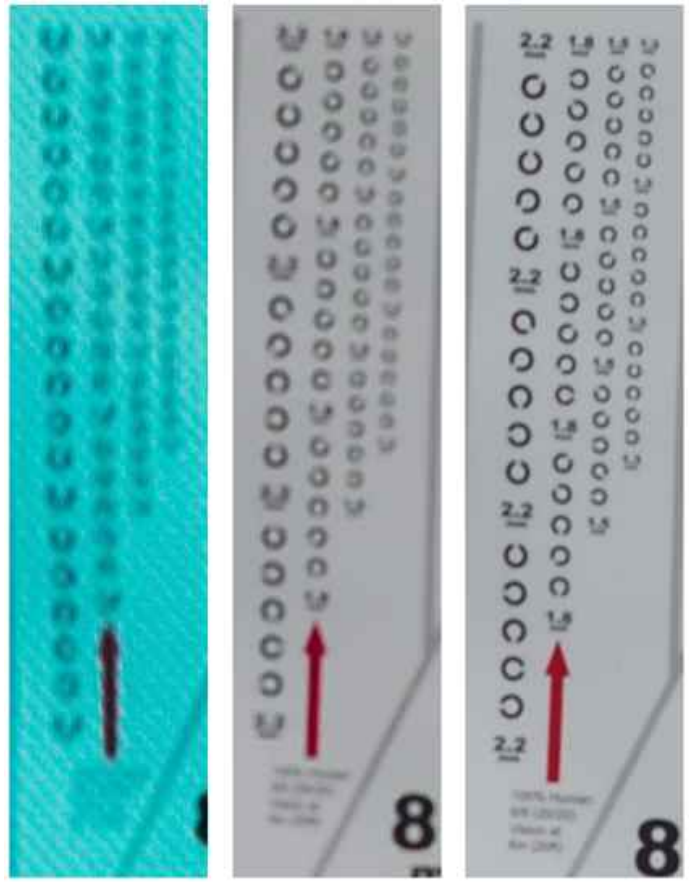
Precise Distance to Targets

Visual, Color, Motion, Thermal Acuity

Measured as Interface (live), Streamed (delayed), and Recovered (removable media)

DIFFERENT LEVELS OF ACUITY

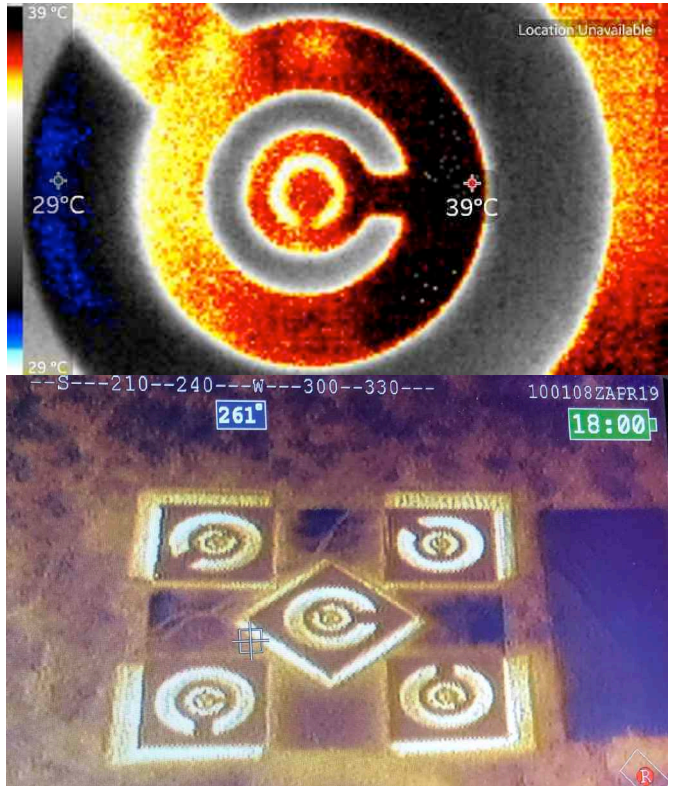
Interface	Streamed	Recovered
LIVE	BETTER	BEST



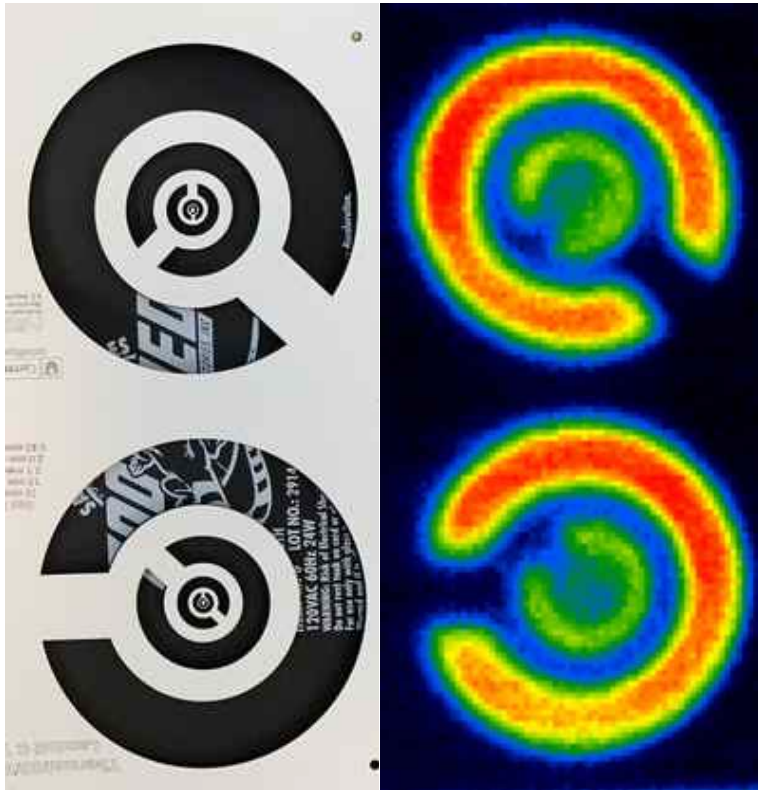
Evaluate Sensors

Precise Distance to Targets

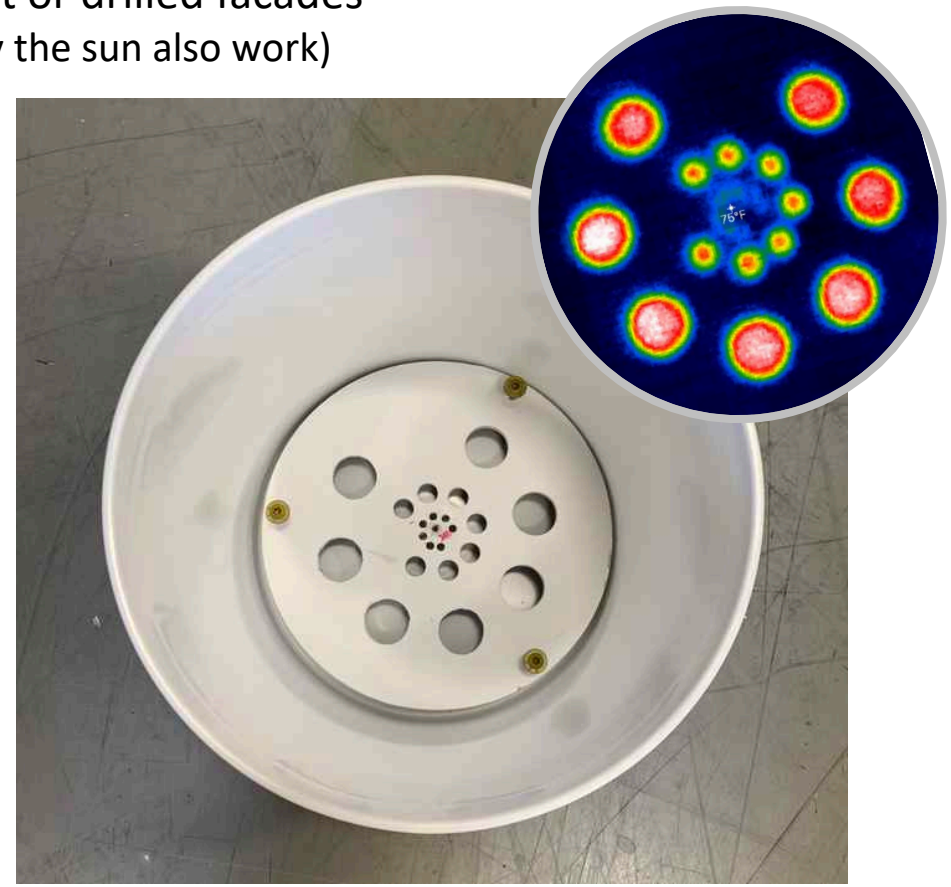
Heated reptile pads or hand warmers behind laser cut or drilled facades
(Indoor or outdoor use – typical sticker targets warmed by the sun also work)



An array of Concentric C thermal targets placed throughout a scenario (needs power).



Concentric Cs laser cut into MDF with a reptile heater. A metal backing helps diffuse the heat.

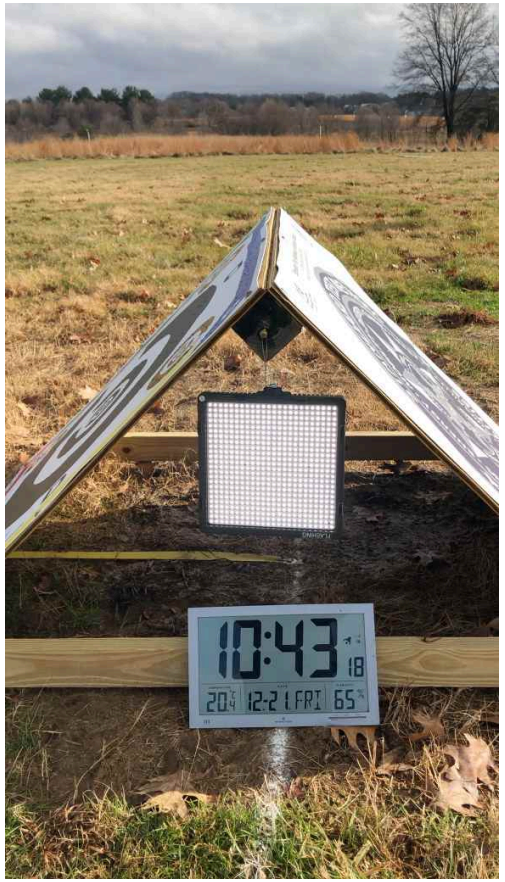


Drill Holes (1in, 1/2in, 1/4in) through plastic disks with hand warmers heating a metal disk backing.

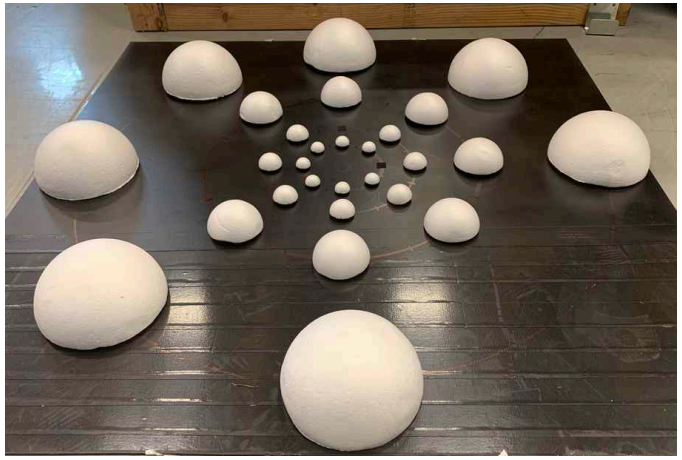
Evaluate Latency, Radio Comms Degradation, 3D Mapping

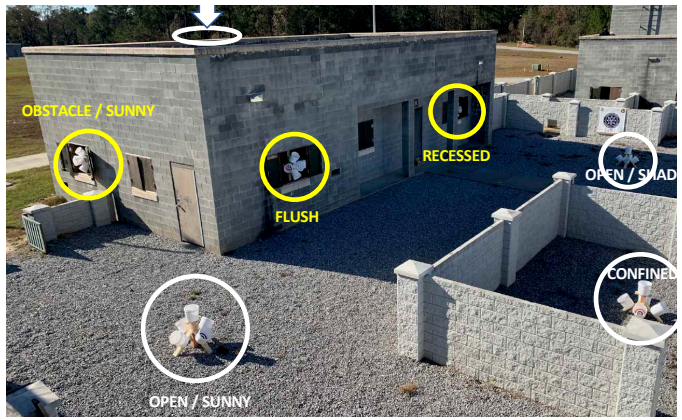
Repeatable Tasks Embedded Into Various Environments

Latency test with flashing “SOS” beacon or other light
(High speed phone camera video captures field and display views simultaneously)



3D Range Imager (LIDAR/LADAR)
Resolution and Mapping



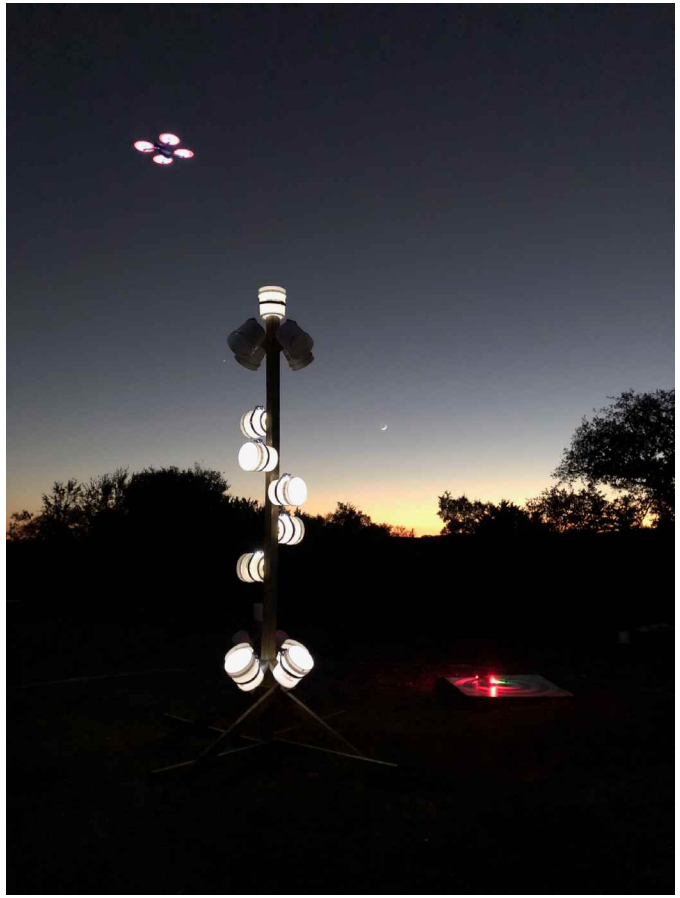


Evaluate Night Operations

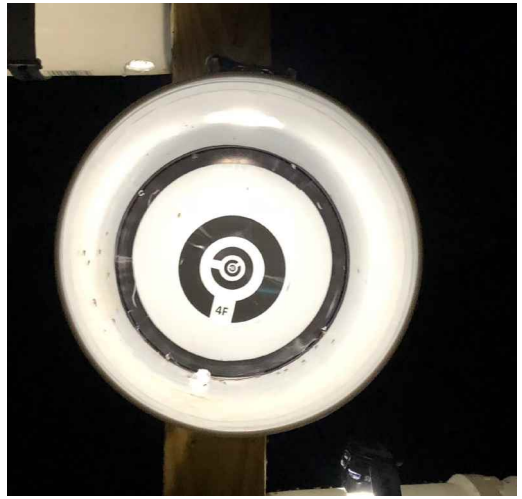
Precise Distance to Targets

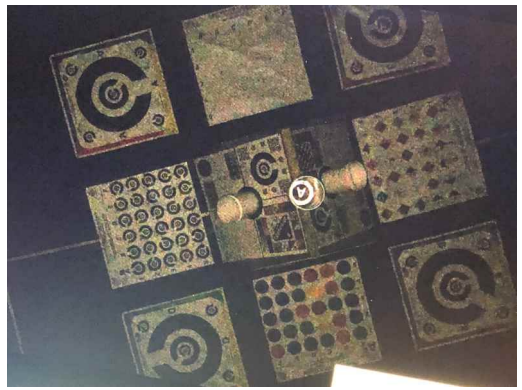
WHITE OR RED HEADLAMPS
WRAPPED AROUND BUCKETS POINTED INWARD

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

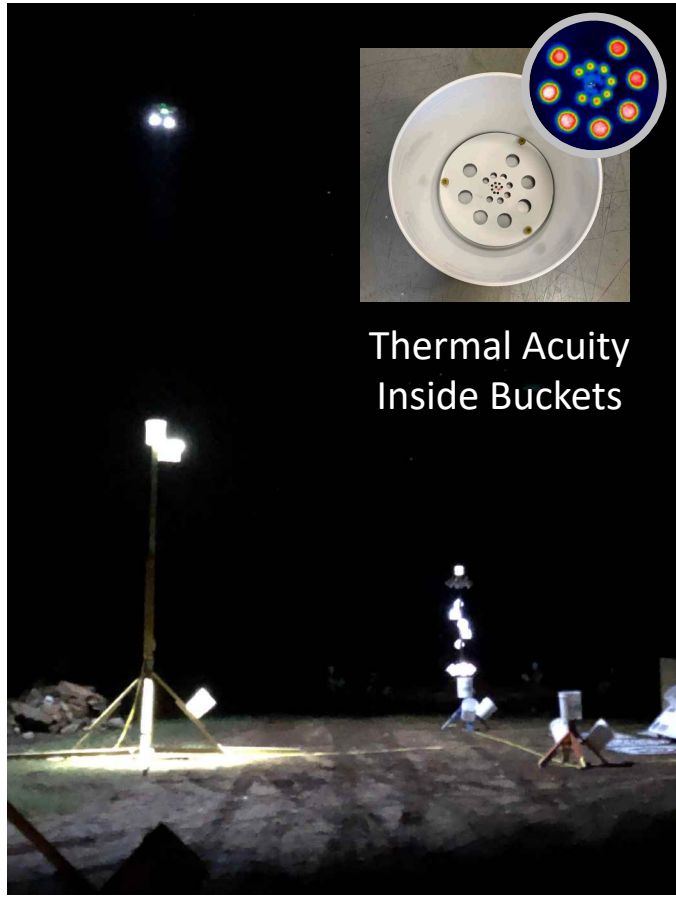


Inspect objects of interest using lighted buckets (red or white)





Identify objects lighted from the aircraft



Measure additional sensor capabilities

Compare Repeatable Scenarios

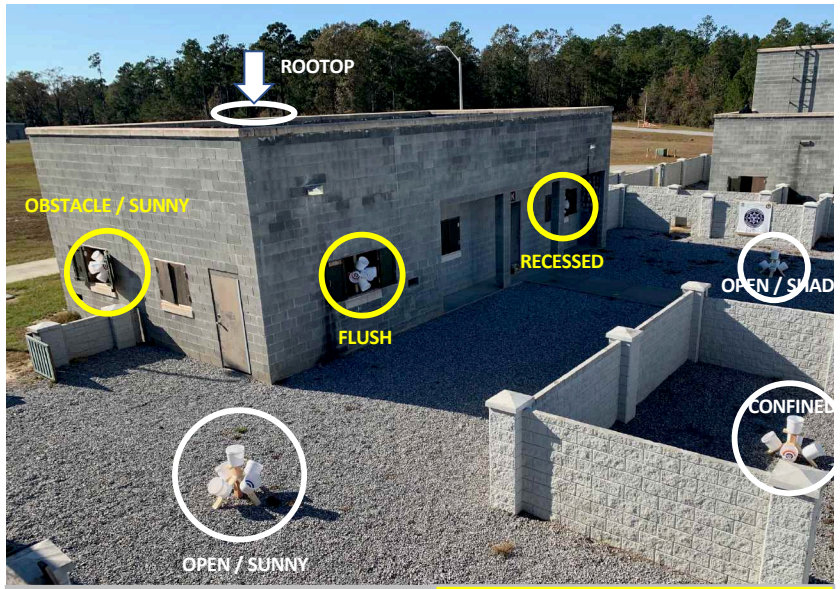
Focus Training and Evaluate Proficiency for Credentialing

20 OMNI TARGETS = 100 PTS

WIDE AREA SEARCH

20 EXTERIOR/INTERIOR = 100 PTS

VEHICLE INSPECTION



20 DOWNWARD | 20 FORWARD

BUILDING EXTERIOR SEARCH

Simple Rules for Comparing Scores

Focus Training and Evaluate Proficiency for Credentialing

- Compare scores for similar aircraft in the same size lanes or embedded scenarios
  Use ALL tests and scenarios that apply to that aircraft or to the intended missions.

- Compare scores with the same trial times
  Trial time limits for MAN = 5 minutes and PAY = 10 minutes to help normalize fatigue across several tests, so novices don't get worn out unnecessarily. They provide enough time for an "expert" to perform a complete trial with 20 tasks. Longer times can be used for scenarios with embedded test apparatuses.

- Compare scores to "average" or "best-in-class" pilots across organizations or regions
  - "Expert" pilots designated by the manufacturer are used to capture the system's best possible performance in each test. Those scores are considered the 100th percentile of remote pilot proficiency for that system. Your score is some percentage of that "expert" score (1-100%).
  - For training, use the entire time limit and track your scores. When they become repeatable, your learning phase is over. The best indicator of your proficiency in each test is the average of your last 5 trials.
  - We will post "average" and "expert" scores and rates for each aircraft in each test as we collect them.

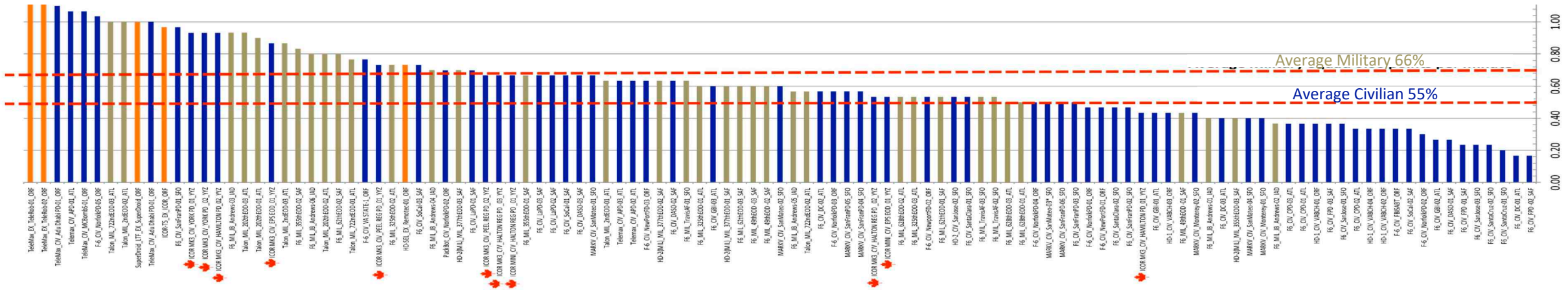
Set Your Minimum Thresholds for Pass/Fail

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 airspace restrictions, environmental variables, and mission complexity (night ops, BVLOS, etc.) to select a pilot and aircraft that’s likely to succeed.



Example proficiency data shown from bomb squads in ground robot tests

Supporting NFPA 2400 and ASTM F38 Practical Skills Requirements

Focus Training and Evaluate Proficiency for Credentialing

"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 Measures

Possible Examples

80-100% ◆ ← Organization or Mission "A" Pass/Fail
(maybe populated, obstructed area, windy, night, etc.)

60-79% ■ ← Organization or Mission "B" Pass/Fail
(maybe populated, open area, windy, daytime, etc.)

40-59% ● ← Organization or Mission "C" Pass/Fail
(maybe rural, open area, calm, daytime, etc.)

20-39% ○

Thresholds Set By Any Organization

Based on Airspace, Mission Complexity, Environment, etc.)

Select Trial Settings for Different Flight Credentials

Focus Training and Evaluate Proficiency for Credentialing

DAYLIGHT / LOS

1) Select the test lane and scenarios based on the intended environment and aircraft capabilities:
   – **Open, Obstructed, or Indoor**

2) Select the test procedure and time limit based on the intended mission:
   – **MAN (5 min. each) or PAY (10 min. each)**

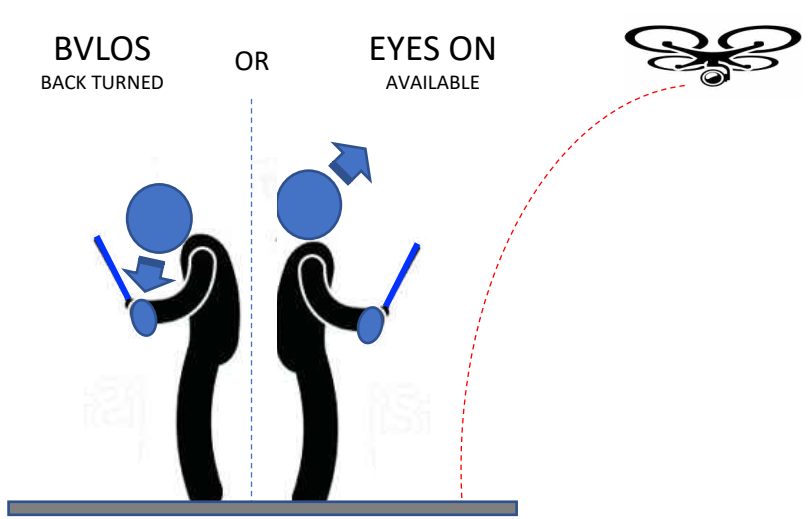
3) Select the minimum proficiency based on average or "expert" scores in the same trials:
   – **Example: 40%, 60%, 80% of "expert"**

ADDITIONAL

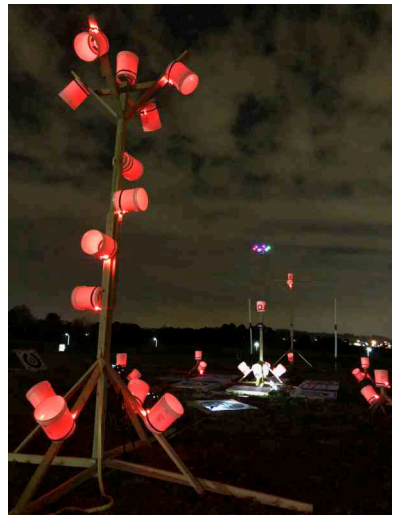
4) Select pilot view for BVLOS credentials:
   – **Eyes On or BVLOS**

5) Select lighting (indoor or outdoor) for daylight or night credentials:
   – **Lighted/Daylight or Dark**

CREDENTIALS	Daylight/LOS	BVLOS	Night Ops
Standard Lane (Indoor or Outdoor)	Pilot's Eyes On (Available)	Pilot's Back Turned (Interface Only)	Lights Out, Buckets Lit
Embedded Scenario (Indoor or Outdoor)	Pilot's Eyes On (Available)	Pilot's Back Turned (Interface Only)	Lights Out, Buckets Lit



THE PILOT'S BACK TURNED TO THE LANE FORCES RELIANCE ON THE INTERFACE (VISUAL OBSERVER REQUIRED)



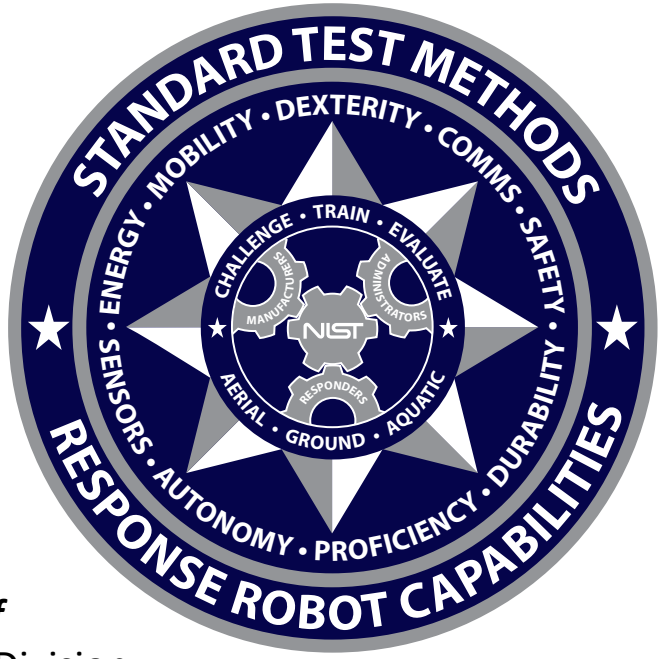
ILLUMINATED BUCKETS PROVIDE POSITIONING AIDS LIKE STRUCTURE WINDOWS OR STREET LIGHTS

Open Test Lane and Embedded Scenarios

Usage Overview

VERSION 2020B

WEBSITE POINTER:
DOWNLOAD STICKER FILES, FORMS AND
PRACTICE SCORING VIDEOS



WEBSITE POINTER:
WATCH FABRICATION VIDEOS
AND FLIGHT PATH ANIMATIONS

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

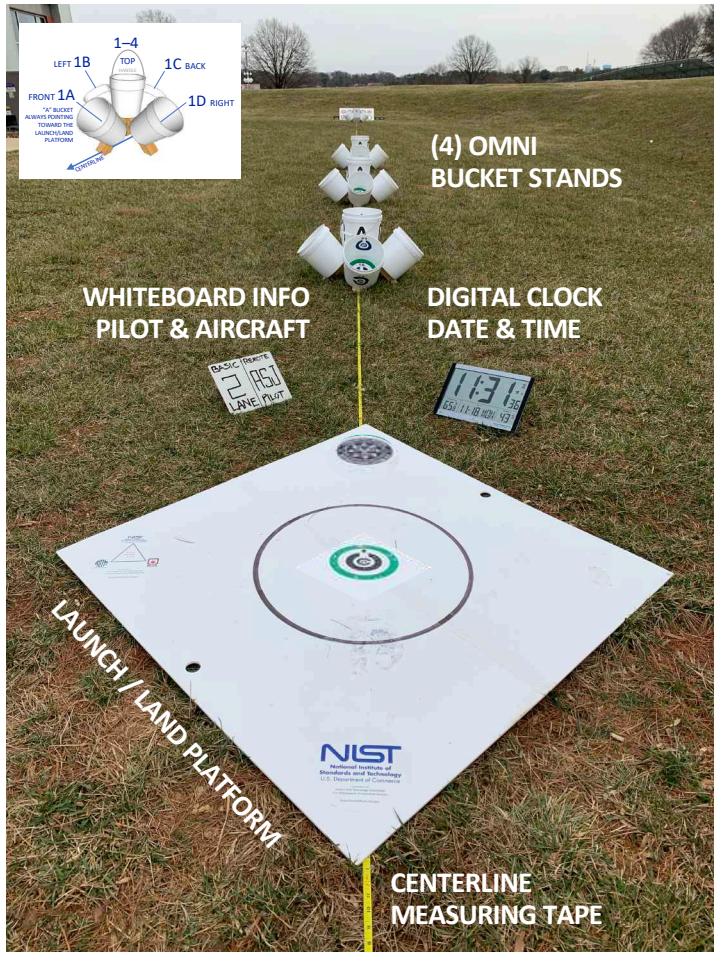
Sponsor:
Phil Mattson
Science and Technology Directorate
U.S. Department of Homeland Security

Internet
RobotTestMethods.nist.gov

Email
RobotTestMethods@nist.gov

Open Test Lane

Safety | Capabilities | Proficiency



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)

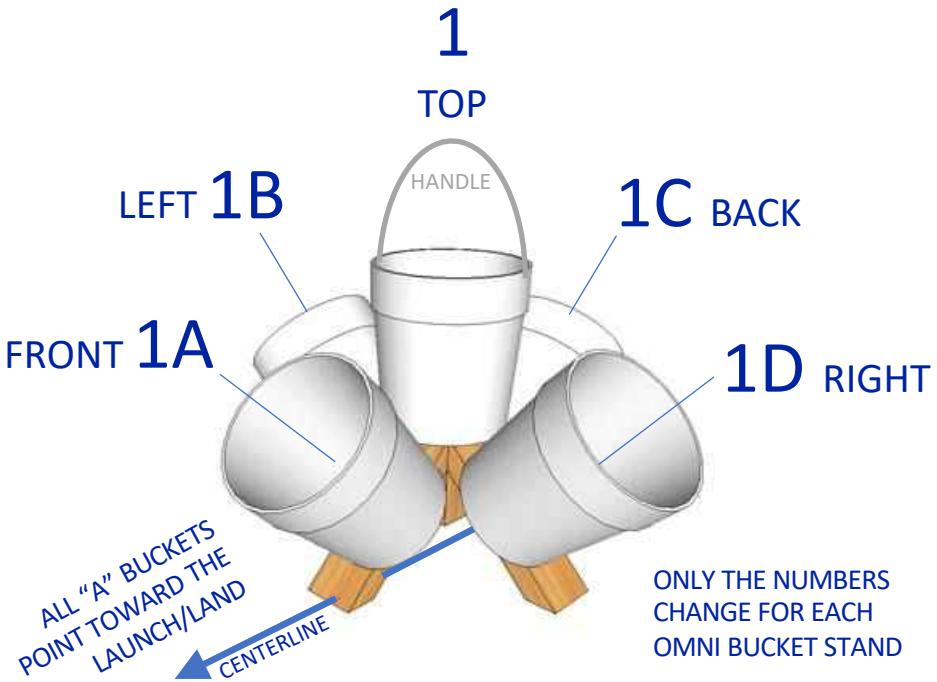
- Designated hover altitudes are scalable to the optics of the drone.
- Altitudes are equal to the ground distance between bucket stands.
- Move the bucket stands apart to any Spacing (S) to scale the entire lane.
- Supports several different flight paths.

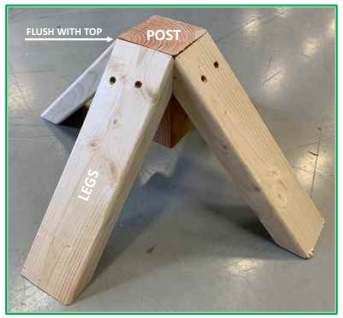
Omni-Directional Bucket Stands

Open Test Lane

WHITE BUCKETS & GREEN RINGS IN STANDARD TEST LANES

SHOWN NOT ALIGNED





BLACK BUCKETS & COLOR RINGS EMBEDDED INTO SCENARIOS

SHOWN ALIGNED

Bucket Alignments Define Points of View

Open Test Lane

COMPLETE GREEN RING

ALIGNED (PERFECTLY)

PARTIAL GREEN RING

ALIGNED (BARELY)

BROKEN GREEN RING

NOT ALIGNED

Visual Acuity Targets

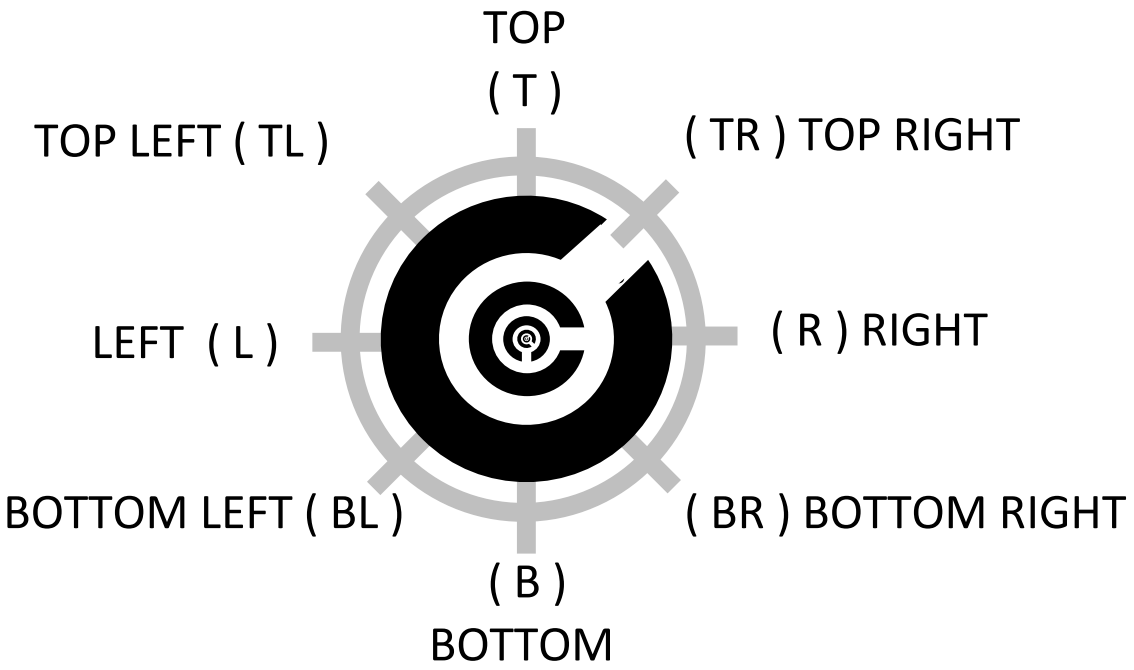
Open Test Lane

ALIGN THE GREEN OR COLORED RING FIRST

Then Read the "Concentric C" Gap Directions

"CONCENTRIC C" GAP DIRECTIONS

5 Increasingly Small Sizes (1 point each)



Conduct Tests Two Ways

Open Test Lane

Basic Maneuvering (MAN)

ALIGN WITH BUCKETS

Align with the 20 designated buckets long enough to capture a single image (**NO ZOOM**) showing a continuous green ring inside each bucket. The numbers and letters are bucket identifiers.

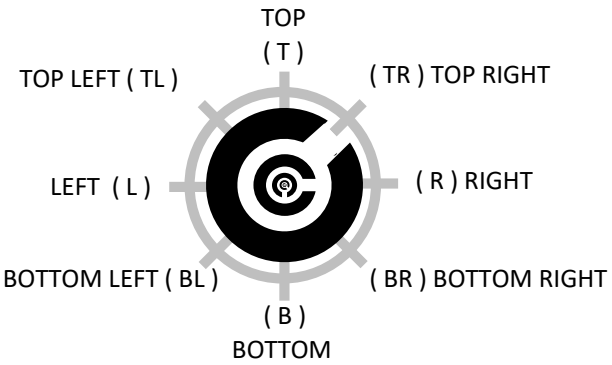
1 point per successfully aligned image
SCORE UP TO 20 POINTS

Payload Functionality (PAY)

ALIGN AND IDENTIFY TARGETS

Align with the 20 designated buckets long enough to capture a single image (**FULL ZOOM**) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep.

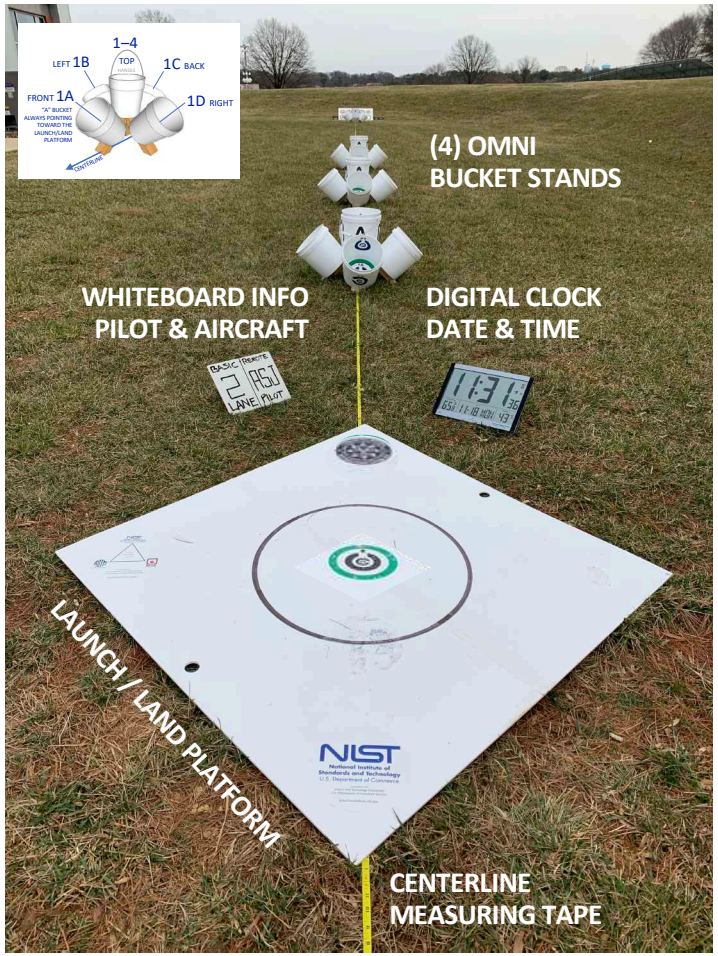
1 point per correct gap shown in the image
SCORE UP TO 100 POINTS

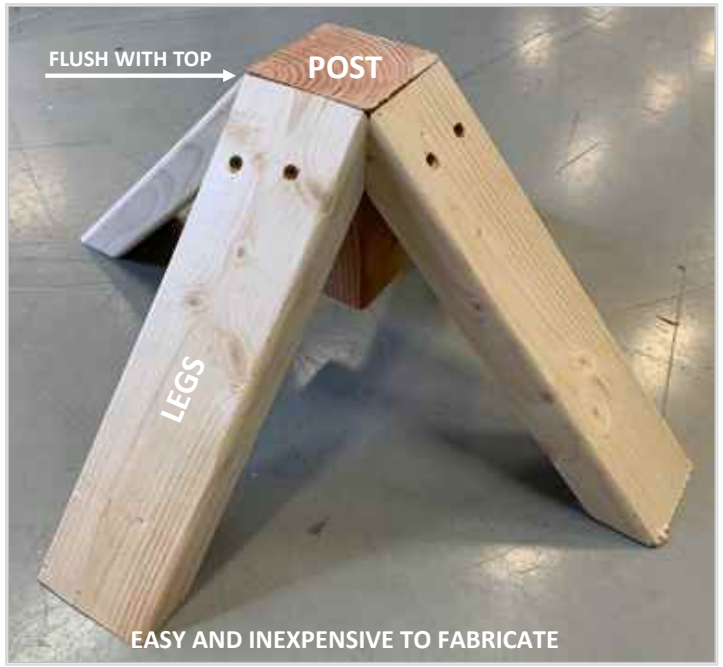


Easy Fabrication

Open Test Lane

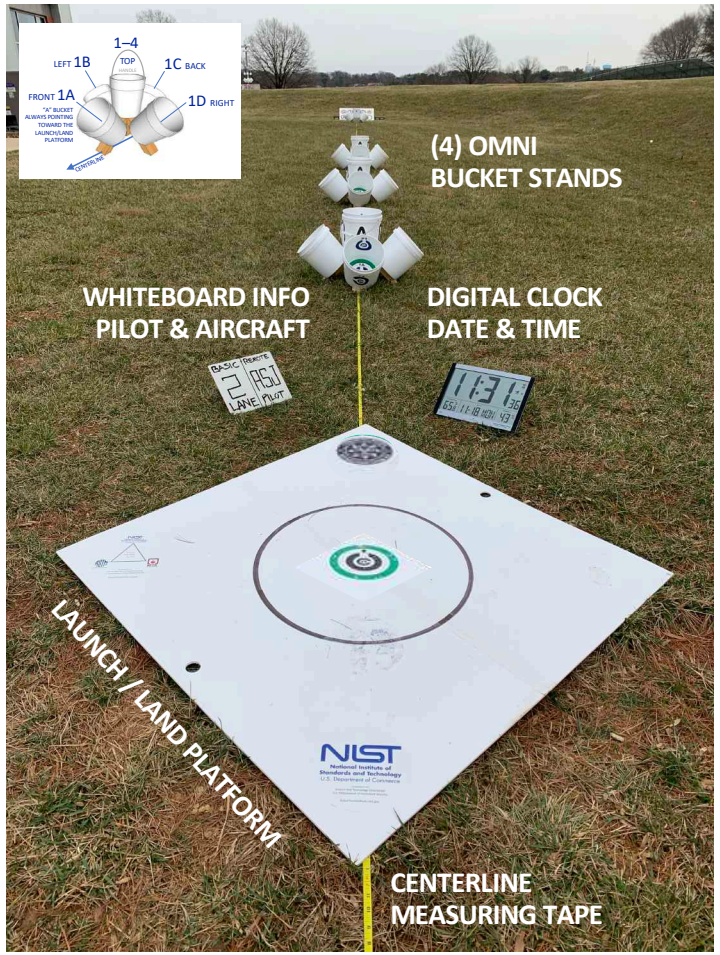
2 Gallon Buckets – Printed Stickers – Stowable and Transportable



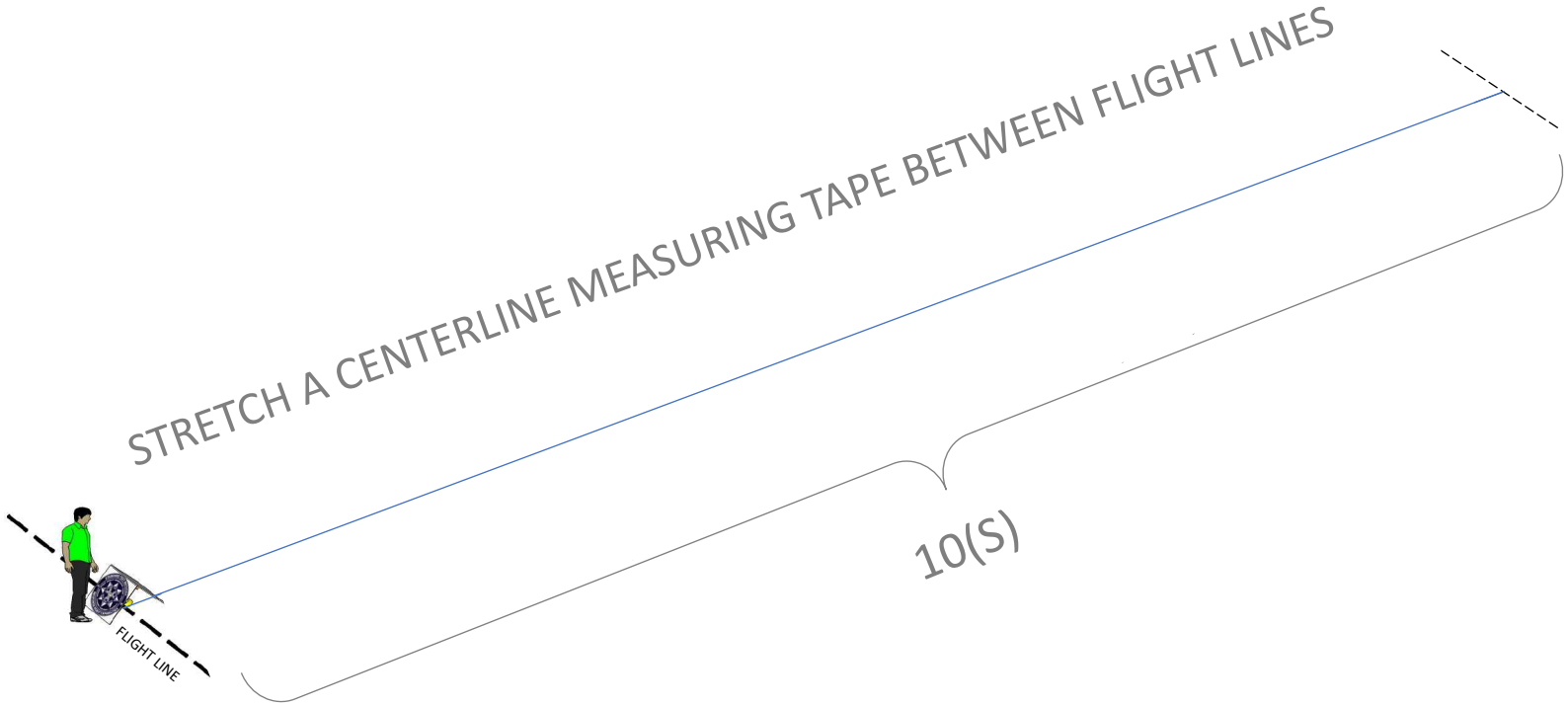


Easy Set Up – Step 1

Open Test Lane

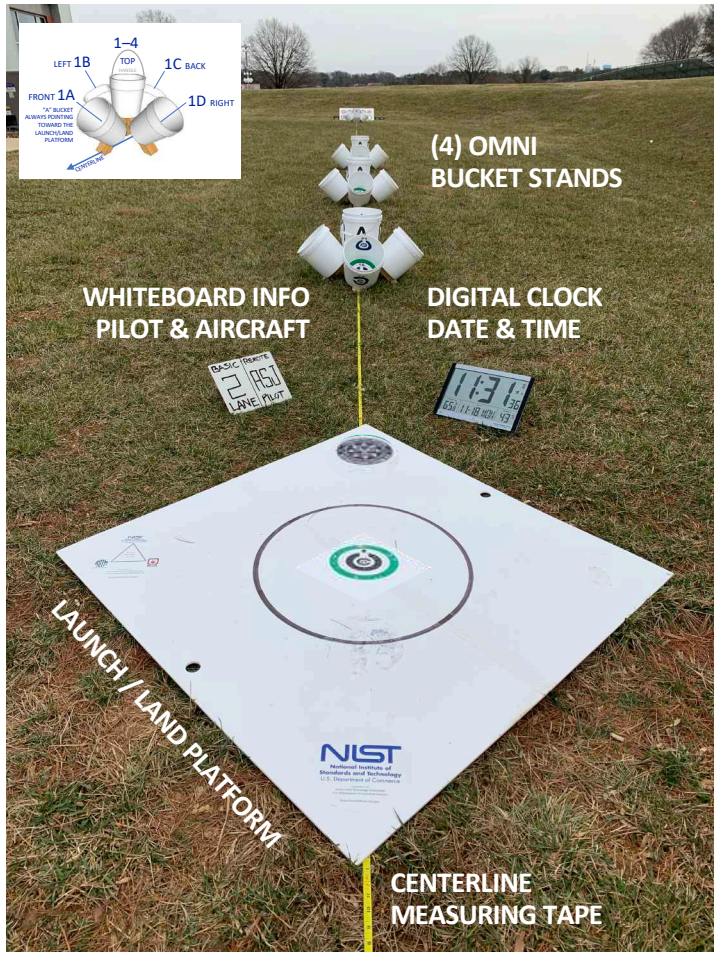


SPACING = S	ALTITUDES = S, 2(S), 5(S)	LENGTH = 10(S)
S = 3 m (10 ft)	3, 6, 15 m (10, 20, 50 ft)	30 m (100 ft)
S = 6 m (20 ft)	6, 12, 30 m (20, 40, 100 ft)	60 m (200 ft)
S = 9 m (30 ft)	9, 18, 45 m (30, 60, 150 ft)	90 m (300 ft)

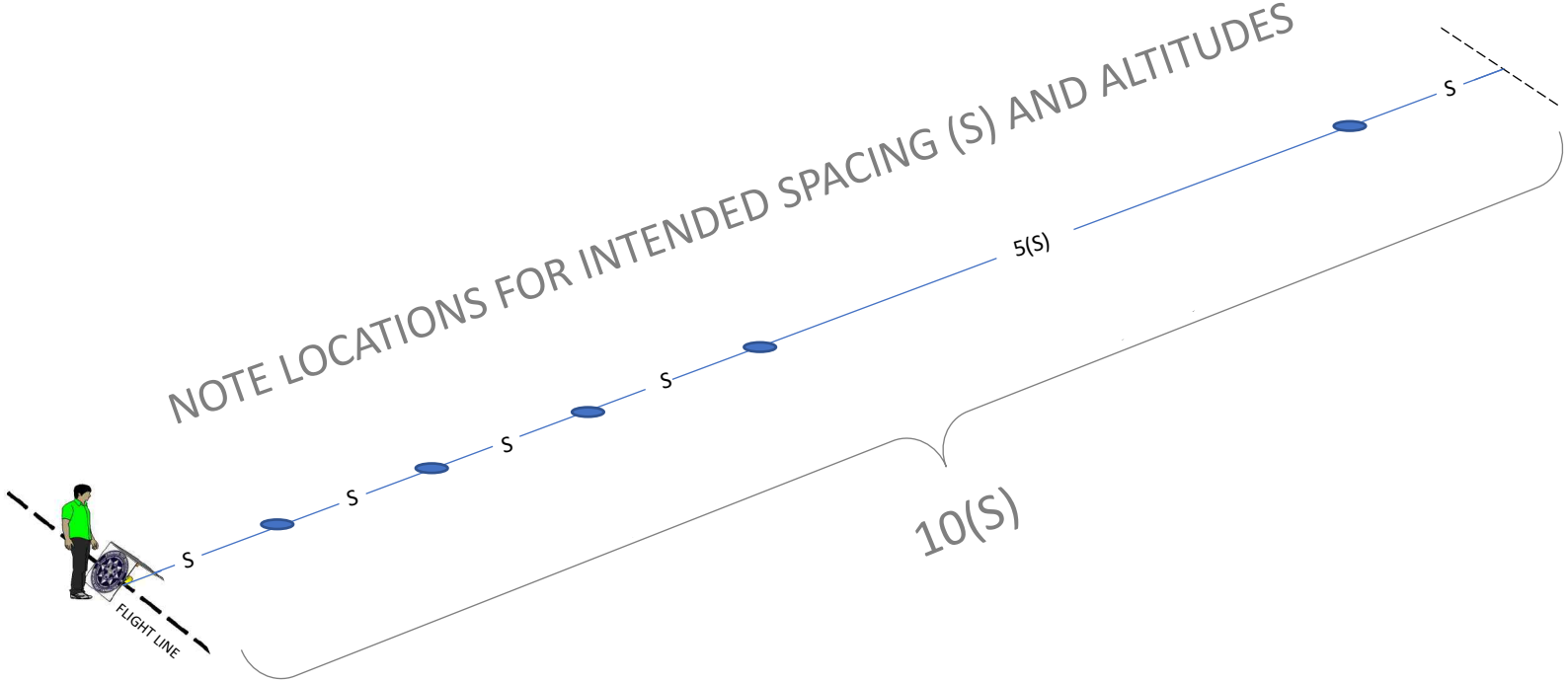


Easy Set Up – Step 2

Open Test Lane

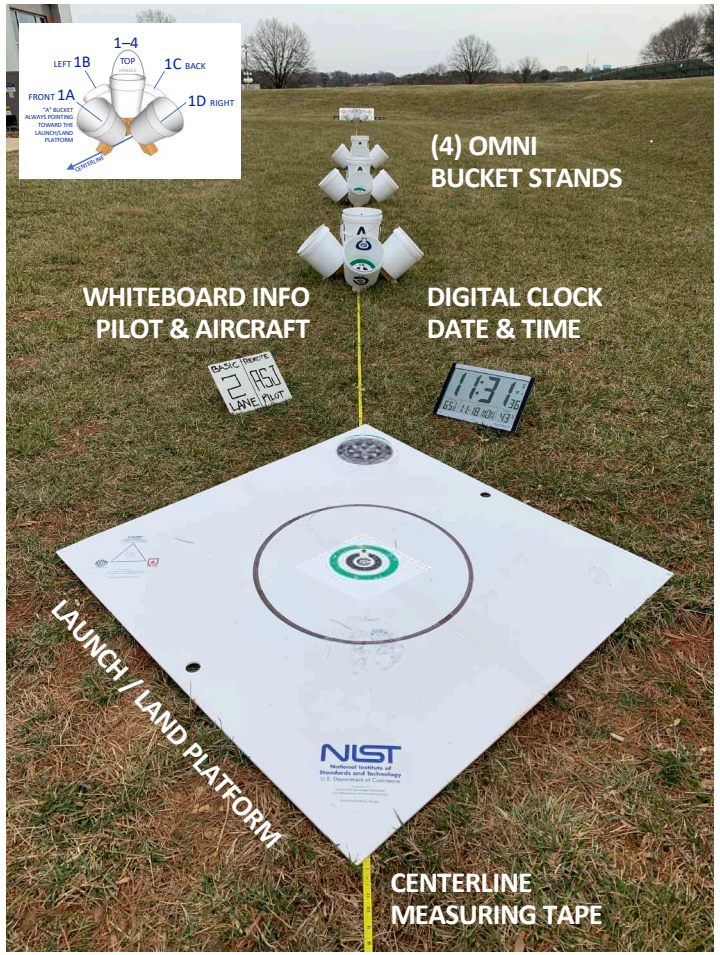


SPACING = S	ALTITUDES = S, 2(S), 5(S)	LENGTH = 10(S)
S = 3 m (10 ft)	3, 6, 15 m (10, 20, 50 ft)	30 m (100 ft)
S = 6 m (20 ft)	6, 12, 30 m (20, 40, 100 ft)	60 m (200 ft)
S = 9 m (30 ft)	9, 18, 45 m (30, 60, 150 ft)	90 m (300 ft)

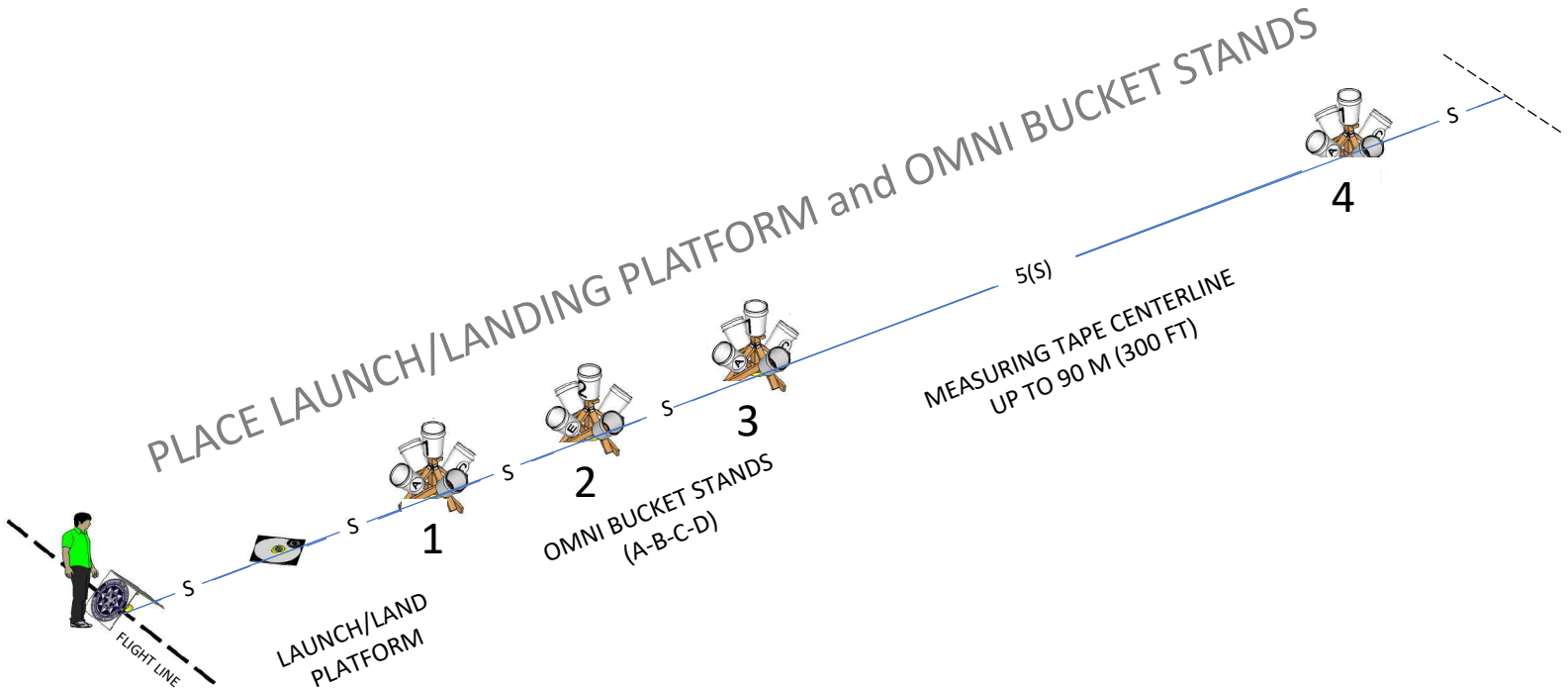


Easy Set Up – Step 3

Open Test Lane

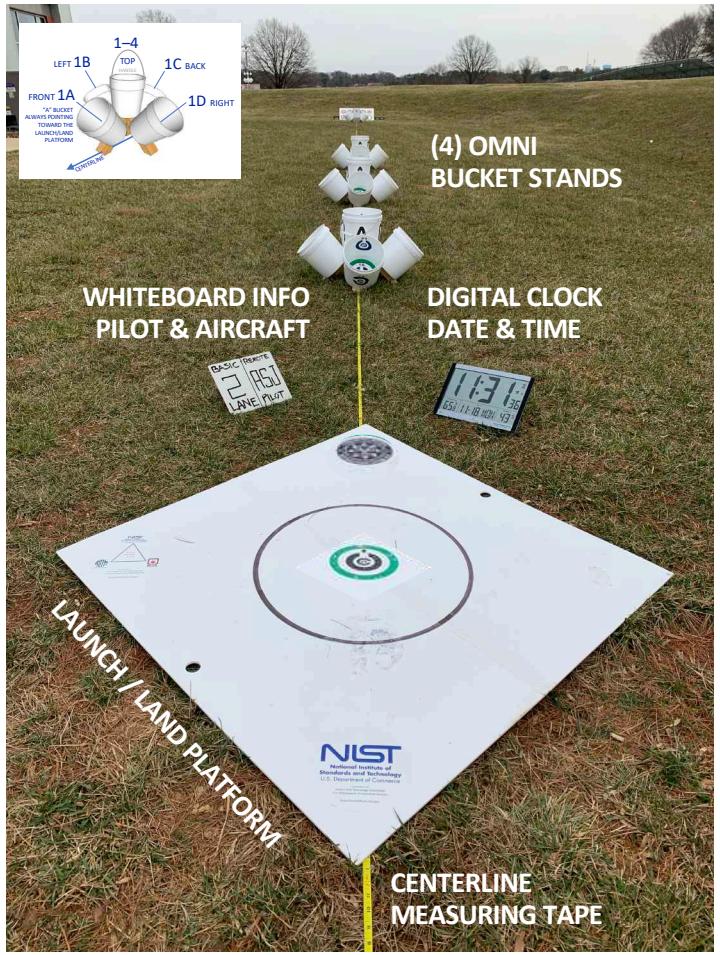


SPACING = S	ALTITUDES = S, 2(S), 5(S)	LENGTH = 10(S)
S = 3 m (10 ft)	3, 6, 15 m (10, 20, 50 ft)	30 m (100 ft)
S = 6 m (20 ft)	6, 12, 30 m (20, 40, 100 ft)	60 m (200 ft)
S = 9 m (30 ft)	9, 18, 45 m (30, 60, 150 ft)	90 m (300 ft)



Align To Buckets

Open Test Lane



SPACING = S	ALTITUDES = S, 2(S), 5(S)	LENGTH = 10(S)
S = 3 m (10 ft)	3, 6, 15 m (10, 20, 50 ft)	30 m (100 ft)
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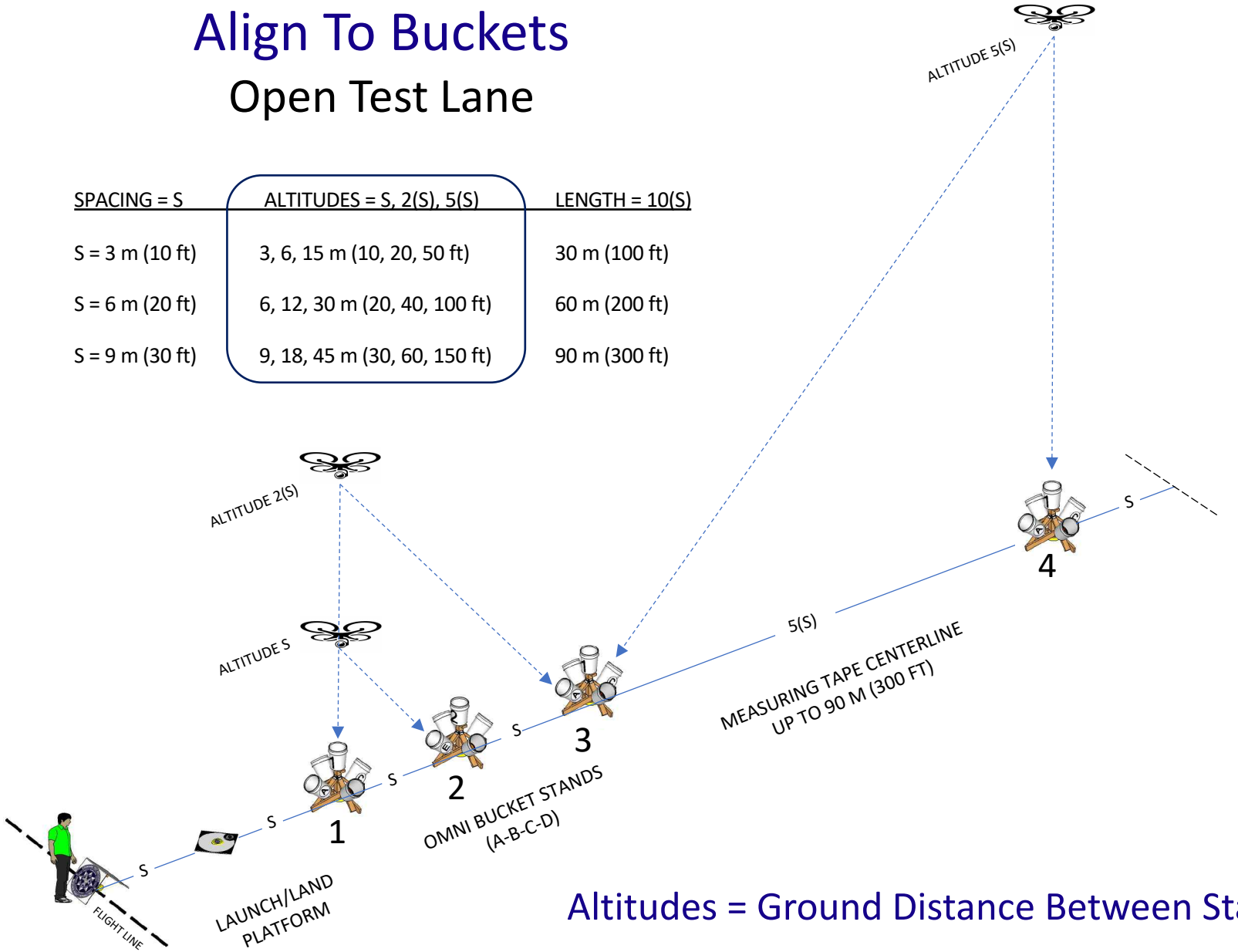
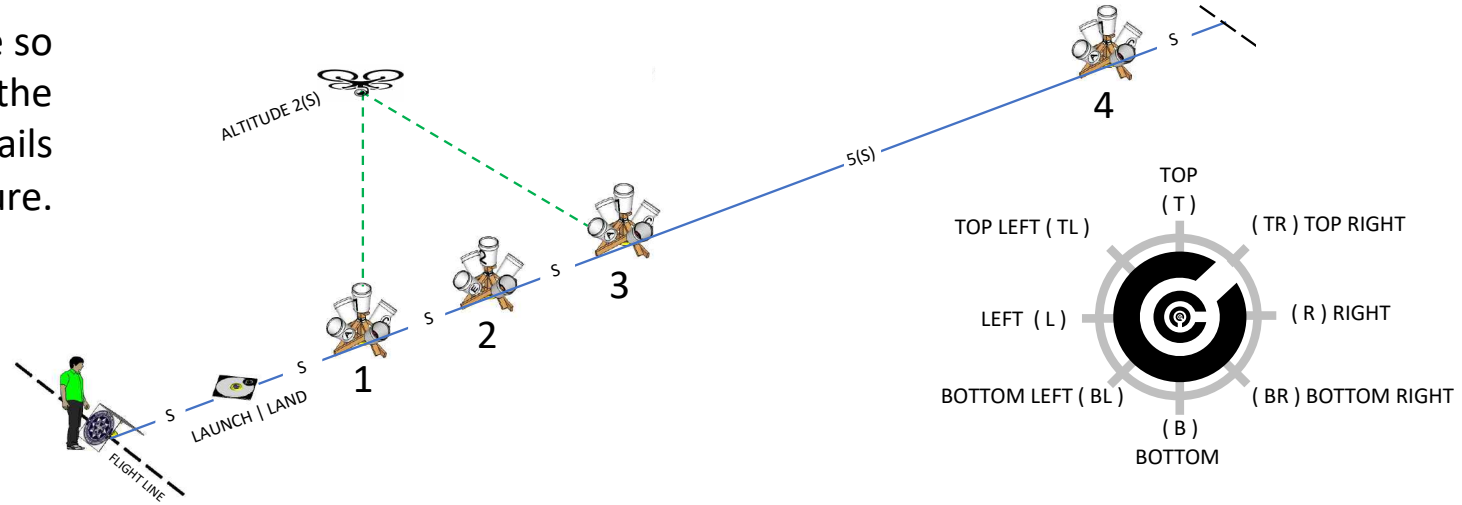


Altitudes = Ground Distance Between Stands

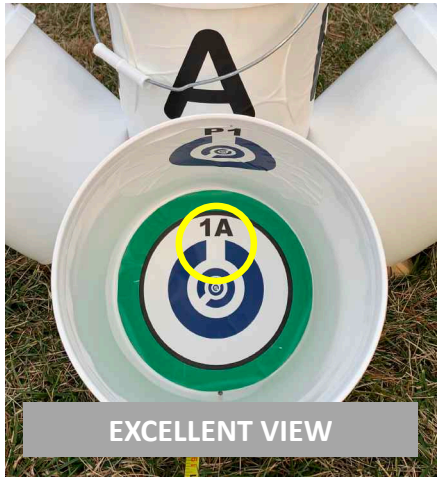
Choose Lane Spacing for Onboard Cameras

Open Test Lane

Alignments should be so obvious that a quick look at the captured image thumbnails show success or failure.

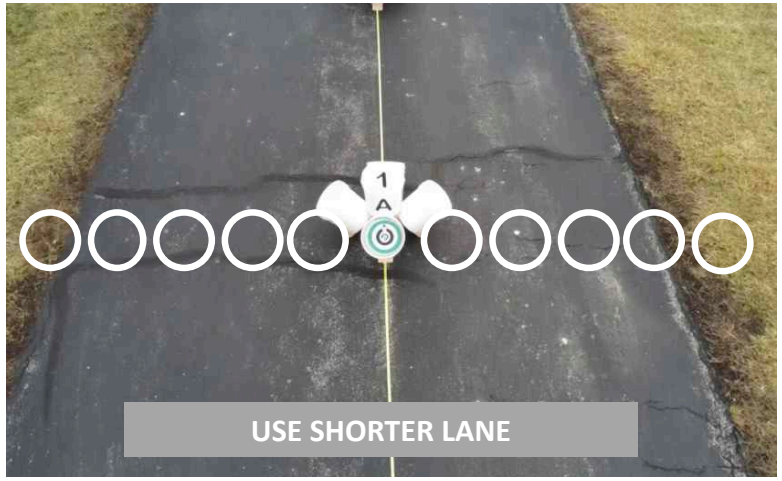


An appropriate lane spacing is when a 2(S) hover allows reading at least the outer concentric C target two stands away.



EXCELLENT VIEW

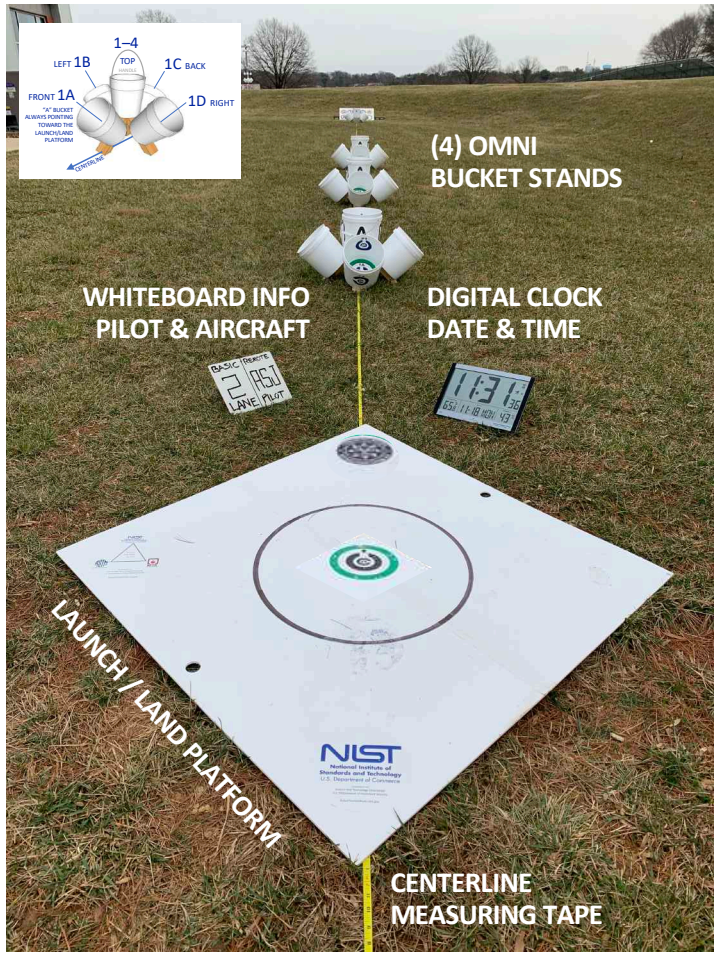
OKAY VIEW



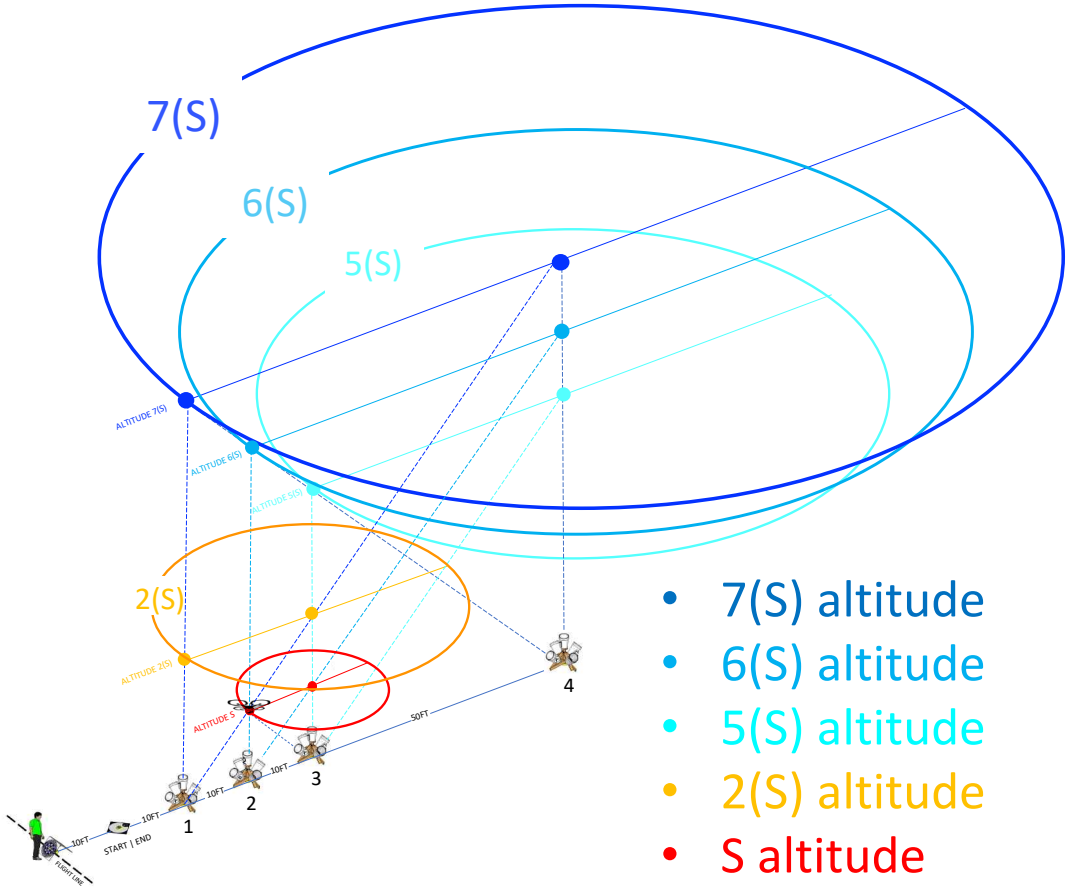
USE SHORTER LANE

Evaluate Various Flight Paths and Sensors

Open Test Lane

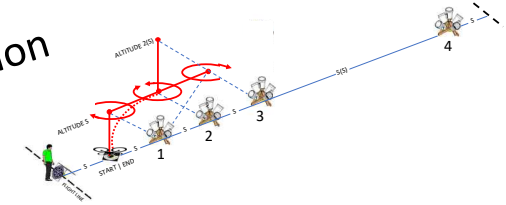


5 Different Orbits in Every Lane Spacing
(S) = 10ft, 20ft, 30ft, or other

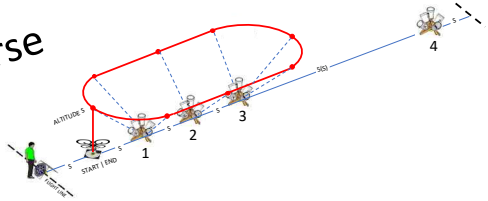


- 7(S) altitude
- 6(S) altitude
- 5(S) altitude
- 2(S) altitude
- S altitude

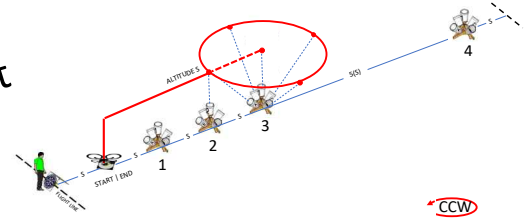
Position



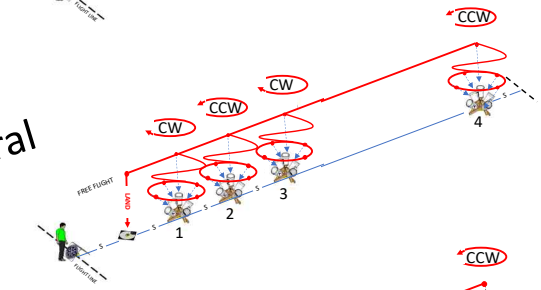
Traverse



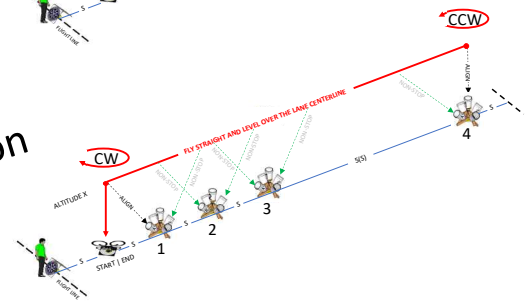
Orbit



Spiral



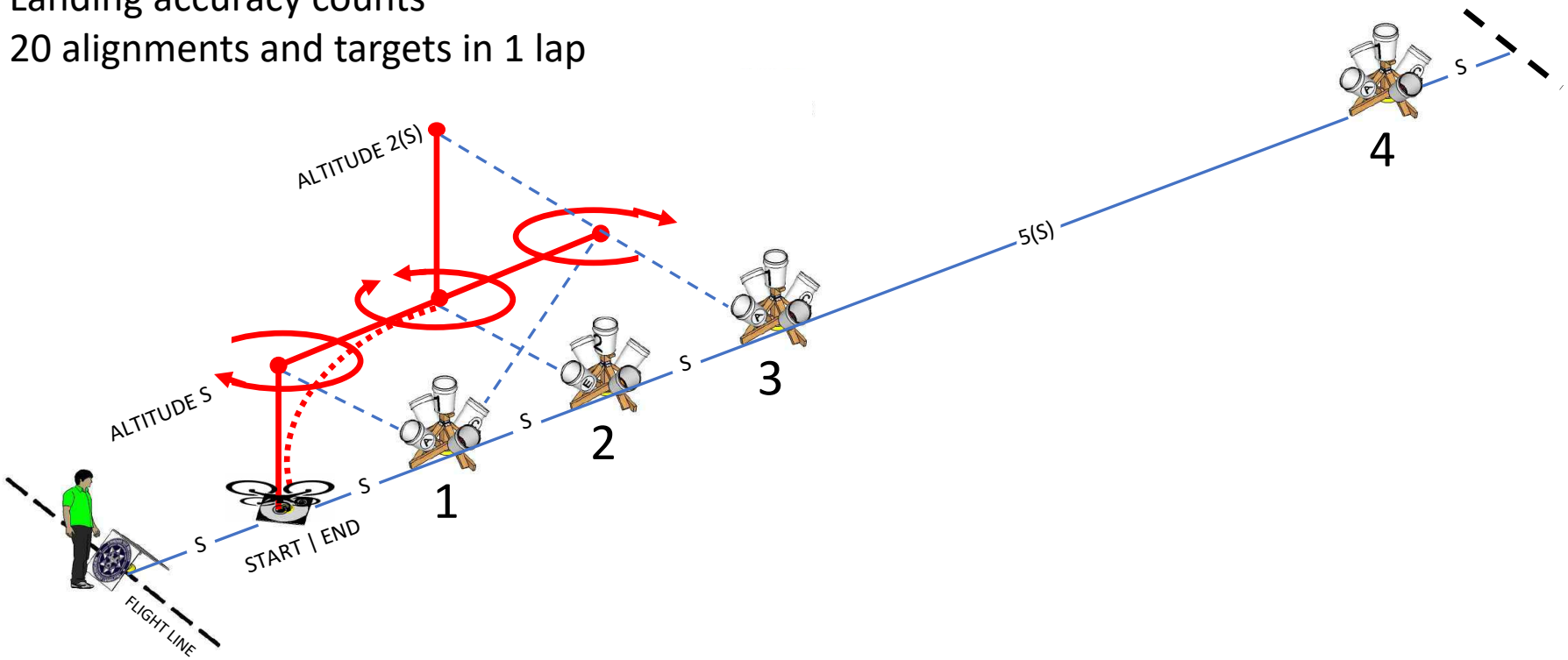
Recon



Position Test

MAN/PAY 1

- Hover stably in designated positions and orientations
- Align with two buckets simultaneously at each position
- Basic maneuvers between positions
- Altitude S and 2(S)
- Landing accuracy counts
- 20 alignments and targets in 1 lap



ALIGNED ALIGNED **NOT** ALIGNED

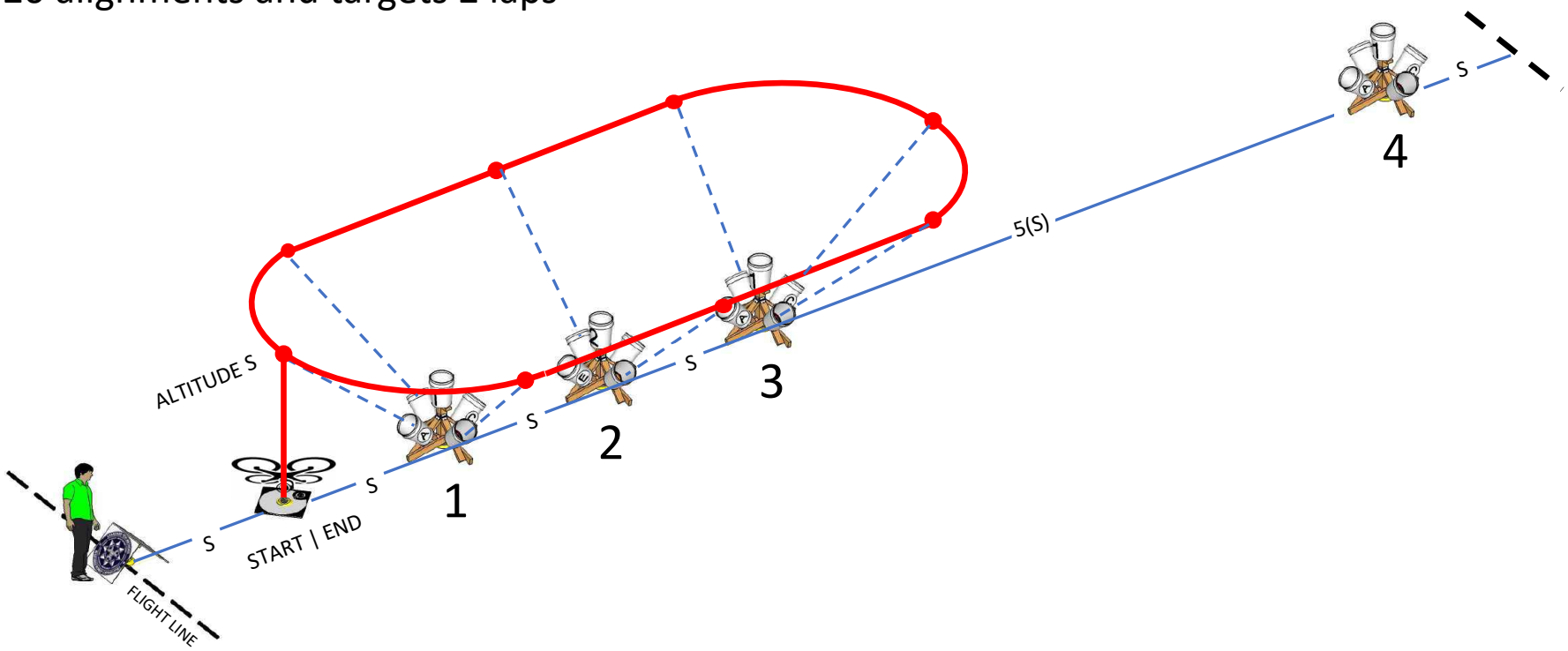
MAN 1-5 BASIC MANEUVERING
ALIGN WITH BUCKETS
Align with 20 buckets long enough to capture a single image (NO ZOOM) showing a continuous green ring inside to determine successful alignment. The numbers/letters are bucket identifiers.

PAY 1-5 PAYLOAD FUNCTIONALITY
IDENTIFY VISUAL ACUITY TARGETS
Align with 20 buckets long enough to capture a single image (FULL ZOOM) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep in 8 different orientations.

Traverse Test

MAN/PAY 2

- Fly sideways along a line or object
- Leftward and rightward directions to align with angled buckets
- Altitude S throughout
- Landing accuracy counts
- 20 alignments and targets 2 laps



ALIGNED ALIGNED **NOT** ALIGNED

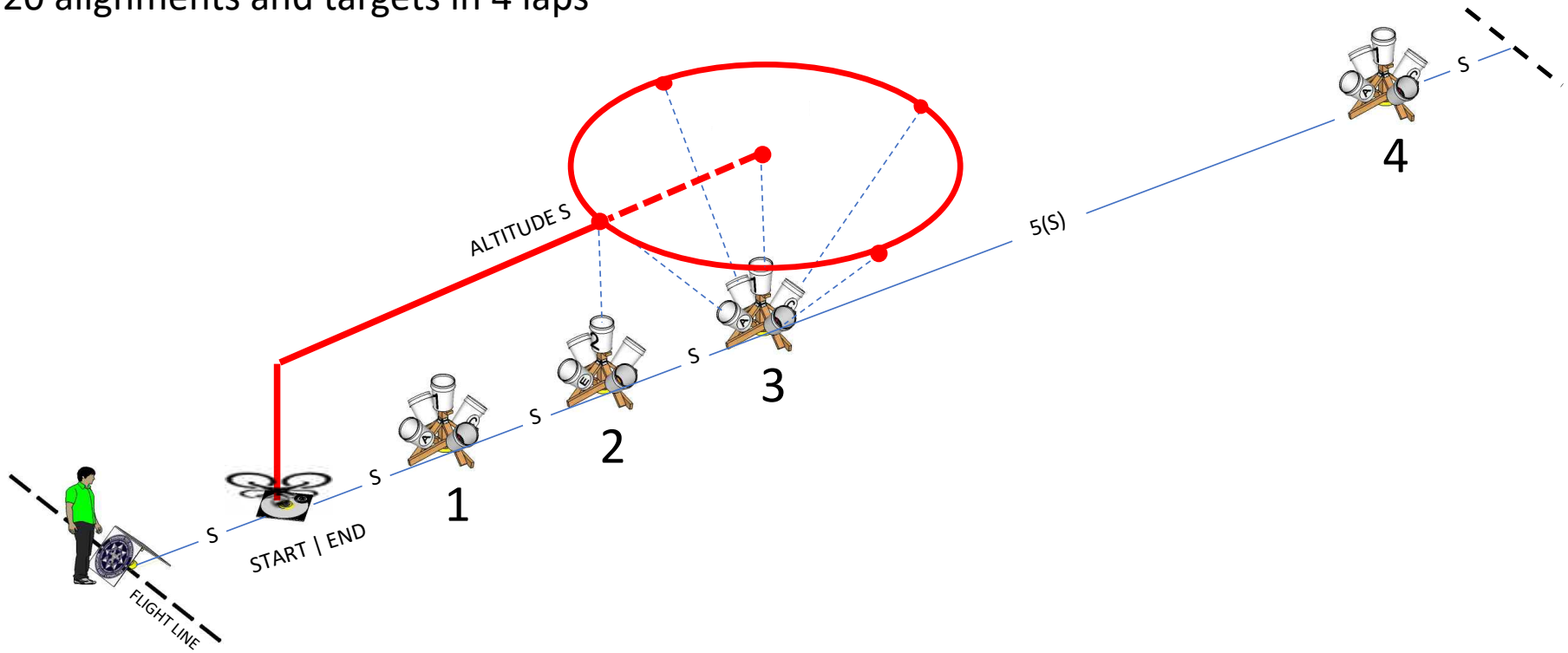
MAN 1-5 BASIC MANEUVERING
ALIGN WITH BUCKETS
Align with 20 buckets long enough to capture a single image (NO ZOOM) showing a continuous green ring inside to determine successful alignment. The numbers/letters are bucket identifiers.

PAY 1-5 PAYLOAD FUNCTIONALITY
IDENTIFY VISUAL ACUITY TARGETS
Align with 20 buckets long enough to capture a single image (FULL ZOOM) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep in 8 different orientations.

Orbit Test

MAN/PAY 3

- Orbit around a designated point
- Leftward and rightward directions to align with angled buckets
- Downward radius checks at start of each orbit
- Altitude S throughout
- 20 alignments and targets in 4 laps



ALIGNED ALIGNED **NOT** ALIGNED

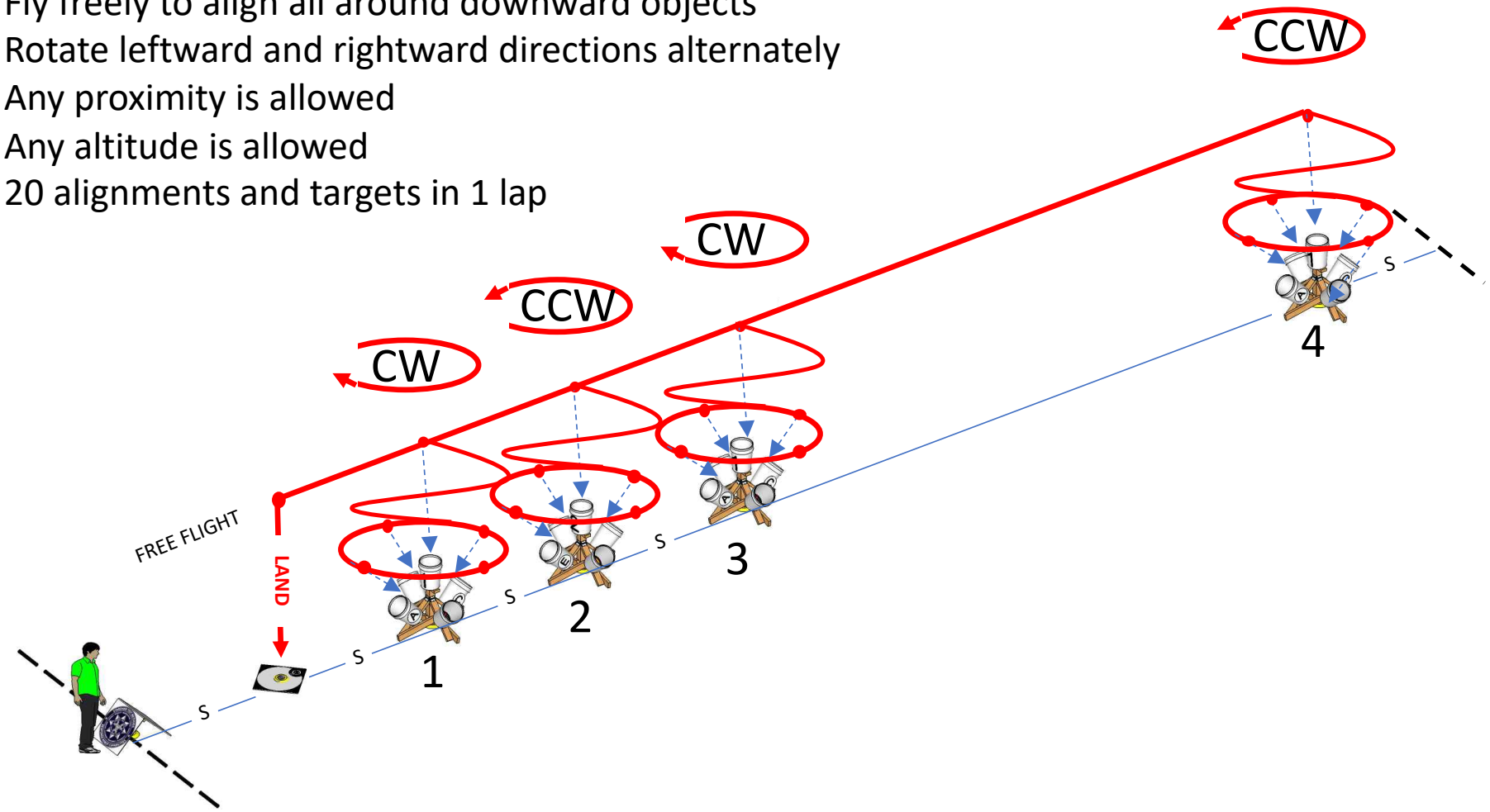
MAN 1-5 BASIC MANEUVERING
ALIGN WITH BUCKETS
Align with 20 buckets long enough to capture a single image (NO ZOOM) showing a continuous green ring inside to determine successful alignment. The numbers/letters are bucket identifiers.

PAY 1-5 PAYLOAD FUNCTIONALITY
IDENTIFY VISUAL ACUITY TARGETS
Align with 20 buckets long enough to capture a single image (FULL ZOOM) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep in 8 different orientations.

Spiral Test

MAN/PAY 4

- Fly freely to align all around downward objects
- Rotate leftward and rightward directions alternately
- Any proximity is allowed
- Any altitude is allowed
- 20 alignments and targets in 1 lap



ALIGNED ALIGNED **NOT** ALIGNED

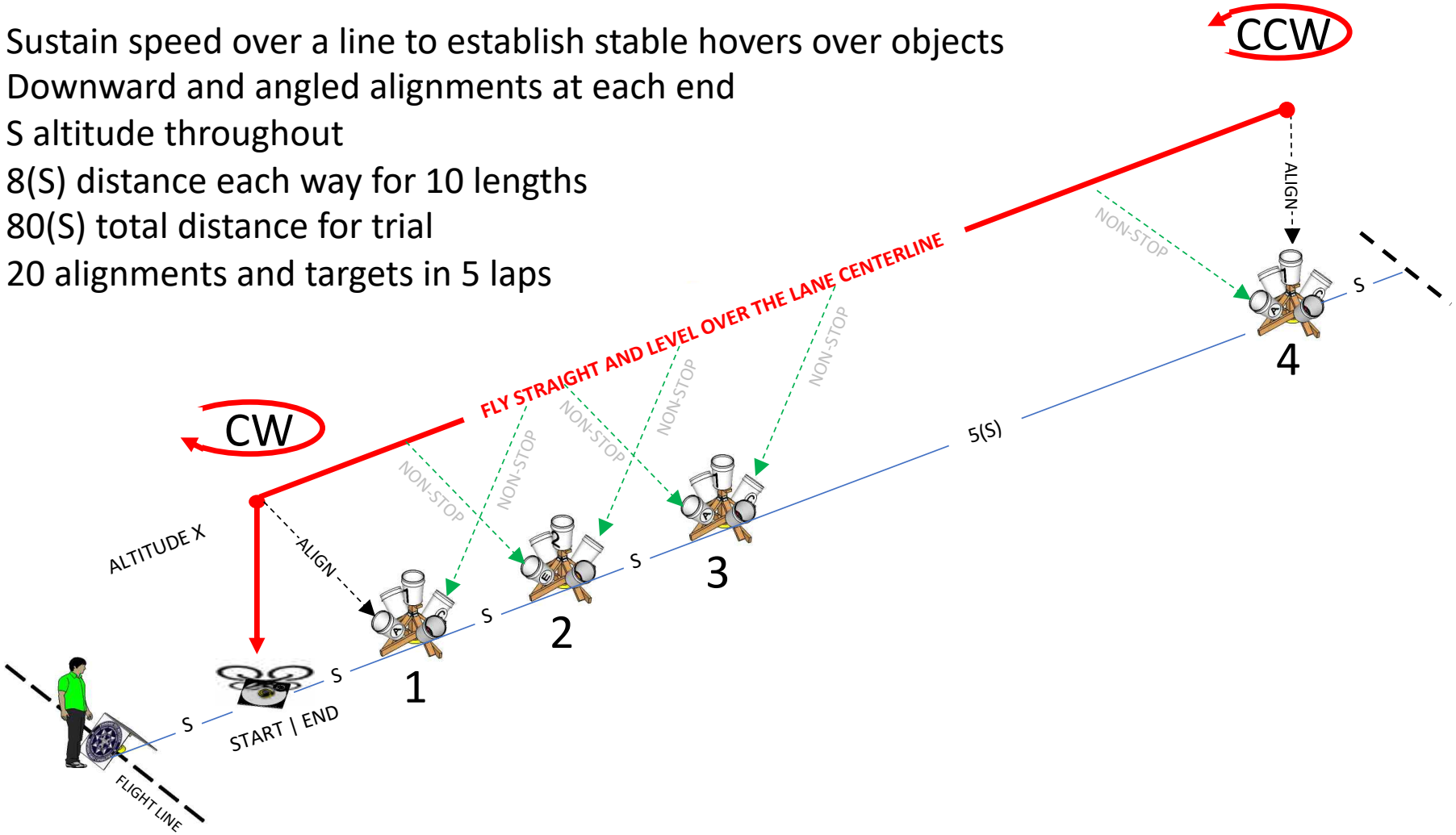
MAN 1-5 BASIC MANEUVERING
ALIGN WITH BUCKETS
Align with 20 buckets long enough to capture a single image (NO ZOOM) showing a continuous green ring inside to determine successful alignment. The numbers/letters are bucket identifiers.

PAY 1-5 PAYLOAD FUNCTIONALITY
IDENTIFY VISUAL ACUITY TARGETS
Align with 20 buckets long enough to capture a single image (FULL ZOOM) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep in 8 different orientations.

Recon Test

MAN/PAY 5

- Sustain speed over a line to establish stable hovers over objects
- Downward and angled alignments at each end
- S altitude throughout
- 8(S) distance each way for 10 lengths
- 80(S) total distance for trial
- 20 alignments and targets in 5 laps



ALIGNED ALIGNED **NOT** ALIGNED

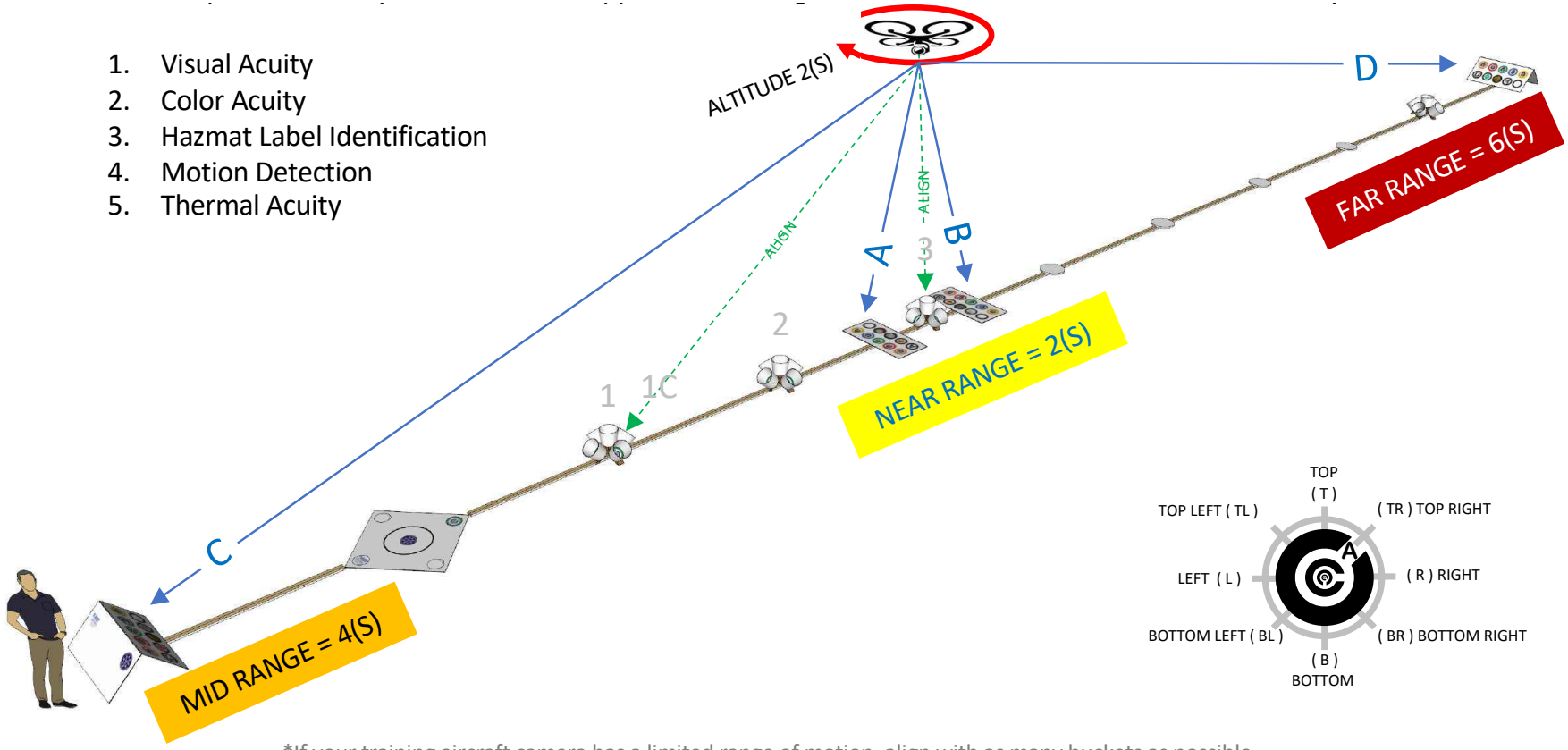
MAN 1-5 BASIC MANEUVERING
ALIGN WITH BUCKETS
Align with 20 buckets long enough to capture a single image (NO ZOOM) showing a continuous green ring inside to determine successful alignment. The numbers/letters are bucket identifiers.

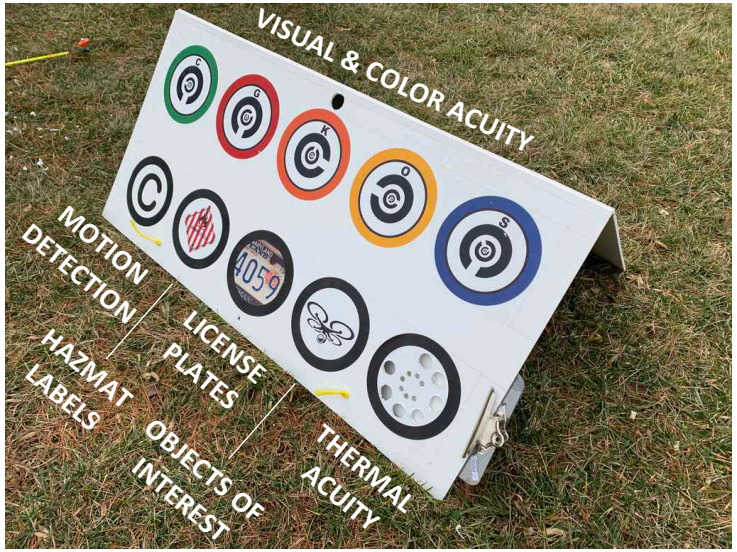
PAY 1-5 PAYLOAD FUNCTIONALITY
IDENTIFY VISUAL ACUITY TARGETS
Align with 20 buckets long enough to capture a single image (FULL ZOOM) showing a continuous green ring AND the increasingly small Concentric C gap directions up to 5 deep in 8 different orientations.

Add Sensor Panels for Cameral Pointing and Zooming Test

Training and Evaluation

1. Visual Acuity
2. Color Acuity
3. Hazmat Label Identification
4. Motion Detection
5. Thermal Acuity

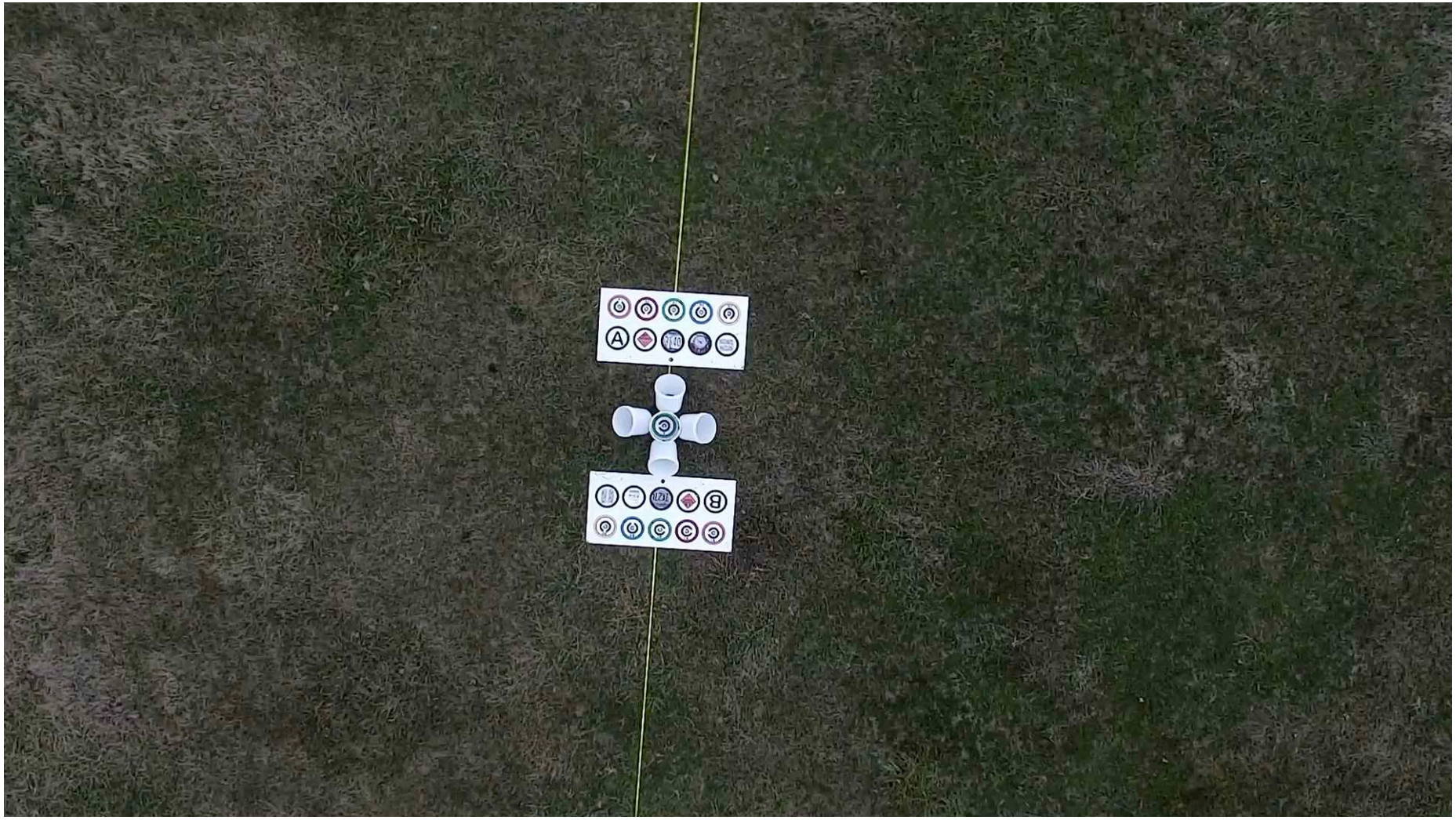




*If your training aircraft camera has a limited range of motion, align with as many buckets as possible.
Pilot proficiency should only be compared using similar systems.

Evaluate Sensors

Precise Distance to Targets



Indoor Layout on Basketball/Tennis Courts

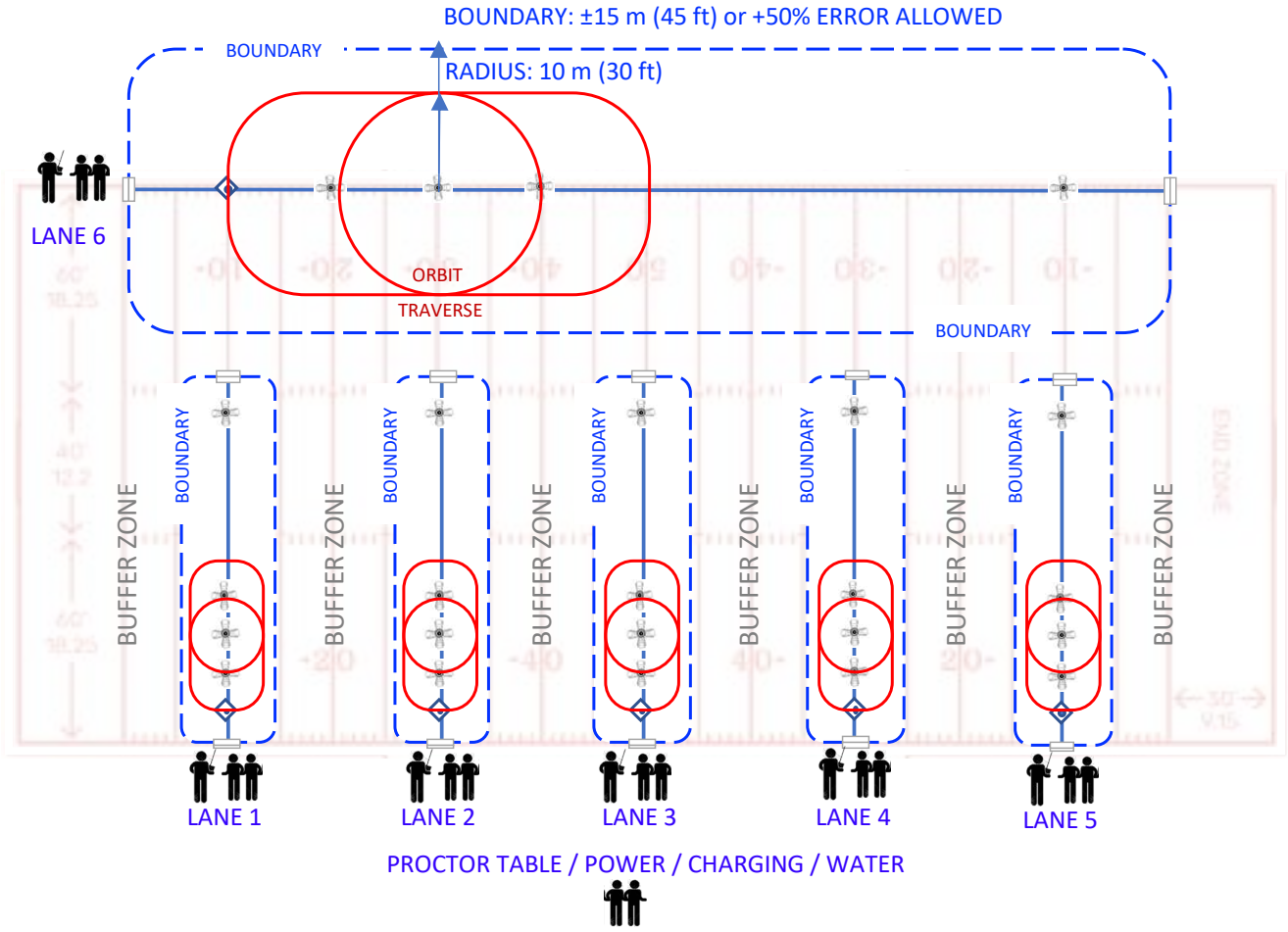
Training and Evaluation

Ceiling height determines maximum safe hover altitude (2X)

Canadian Police College, London, Ontario, Canada

Football Field Layout for Concurrent Lanes

Training and Evaluation



LANE SPACING
10 m (30 ft)

BOUNDARY (+50%)
± 15 m (45 ft)

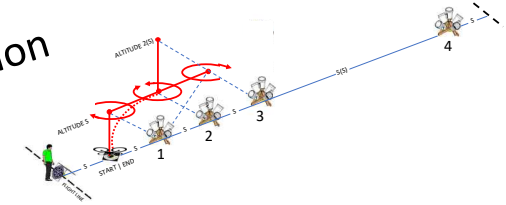
LANE LENGTH
100 m (300 ft)

LANE SPACING
3 m (10 ft)

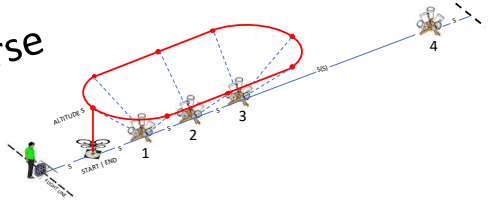
BOUDARY (+50%)
±5 m (15 ft)

LANE LENGTH
30 m (100 ft)

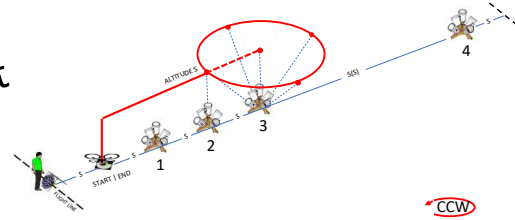
Position



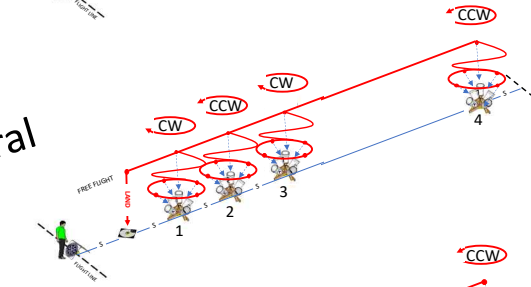
Traverse



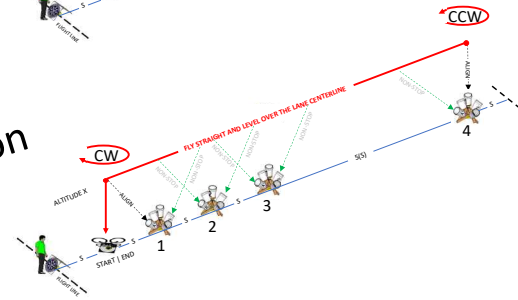
Orbit



Spiral



Recon



SENSOR PANELS & FLIGHT LINES

LAUNCH/LAND PLATFORM

OMNI BUCKET STANDS #1, #2, #3, #4

ORBIT PATH AND TRAVERSE PATH

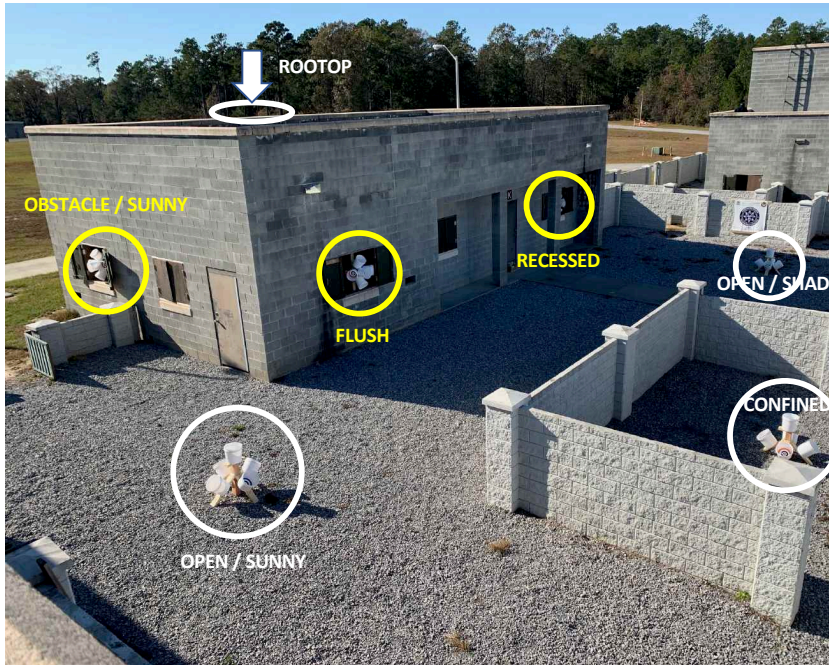
PILOT, VISUAL OBSERVER, AND FORM FILLER

Open Area Scenarios with Directed Points of View

Training and Evaluation

WIDE AREA SEARCH
(DOWNWARD OBJECTS)

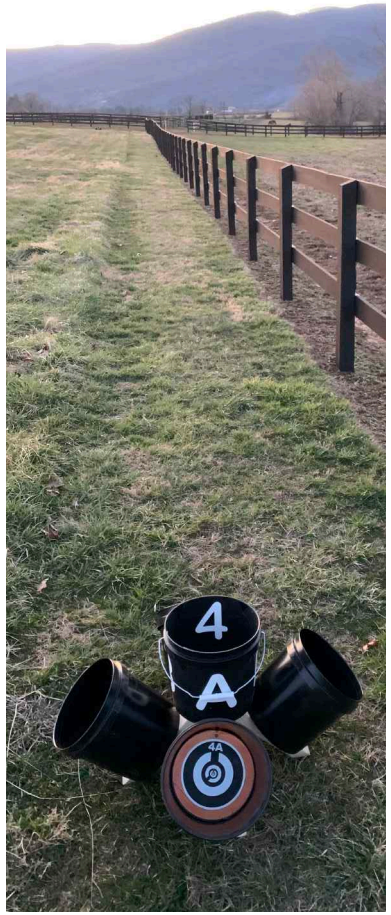
VEHICLE INSPECTION
(EXTERIOR AND INTERIOR)



BUILDING EXTERIOR SEARCH
(DOWNWARD OBJECTS)

Wide Area Search

Training and Evaluation



Conducted at Multiple Exercise Locations

Vehicle Inspection

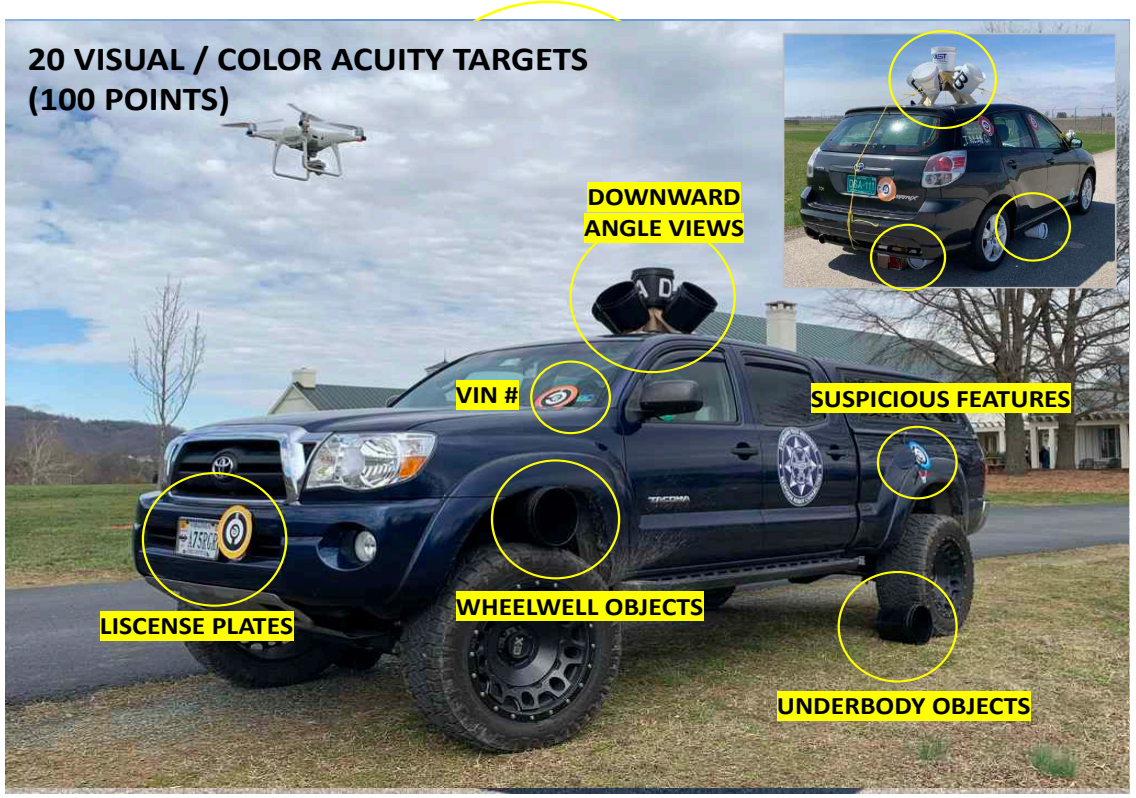
Training and Evaluation

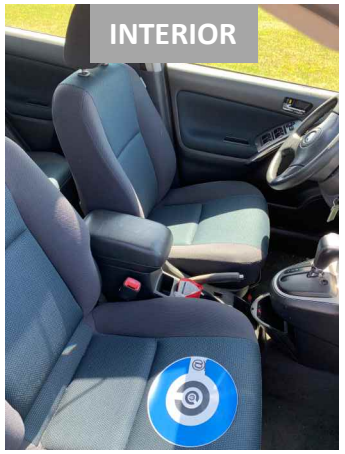
Establish a hover aligned directly over top of the omni bucket stand on the roof. The top bucket contains a number, visual acuity target, hazmat label, or other operationally significant object.

Based on that initial target determine if further inspection is warranted. There could be several vehicles in the scenario.

Inspect the A-B-C-D sides of the vehicle in order starting with the front (A) side to identify 20 targets with 5 levels of acuity (1 point each up to 100 points). Each side has a rooftop angled bucket, exterior, interior, and underbody locations to identify targets.

Perch on the ground to identity underbody targets if necessary. This demonstrates ability to maintain the view and assist ground robots coming down range to deal with the object.





A Side Targets (Front): Rooftop Omni, License, VIN#, Interior, Interior
B Side Targets (Pass): Rooftop Omni, Exterior Feature, Underbody, Interior, Interior
C Side Targets (Rear): Rooftop Omni, License, Exterior feature, Interior, Interior
D Side Targets (Driver): Rooftop Omni, Exterior Feature, Underbody, Interior, Interior

Canadian Police College, London, Ontario, Canada

Box Truck Inspection

Training and Evaluation

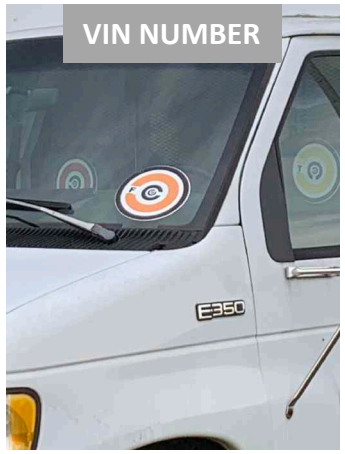
Establish a hover aligned directly over top of the omni bucket stand on the roof. The top bucket contains a number, visual acuity target, hazmat label, or other operationally significant object.

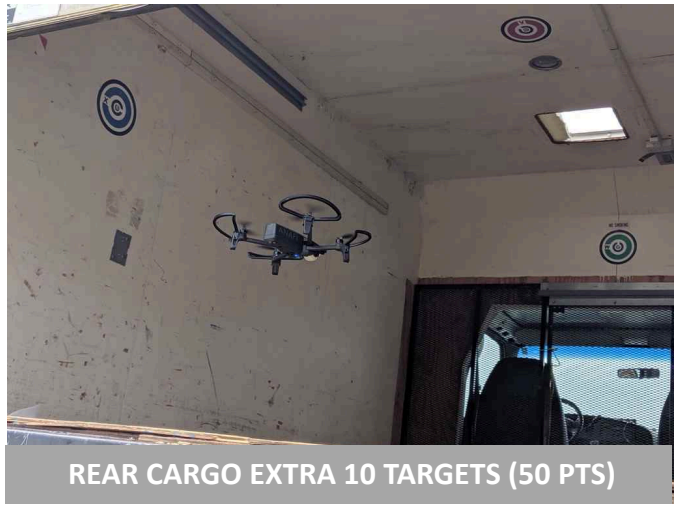
Based on that initial target determine if further inspection is warranted. There could be several vehicles in the scenario.

Inspect the A-B-C-D sides of the vehicle in order starting with the front (A) side to identify 20 targets with 5 levels of acuity (1 point each up to 100 points). Each side has a rooftop angled bucket, exterior, interior, and underbody locations to identify targets.

Perch on the ground to identity underbody targets if necessary. This demonstrates ability to maintain the view and assist ground robots coming down range to deal with the object.

A Side Targets (Front): Rooftop Omni, License, VIN#, Interior, Interior
B Side Targets (Pass): Rooftop Omni, Exterior Feature, Underbody, Interior, Interior
C Side Targets (Rear): Rooftop Omni, License, Exterior feature, Interior, Interior
D Side Targets (Driver): Rooftop Omni, Exterior Feature, Underbody, Interior, Interior





NIST, Gaithersburg, MD

Fuel Truck / Rail Car Inspection

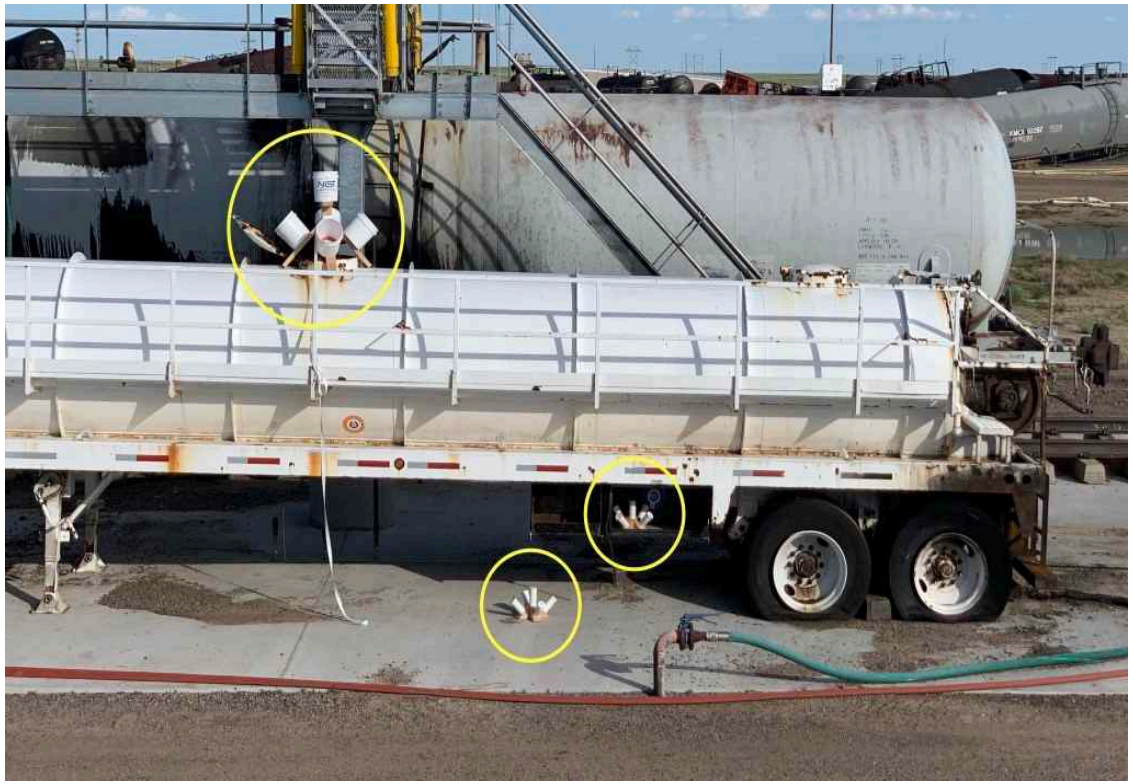
Training and Evaluation

Establish a hover aligned directly over top of the omni bucket stand on the roof. The top bucket contains a number, visual acuity target, hazmat label, or other operationally significant object.

Based on that initial target determine if further inspection is warranted. There could be several vehicles in the scenario.

Inspect the A-B-C-D sides of the vehicle in order starting with the front (A) side to identify 20 targets with 5 levels of acuity (1 point each up to 100 points). Each side has a rooftop angled bucket, exterior, interior, and underbody locations to identify targets.

Perch on the ground to identity underbody targets if necessary. This demonstrates ability to maintain the view and assist ground robots coming down range to deal with the object.



A Side Targets (Front): Rooftop Omni, License, VIN#, Interior, Interior
B Side Targets (Pass): Rooftop Omni, Exterior Feature, Underbody, Interior, Interior
C Side Targets (Rear): Rooftop Omni, License, Exterior feature, Interior, Interior
D Side Targets (Driver): Rooftop Omni, Exterior Feature, Underbody, Interior, Interior

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

Exterior Structure Search

Training and Evaluation

DOWNWARD TARGETS
- 4 OMNI STANDS
- 20 BUCKETS
- 100 POINTS

FORWARD TARGETS
- 4 OMNI STANDS
- 20 BUCKETS
- 100 POINTS

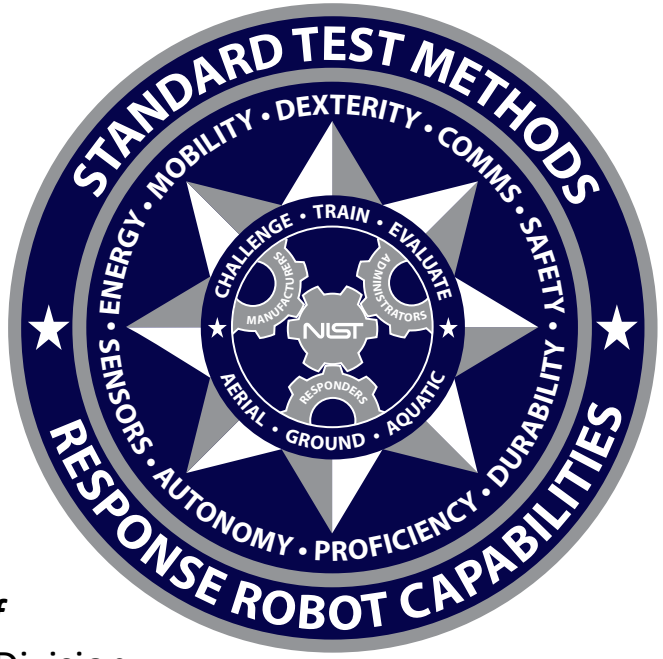
DHS Responder Familiarization Exercise

Open Test Lane

Fabrication Overview

VERSION 2020B

WEBSITE POINTER:
DOWNLOAD STICKER FILES, FORMS AND
PRACTICE SCORING VIDEOS



WEBSITE POINTER:
WATCH FABRICATION VIDEOS
AND FLIGHT PATH ANIMATIONS

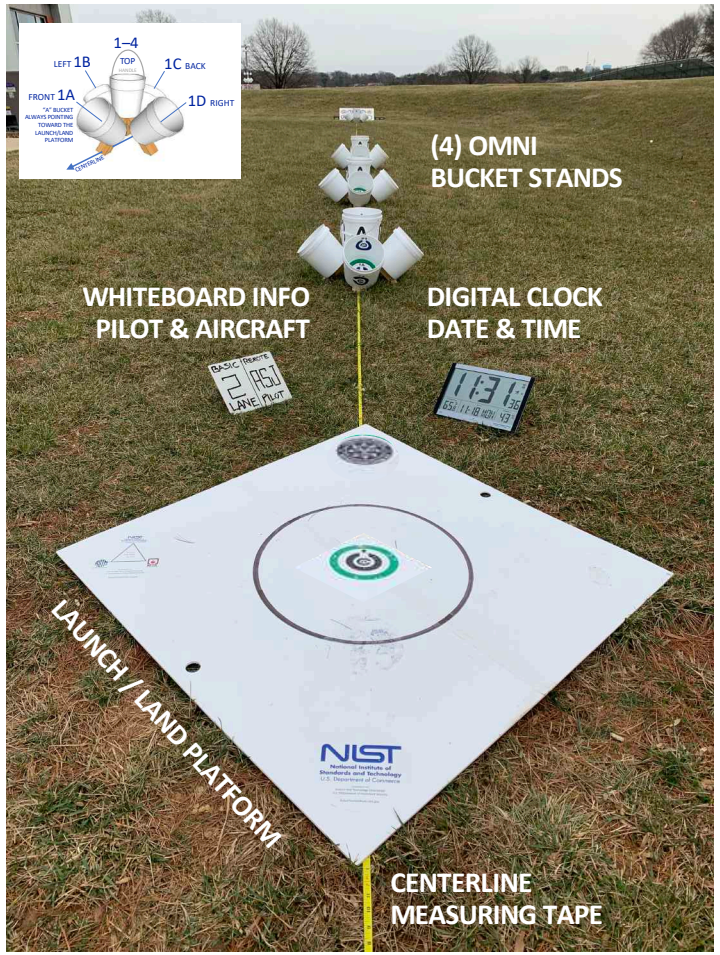
Test Director:
Adam Jacoff
Intelligent Systems Division
National Institute of Standards and Technology
U.S. Department of Commerce

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

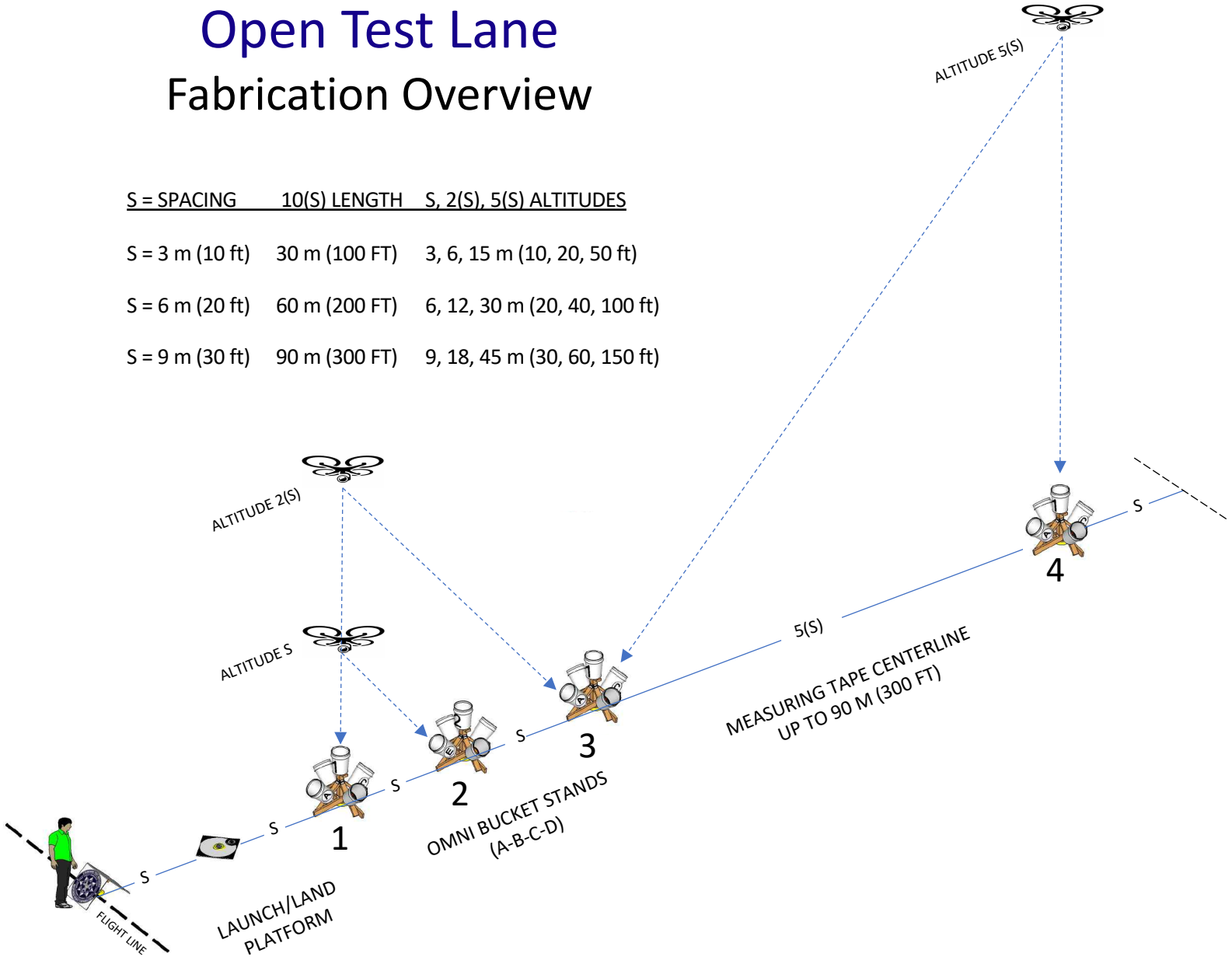
Internet
RobotTestMethods.nist.gov

Email
RobotTestMethods@nist.gov

Open Test Lane
Fabrication Overview

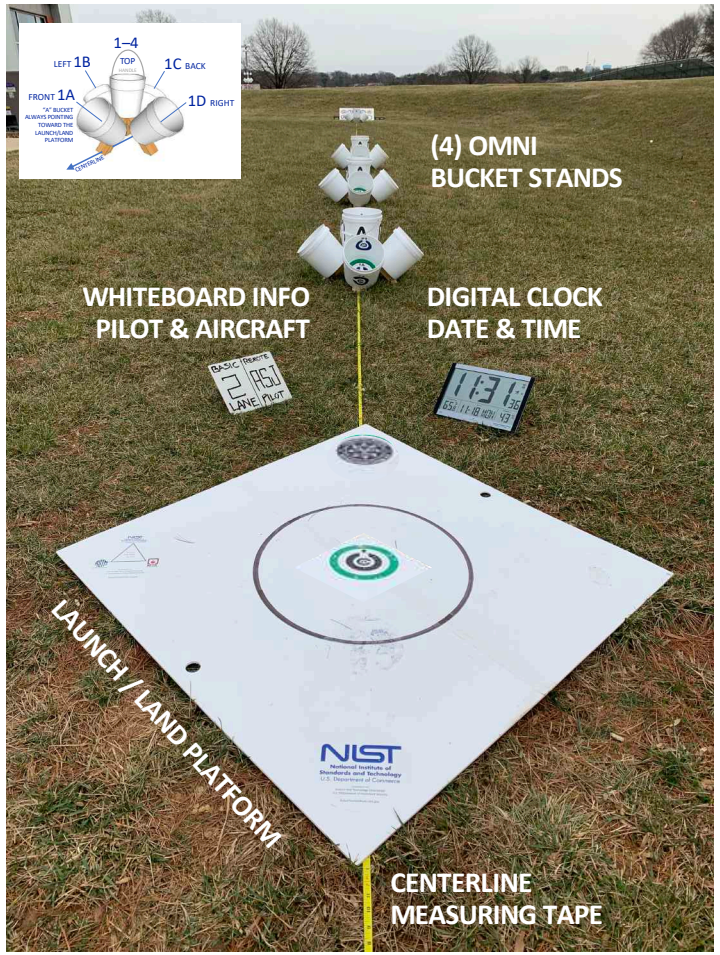


S = SPACING	10(S) LENGTH	S, 2(S), 5(S) ALTITUDES
S = 3 m (10 ft)	30 m (100 FT)	3, 6, 15 m (10, 20, 50 ft)
S = 6 m (20 ft)	60 m (200 FT)	6, 12, 30 m (20, 40, 100 ft)
S = 9 m (30 ft)	90 m (300 FT)	9, 18, 45 m (30, 60, 150 ft)



Open Test Lane

Fabrication Overview



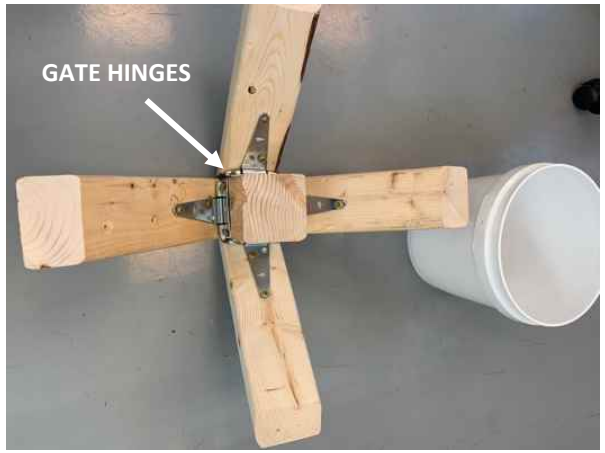
Stowing and Transport

Fabrication Overview

Stacking Lanes and Scenarios in Sets
(Top Bucket Handles Ready to Grab)

Transporting Multiple Lanes
(Stands and Buckets Stacked Separately)

Hinged Stands Fold Into Buckets for Golf Bag Storage and Transport
(2 Golf Bags per Lane)



Omni Bucket Stands

Fabrication Overview

Fabricate Stand:

[1] POST 10 x 10 x 15cm (4 x 4 x 6in)
[4] LEGS 5 x 10 x 30cm (2 x 4 x 12) with 45-degree tapers on both ends cut tall on the miter saw with opposing tapers.
[8] 7.5cm (3in) screws to affix the legs flush with the top of the POST. Use 2 screws per leg through the tapered top end.

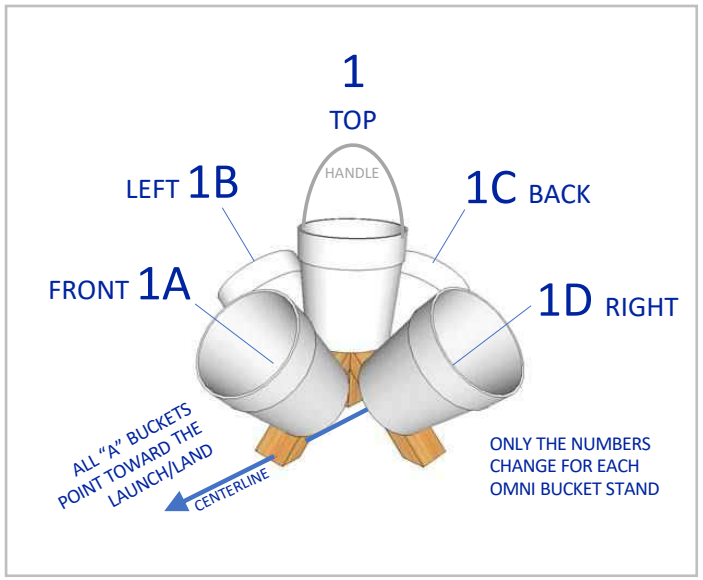
Sticker Buckets: *(download the sticker files here)*

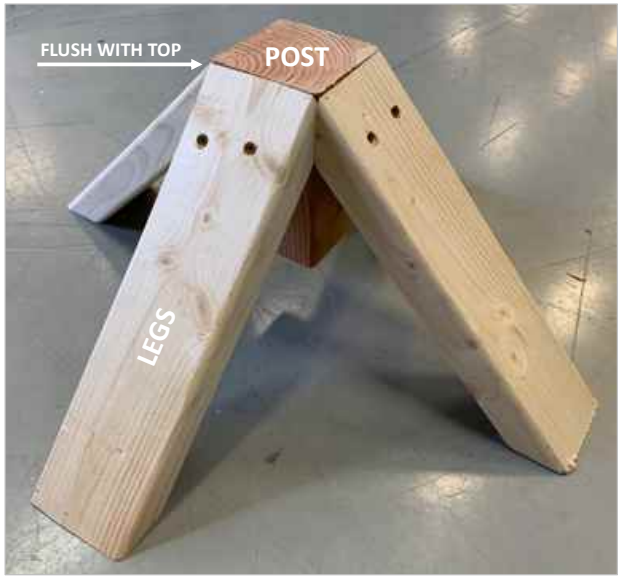
[5] White buckets 7.5-liter (2-gallon) or 20cm (8in) diameter.
[15] 8in diameter matte weatherproof polyester stickers.
[4] Big numbers inside each top bucket 1111 , 2222, 3333, 4444.
[4] Big letters around each top bucket ABCD, ABCD, ABCD, ABCD.
[5] Acuity targets inside all bottoms 1-1A-1B-1C-1D, 2-2A-2B-2C-2D, 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] 7.5cm (3 in) screws with washer heads attach top buckets 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] 4cm (1-1/2in) screws with washer heads to affix the angled buckets. Angled buckets should be touching the top bucket to support stacking. Both screws should go through the green inscribed alignment ring.





Washer Head Star/Torx Bit Screws

Fabrication Overview

LIGHT DUTY – IF BUILDING ONLY SHORT OMNI-STANDS

(100) **#8 x 1-1/2in** screws with WASHER HEADS
FOR ATTACHING BUCKETS (WASHER HEADS ARE ESSENTIAL)
$10 per 175 count box
https://www.homedepot.com/p/SPAX-8-x-1-1-2-in-T-Star-Plus-Drive-Washer-Wafer-Head-Partial-Thread-Yellow-Zinc-Coated-Cabinet-Screw-175-Box-4281020400406/204403038

(100) **#10 x 2-1/2in** screws with WASHER HEADS
FOR ASSEMBLY OF LEGS TO POSTS (NON WASHER HEADS WORK)
10 per omni-stand – $10 per 75 count box
https://www.homedepot.com/p/SPAX-10-x-2-1-2-in-T-Star-Drive-Washer-Wafer-Head-Partial-Thread-Yellow-Zinc-Coated-Cabinet-Screw-75-per-Box-4281020050606/206870578?MERCH=REC-_-pipinstock-_-204403038-_-206870578-_-N

HEAVY DUTY – TALLER/LARGER/HINGING APPARATUS FABRICATION AND SHORT OMNI-STANDS TO KEEP THE TOOL BITS THE SAME (PREFERRED)

(100) **1/4in x 1-1/2in** screws (T25 BIT) with WASHER HEADS – FOR ATTACHING BUCKETS (WASHER HEADS ARE ESSENTIAL)
http://www.screwsolutions.com/CCTX- 14150100-14-x-1-12-Bronze-Star-ACQ-Compatible-Star-Drive-Exterior- Construction-Lag-Screws--100- count_p_364.html

(100) **1/4in x 2-1/2in** screws (T25 BIT) with WASHER HEADS – FOR ASSEMBLY OF LEGS TO POSTS
https://www.screwsolutions.com/CCTX-14250100-14-x-2-12-Bronze-Star-ACQ-Compatible-Star-Drive-Exterior-Construction-Lag-Screws--100-count_p_368.html

(100) **1/4in x 4in** screws (T25 BIT) with WASHER HEADS – FOR ALL HINGE JOINTS IN STOWABLE APPARATUSES
http://www.screwsolutions.com/CCTX- 14400100-14-x-4-Bronze-Star-ACQ- Compatible-Star-Drive-Exterior- Construction-Lag-Screws--100- count_p_372.html
or
https://www.homedepot.com/p/SPAX-1-4-in-x-4-in-T-Star-Washer-Head-Exterior-HCR-PowerLag-Screw-4581820701007/206680927
or
https://www.amazon.com/4581820701555-T-Star-Washer-Exterior-Powerlag/dp/B018JQFDLM/ref=sr_1_2?crid=3REZPBUZV1C5T&dchild=1&keywords=spax+washer+head+screws&qid=1585935770&sprefix=spax+washer+head%2Caps%2C251&sr=8-2#customerReviews

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White/Black Buckets

Fabrication Overview

- Any 7.5-liter (2-gallon) or 20cm (8in) diameter buckets fit the printed stickers and disk inserts perfectly
- White buckets for standard lanes (using white printed sticker target files) and embedding into scenarios as s more obvious scoring system among operational tasks.
- Black buckets for embedding into scenarios (using black printed sticker target files) to hid better in shadows.

ULINE 7.5-liter (2-gallon) Pail, $3 each, Need 20 per standard lane or scenario
Part# S-9941W (WHITE) for standard test lanes or S-9941B (BLACK)

WHITE: https://www.uline.com/Product/Detail/S-9941W/Pails/Plastic-Pail-2-Gallon-White

BLACK: https://www.uline.com/Product/Detail/S-9941BL/Pails/Plastic-Pail-2-Gallon-Black

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Stickers for Acuity Targets and Others

Fabrication Overview

- Any 20cm (8in) round sticker can work.
- Polyester waterproof stickers are very forgivable at first placement. They can be easily removed and placed again if not quite centered or oriented correctly.
- They are also waterproof so can last a long time outdoors in rain and sun.
- 50 stickers needed for a basic Open Area Lane lane or scenario. More if you want to Disk Inserts with operational sticker targets to randomize.
- See POINTERS to download various sticker files to print for standard lanes and scenarios.

ONLINE LABELS – 20cm (8in) round, waterproof polyester/matte
100 sheets, $50, 50 sheets needed for a basic open lane or scenario

Part#: OL3033LP for Waterproof Polyester for Laser Printers (preferred)
https://www.onlinelabels.com/products/OL3033

Part#: OL3033WJ for Waterproof Matte for Inkjet Printers
https://www.onlinelabels.com/products/OL3033

DOWNLOAD **WHITE** OMNI BUCKET STICKERS FILE HERE

DOWNLOAD **BLACK** OMNI BUCKET STICKER FILE HERE

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Disk Inserts

Fabrication Overview

- Any 20cm (8in) round disk insert can work.
- Affix the visual acuity target stickers permanently inside the buckets at fabrication time. Then use disk inserts to enable randomization of various operationally significant objects of interest. Make your own too.
- Wood disks appear to be cheapest, easiest, and durable enough even though they are relatively thin. PVC foam, plastic and metal are options may also work.
- Affix different types on BOTH sides of the disks to change themes easily.
- Use one disk per stand. So 10 per lane/scenario (20 stickers) is plenty.

Wood 8in round disk x 0.1in thick (preferred)
Amazon, Juvale Unfinished Wood 8" Circle 10-Pack for DIY Crafts, Item# B07C49QVWK, 10-pack, $13
https://www.amazon.com/dp/B07C49QVWK/?coliid=IR5XU8X86ES5T&colid=24KBO1BGJ06L5&psc=1&ref_=lv_ov_lig_dp_it

Wood 8in round disk x 1/8in thick
Amazon, Craft Parts Direct, Item# PC080010, 10-pack, $17.
https://www.amazon.com/Natural-Unfinished-Round-Circle-Cutout/dp/B00YYCVBS0

Aluminum 8in round disk
American Metalcraft, Item#18908. 24 pack, $2.30 each, 6lbs total
https://www.amnow.com/product-category/pizza-supplies/separators/round-separators/
https://www.amnow.com/product/18908/

DOWNLOAD **VEHICLE SCENARIO** STICKER FILE

DOWNLOAD **SEARCH SCENARIO** DISK INSERTS

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Leveling Feet (Optional)
Fabrication Overview

Optional:

[4] Adjustable foot inserts (plastic/felt)

- Can level to 5-10 degrees in uneven parking areas or clump grass fields.
- Can protect improved flooring like basketball or tennis courts.
- Can protect the roof of a rented vehicle scenario.

Swivel Furniture Leg Levelers - Adjustable Leveling Feet Glide for Tables Chairs Cabinets Workbench Shelving Rack

https://www.amazon.com/dp/B07RXHRKB7/ref=dp_cerb_3

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Leg Extensions for Uneven Terrain (Optional)

Fabrication Overview

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Leg Extensions for Uneven Terrain (Optional)

Fabrication Overview

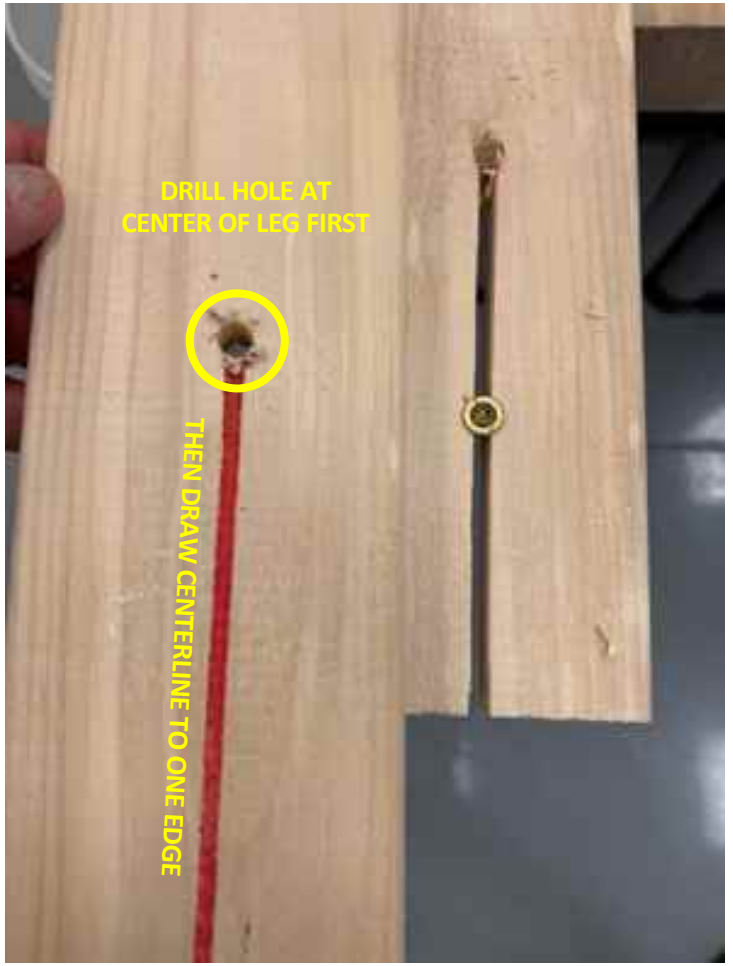
2.5 x 10 x 30cm (1 x 4 x 12in) wood leg extensions can level in any terrain

A) WIDE VELCRO STRIPS STAPLED to the underside of the legs and one face of the extensions can provide enough strength and adjustment to level in ANY TERRAIN.

B) SLOTS can slide on hanger bolts twice as thick as the wood extension and tighten [illegible] of legs.

https://www.amazon.com/dp/B001DT4T9A/?coliid=I1XL8PHSYIOJ1U&colid=24KBO1BGJ06L5&psc=1&ref_=lv_ov_lig_dp_it_im

https://www.amazon.com/dp/B00GAEOHHM/?coliid=IWB7Y6WN997EB&colid=24KBO1BGJ06L5&psc=1&ref_=lv_ov_lig_dp_it



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Launch/Land Platform

Fabrication Overview

Any thin panel of PVC or wood laminates can be used. Need 2 sheets for landing.

Home Depot, 1/4 in x 24 in x 4 ft White PVC Trim, 1 per, $16 each
https://www.homedepot.com/p/1-4-in-x-24-in-x-4-ft-White-PVC-Trim-1506278/301230763

Amazon, Online Metal Supply, Expanded PVC Sheet 3mm x 24" x 48", White (3-Pack), $48,
https://www.amazon.com/dp/B07Y4495LS/?coliid=I39TE4NX5CNOQC&colid=24KBO1BGJ06L5&psc=1&ref_=lv_ov_lig_dp_it_im

[1] ROLL WHITE 2 IN WIDE DUCT TAPE FOR HINGE ON BOTH SIDES OF PANELS
https://www.amazon.com/Gorilla-6025302-White-Tough-Wide/dp/B07LFZF9KN/ref=sr_1_6?dchild=1&keywords=white+3in+duct+tape&qid=1585934432&sr=8-6

[1] ¼ IN DRILL BIT FOR ROPE HOLES IN FOLDING SENSOR PANEL A-FRAMES
https://www.amazon.com/DEWALT-DW1354-14-Piece-Titanium-Yellow/dp/B0045PQ762/ref=sr_1_5?dchild=1&keywords=drill+bit+set&qid=1585934827&sr=8-5

[1] ¼ IN POLY ROPE x 100 FT FOR A-FRAME BOTTOM TO LIMIT 90 DEGREE OPEN ANGLE (TIE KNOTS OUTSIDE HOLES)
https://www.amazon.com/Lehigh-Group-DF4100W-P-Df4100Hd-Braided/dp/B000SKZND6/ref=sr_1_13?dchild=1&keywords=1.4in+poly+rope+100ft&qid=1585934671&sr=8-13

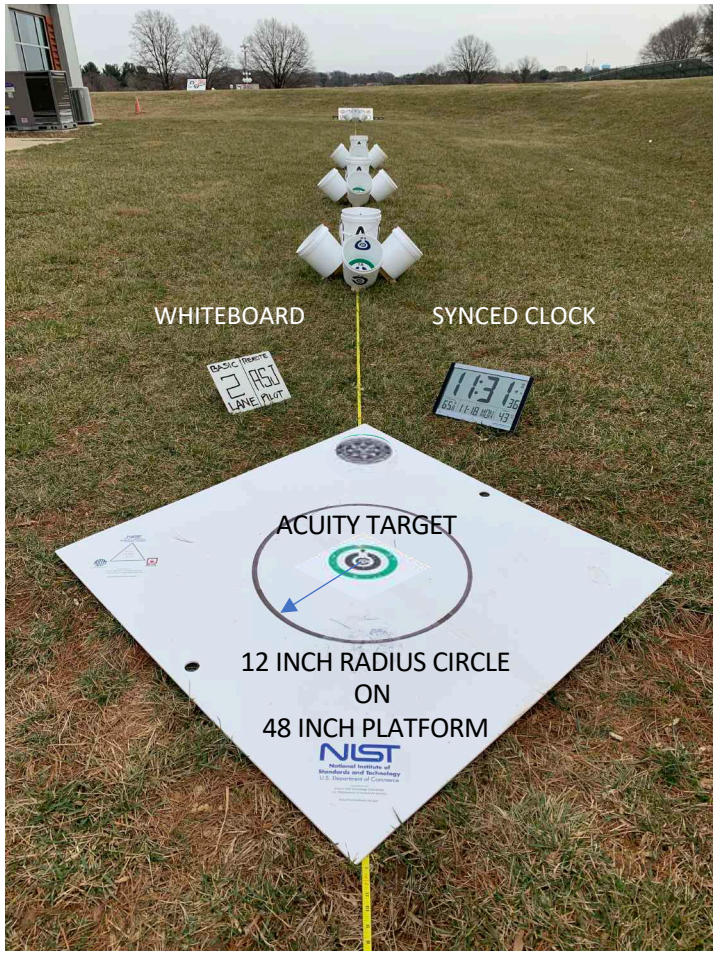
[1] SCISSOR TO CUT EXCESS POLY ROPE AND EXCESS DUCT TAPE
https://www.amazon.com/Acelone-Stainless-Multi-function-Scissors-Vegetables/dp/B07K72PHLS/ref=sr_1_8?dchild=1&keywords=scissors&qid=1588007052&s=industrial&sr=1-8

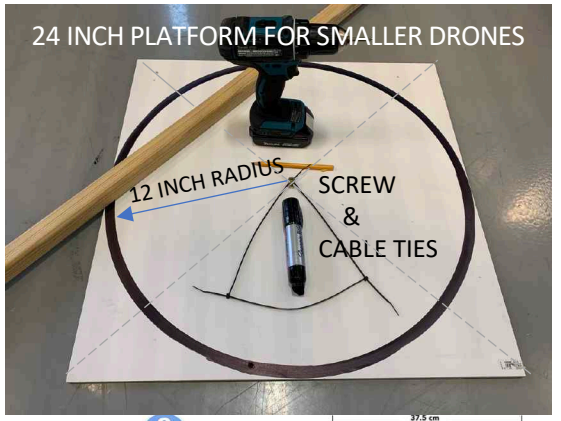
[1] 1-1/2 IN PADDLE BIT FOR CARRY THUMB HOLES ON TOP
https://www.amazon.com/DEWALT-DW1586-2-Inch-6-Inch-Spade/dp/B0001LQYIU/ref=sr_1_5?dchild=1&keywords=paddle+bit+large&qid=1585935081&sr=8-5

[1] SHARPIE MAGNUM MARKER FOR 12IN RADIUS CENTER CIRCLE (USE A CENTER SCREW AND ADJUSTABLE LOOP OF CABLE TIES)
https://www.amazon.com/SNF44001-Sharpie-Magnum-Permanent-Marker/dp/B003WPC3NC/ref=sr_1_6?dchild=1&keywords=sharpie+magnum&qid=1588084926&sr=8-6

[1] WHITEBOARD AND THICK MARKERS
https://www.amazon.com/gp/product/B06VVBW9BQ/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1

[1] DIGITAL CLOCK SYNCED TO NIST TIME
https://www.amazon.com/Marathon-Temperature-Humidity-Color-Graphite-SKU-CL030062GG/dp/B01M11AJTN/ref=sr_1_12?dchild=1&keywords=synced+clock&qid=1588085468&sr=8-12





1) Use a long straight edge across both diagonals to mark the panel center.

2) Insert a short screw at the intersection and mark the 12 inch radius.

3) Loop and adjust a series of cable ties around the screw while pulling the loop tight with the tip of the thick marker at the 12 inch radius.

4) Rotate the marker tip to mark the thickest possible dimension.

5) Kneel on the landing as a counter-weight and push away from your body to ensure a circular mark all the way around.

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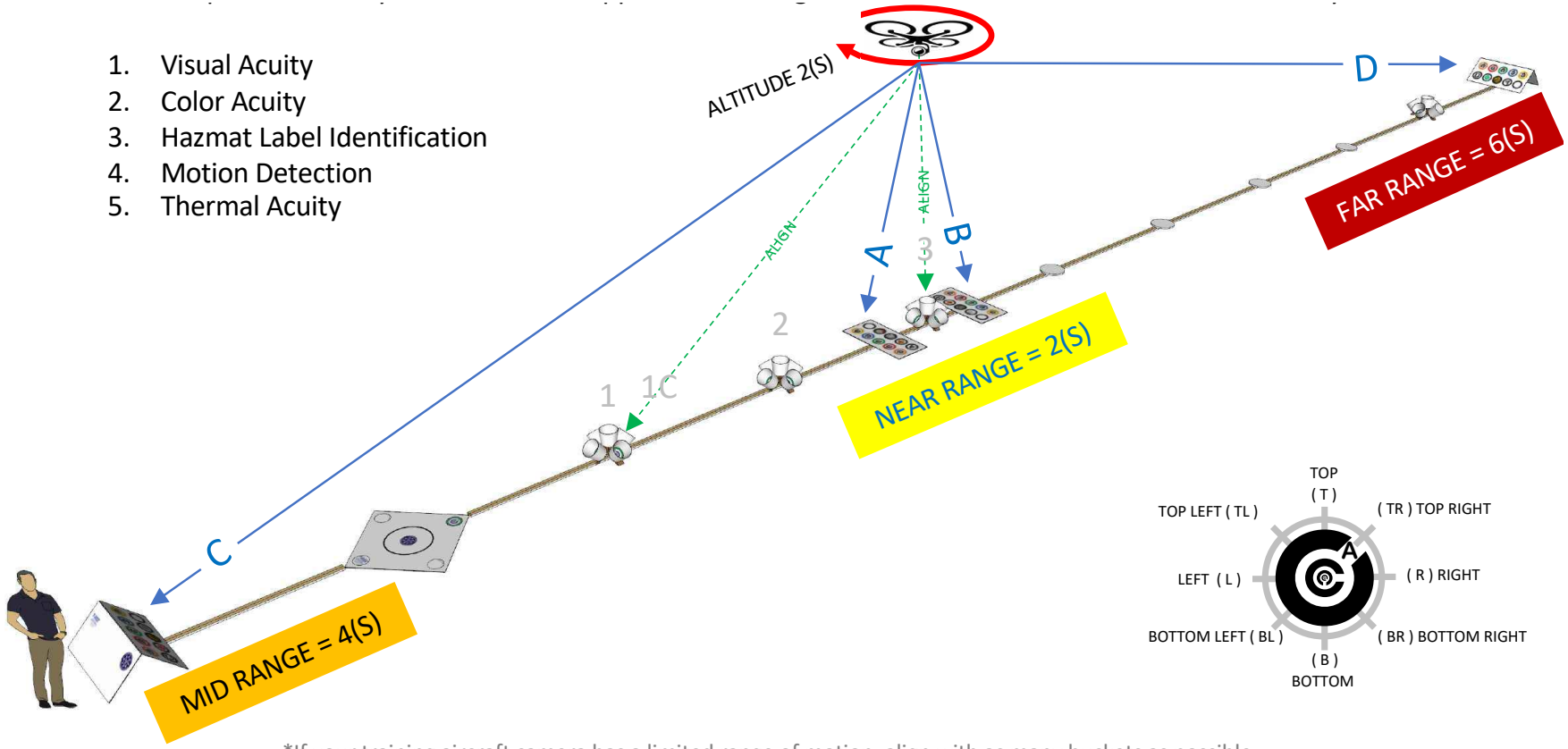
Sensor Panels for Point and Zoom Camera Tests

Fabrication Overview

1. Visual Acuity
2. Color Acuity
3. Hazmat Label Identification
4. Motion Detection
5. Thermal Acuity



*If your training aircraft camera has a limited range of motion, align with as many buckets as possible.
Pilot proficiency should only be compared using similar systems.

Sensor Panels for Point and Zoom Camera Tests

Fabrication Overview

Any thin panel of PVC or wood laminates can be used, although the PVC will last longer.

Home Depot, 1/4 in x 24 in x 4 ft White PVC Trim (the picture isn't quite reflective of the product), $16 each
Need 6 sheets for Sensor panels and 2 sheets for foldable 4ft landing per lane.
https://www.homedepot.com/p/1-4-in-x-24-in-x-4-ft-White-PVC-Trim-1506278/301230763

Amazon, Online Metal Supply, Online Metal Supply Expanded PVC Sheet 3mm x 24" x 48", White, 3-pack, $48,
Need 6 sheets for Sensor panels and 2 sheets for foldable 4ft landing per lane.
https://www.amazon.com/dp/B07Y4495LS/?coliid=I39TE4NX5CNOQC&colid=24KBO1BGJ06L5&psc=1&ref_=lv_ov_lig_dp_it_im

[1] ROLL WHITE 2 IN WIDE DUCT TAPE FOR HINGE ON BOTH SIDES OF PANELS
https://www.amazon.com/Gorilla-6025302-White-Tough-Wide/dp/B07LFZF9KN/ref=sr_1_6?dchild=1&keywords=white+3in+duct+tape&qid=1585934432&sr=8-6

[1] ¼ IN DRILL BIT FOR ROPE HOLES IN FOLDING SENSOR PANEL A-FRAMES
https://www.amazon.com/DEWALT-DW1354-14-Piece-Titanium-Yellow/dp/B0045PQ762/ref=sr_1_5?dchild=1&keywords=drill+bit+set&qid=1585934827&sr=8-5

[1] ¼ IN POLY ROPE x 100 FT FOR A-FRAME BOTTOM TO LIMIT 90 DEGREE OPEN ANGLE (TIE KNOTS OUTSIDE HOLES)
https://www.amazon.com/Lehigh-Group-DF4100W-P-Df4100Hd-Braided/dp/B000SKZND6/ref=sr_1_13?dchild=1&keywords=1.4in+poly+rope+100ft&qid=1585934671&sr=8-13

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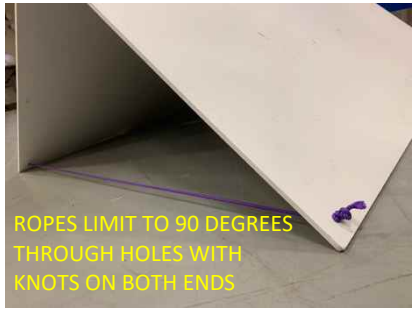
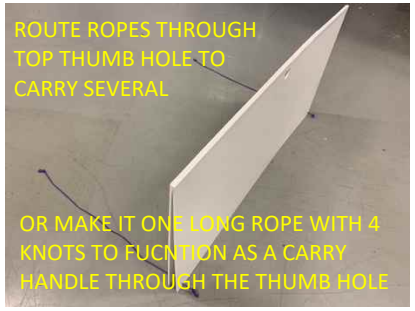
https://www.amazon.com/Acelone-Stainless-Multi-function-Scissors-Vegetables/dp/B07K72PHLS/ref=sr_1_8?dchild=1&keywords=scissors&qid=1588007052&s=industrial&sr=1-8

[1] 1-1/2 IN PADDLE BIT FOR CARRY THUMB HOLES ON TOP
https://www.amazon.com/DEWALT-DW1586-2-Inch-6-Inch-Spade/dp/B0001LQYIU/ref=sr_1_5?dchild=1&keywords=paddle+bit+large&qid=1585935081&sr=8-5

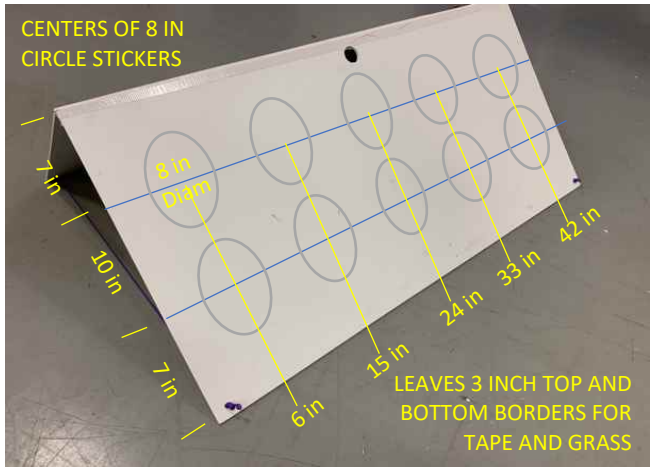
[40] CHEMICAL HAND WARMERS 4X5IN (FOLD IN HALF TO MAKE THINNER TARGET)
https://www.uline.com/Product/Detail/S-14298B/Hand-and-Foot-Warmers/Super-HotHands-Hand-and-Body-Warmers-Bulk-Pack

[1] STAPLE GUN AND STAPLERS TO ATTACH THE THERMAL TARGETS TO THE PVC PANELS
https://www.amazon.com/Staple-Manual-Nail-1800-Staples/dp/B07HMY19D1/ref=sr_1_6?dchild=1&keywords=staple+gun&qid=1585942220&sr=8-6





WATCH MOVIE OF ASSEMBLY PROCESS HERE



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Sensor Panels for Point and Zoom Camera Tests

Fabrication Overview

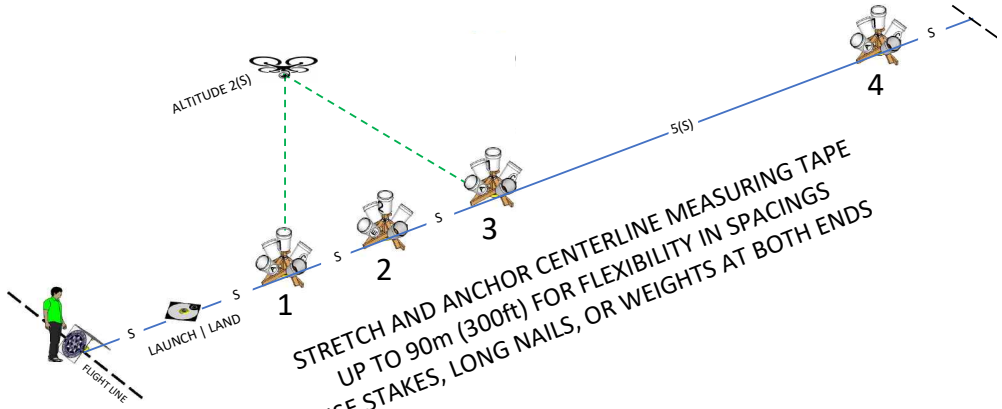
Thermal acuity circular hole patterns. The large holes are 1 inch diameter and small holes are 1/2 inch diameter. One of the 8 directions is missing, like the gap on the visual acuity targets. There is a sticker template to drill through in the Disk Insert file.

A simpler approach is to fold a hand warmer into roughly a line and staple it to the panel vertical, horizontal, or diagonal

Miscellaneous Items

Fabrication Overview

[1] 90M (300FT) MEASURING TAPE CENTERLINE - $30
https://www.homedepot.com/p/Stanley-300-ft-Tape-Measure-34-762/100318954?mtc=Shopping-VF-F_D25T-G-D25T-25_90_Hand_Tools-Stanley_Tools-NA-Feed-PLA-NA-NA-HandTools&cm_mmc=Shopping-VF-F_D25T-G-D25T-25_90_Hand_Tools-Stanley_Tools-NA-Feed-PLA-NA-NA-HandTools-71700000058470929-58700005391956982-92700048951171413&gclid=EAIaIQobChMI-Oqf_9zM6AIVBIbICh0rEAcrEAQYASABEgLCv_D_BwE&gclsrc=aw.ds%20%20or
or
https://www.amazon.com/Measuring-Tape-Open-300-Ft/dp/B000FNB4AC



[10] TENT STAKES or 60 PENNY 6IN NAILS - $2-8
Used to STRETCH AND PULL TIGHT the measuring tape centerline from end to end to ensure a straight line. These are also used to hold down the Sensor A-Frame ropes, landing or banners.
https://www.amazon.com/Hikemax-7075-Aluminum-Tent-Stakes/dp/B07H2WTZT5/ref=sr_1_1_sspa?crid=1JW6IEQDW4IG7&dchild=1&keywords=tent+stakes+lightweight&qid=1585935504&sprefix=tent+stakes%2Caps%2C413&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyUklJNVRTUFg2UUxLJmVuY3J5cHRlZElkPUEwNjQ3MzcwMktNT1Y2Q1ZWWDJTSSZlbmNyeXB0ZWRBZElkPUEwNjQwMDc1MjgzTEFWWFlYMEM5TiZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=

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)

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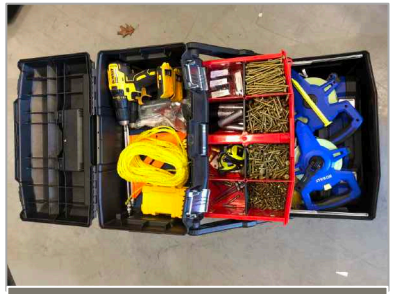
Helpful Tools
Fabrication Overview

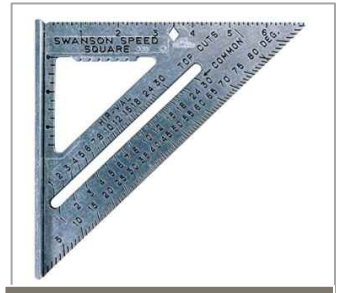


A miter saw with physical guides (2x4s or 4x4s) placed at the most used lengths (12in, 24in, 48in at least) provides quick and precise replication of cuts. Also, MEASURE AND MARK THE MITER SAW to replicate the 45-degree taper cuts to coincide with the end cuts exactly. Cut blunt lengths then taper. When the tool is marked, its easier. Foldable table and wheels for mobility are bonus features. The frame is screwed up from under the table. The strap shown stows the legs when folded for rolling. For several lanes, this is worth the effort.


MISC TOOL CASE

MISC TOOL CASE


ROLLER BOX



SQUARE

8-10 INCH BIT EXTENDER

Disclaimer: Commercial equipment shown in this document are for illustrative purposes only. This does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products identified are necessarily the best available for the purpose.

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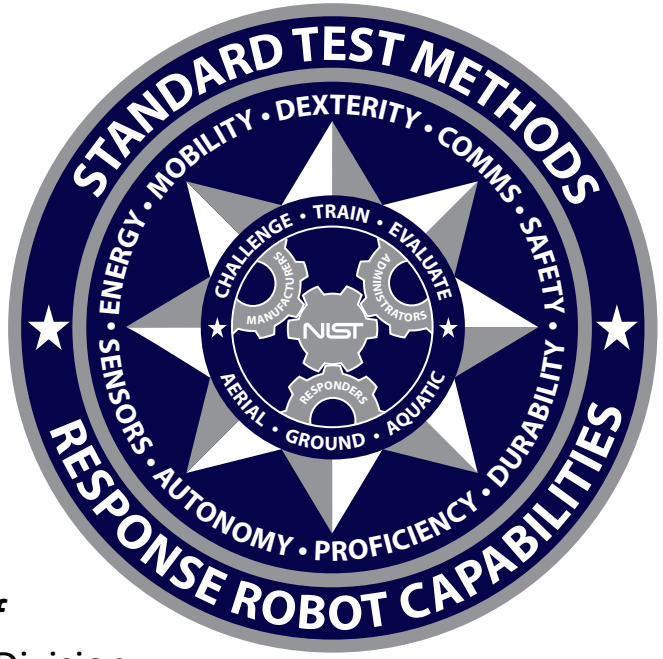

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