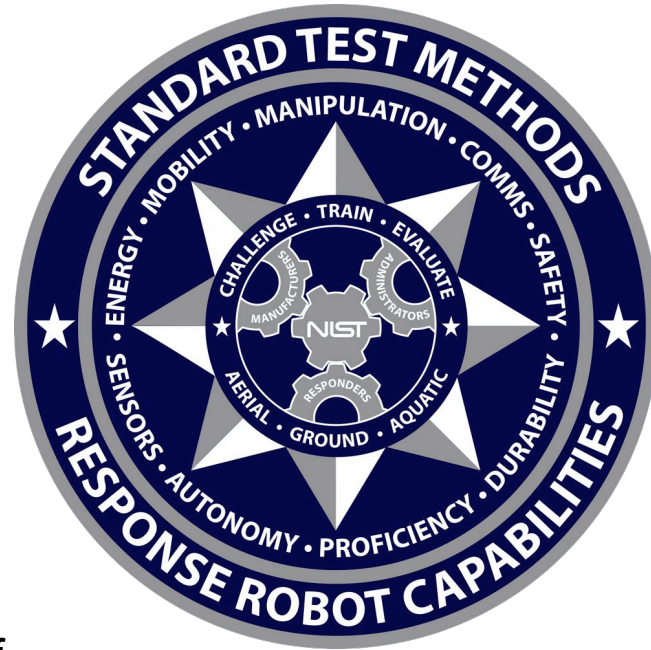


# Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

## Quick Start Guide



WATCH THE VIDEO VERSION WITH  
TEST METHOD FLY THROUGHS

<https://vimeo.com/354145833>

*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

# 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, Kamel Saidi, Raymond Sheh, 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.

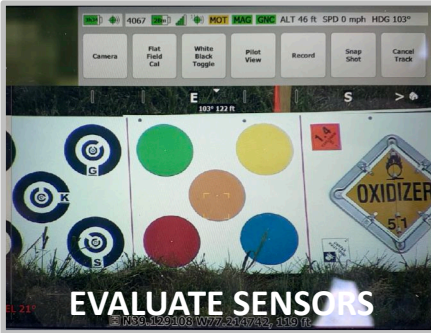
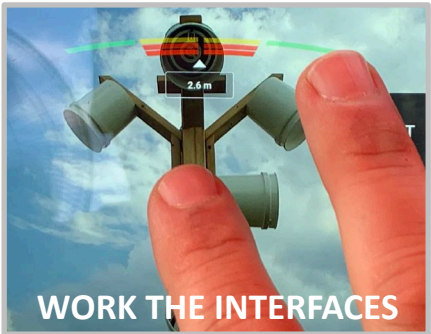
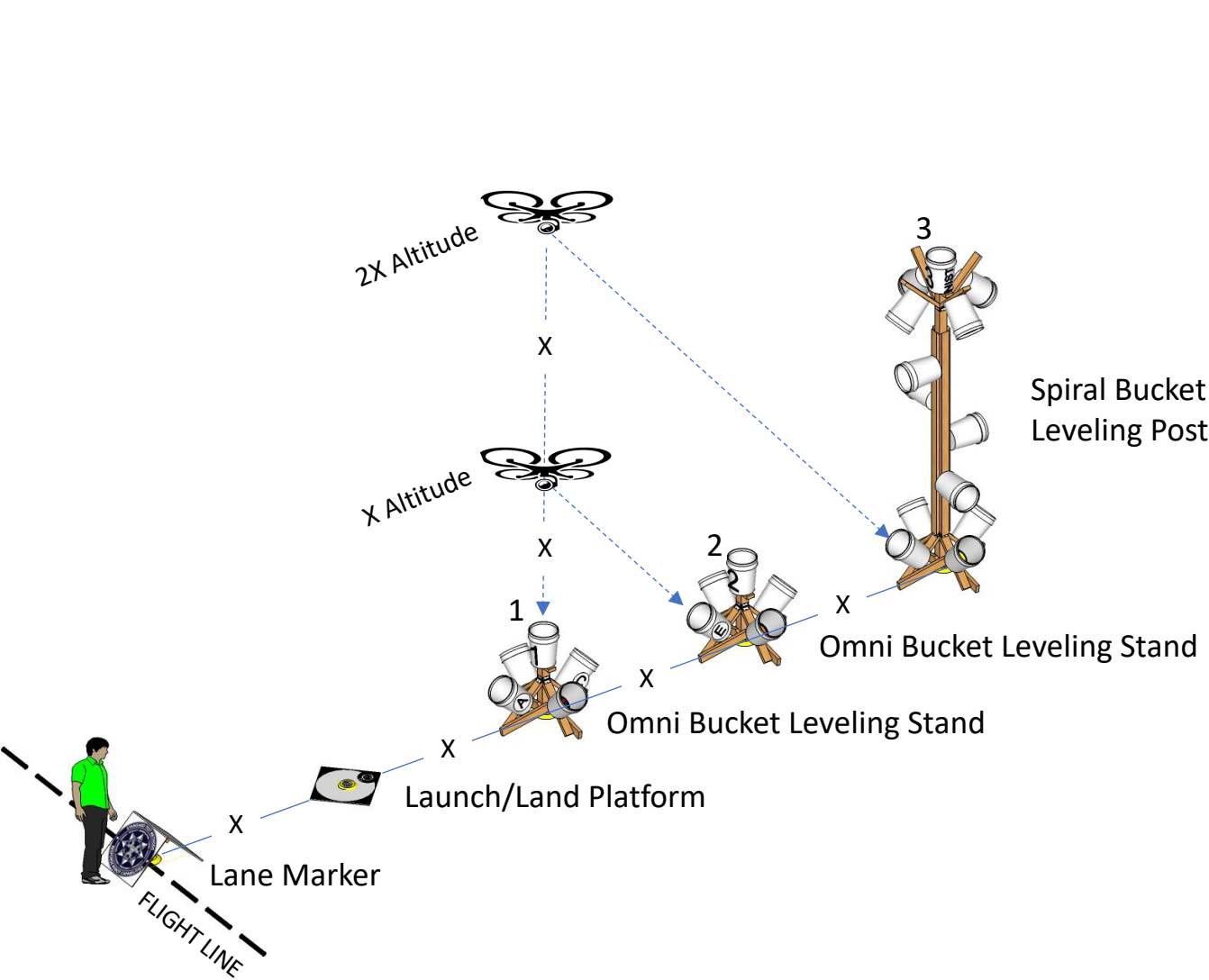
## Collaborators

- 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, VA
- Michael O’Shea, U.S. Dept. of Justice, DC
- 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
- Al Frazier, Grand Forks County Sheriff’s Dept., ND
- Ben Miller, DFPC Center of Excellence for Aerial Fire Fighting, CO
- Max Delo, ESF-13, U.S. Marshals Service, DOJ
- Bryan Gillespy, ESF-13, U.S. Marshals Service, DOJ
- Howie Stockhowe, Virginia Beach Fire Dept, Virginia Beach, VA
- Tony Galladora, Montgomery County Police, MD
- Satoshi Tadokoro, Tohoku University, Sendai, Japan
- Tetsuya Kimura, Nagoaka Univ. of Technology, Nagoaka, Japan

- Andy Olesen, Canadian Explosives Technicians Assoc., Canada
- Tom Prentice, Reveille Peak Ranch, Burnet, TX
- Michael Leo, Fire Department of New York City, NY
- Katie Thielmeyer, Woodlawn Fire Dept. OH

# Scalable Test Lane

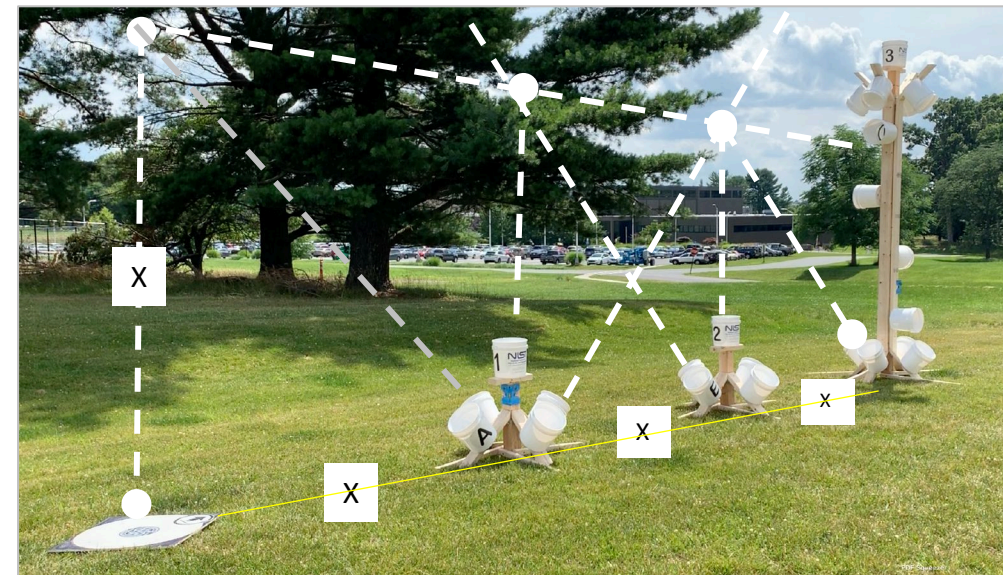
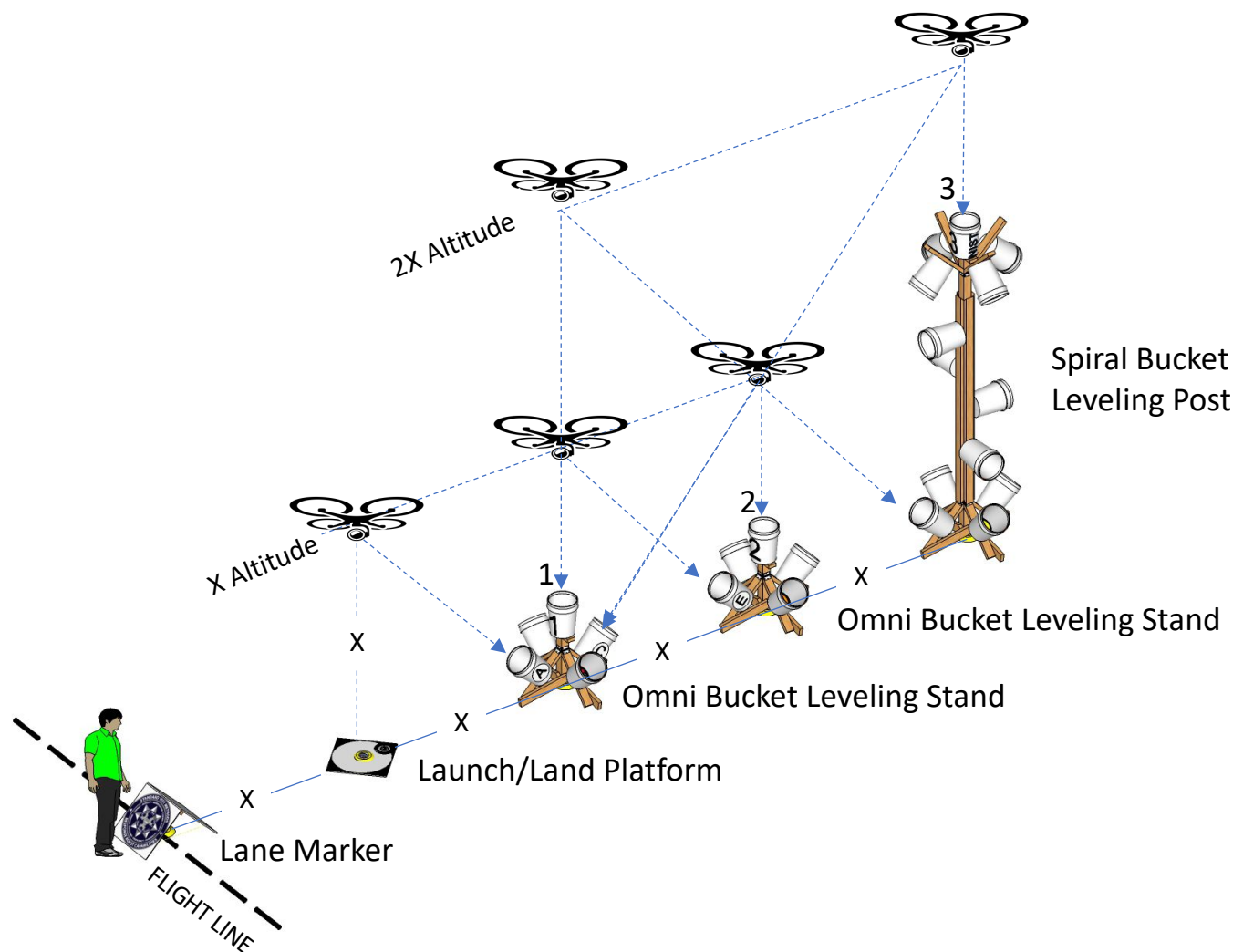
## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)





# Scalable Test Lane

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)



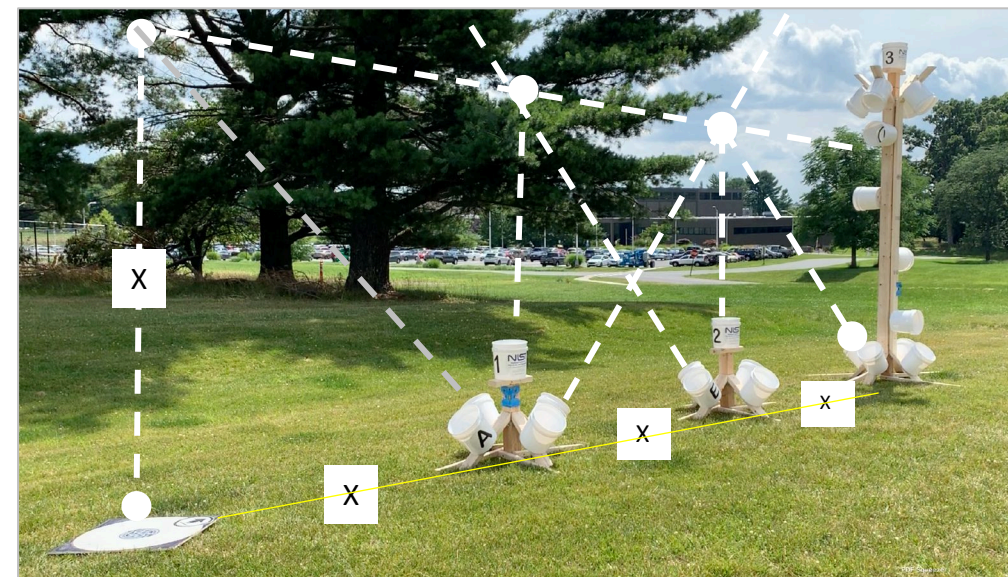
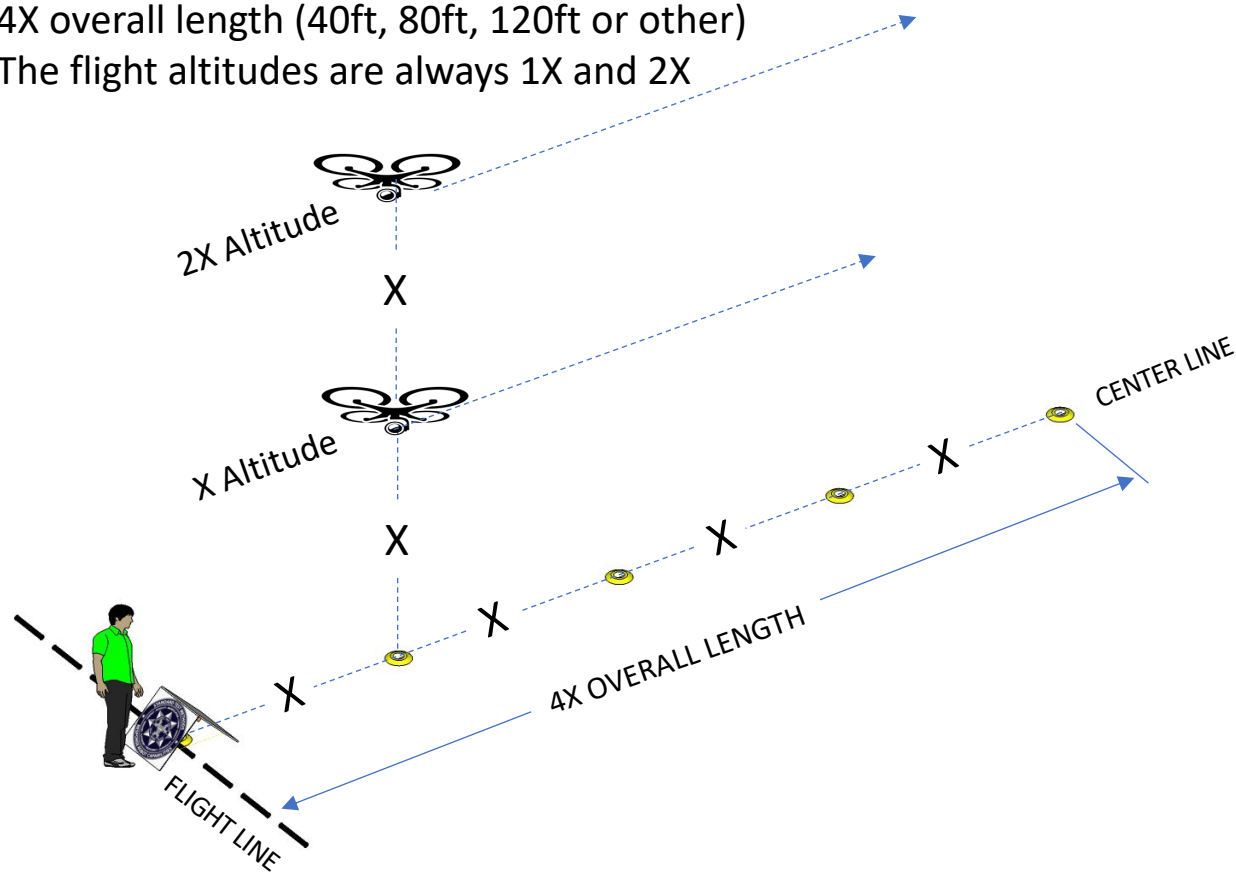
Inside each bucket is an inscribed ring to evaluate alignment. LEFT is aligned, RIGHT is not quite. Center targets can be letters, visual/color/thermal acuity charts, hazmat labels, or other items.



# Test Lane Layout

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

- Pilot flight line with lane marker (A-frame)
- Centerline (long measuring tape or flat cones)
- 1X spacing (10ft, 20ft, 30ft or other)
- 4X overall length (40ft, 80ft, 120ft or other)
- The flight altitudes are always 1X and 2X



Inside each bucket is an inscribed ring to evaluate alignment. LEFT is aligned, RIGHT is not quite. Center targets can be letters, visual/color/thermal acuity charts, hazmat labels, or other items.

# Bucket Details – Align and Identify Visual Acuity Targets

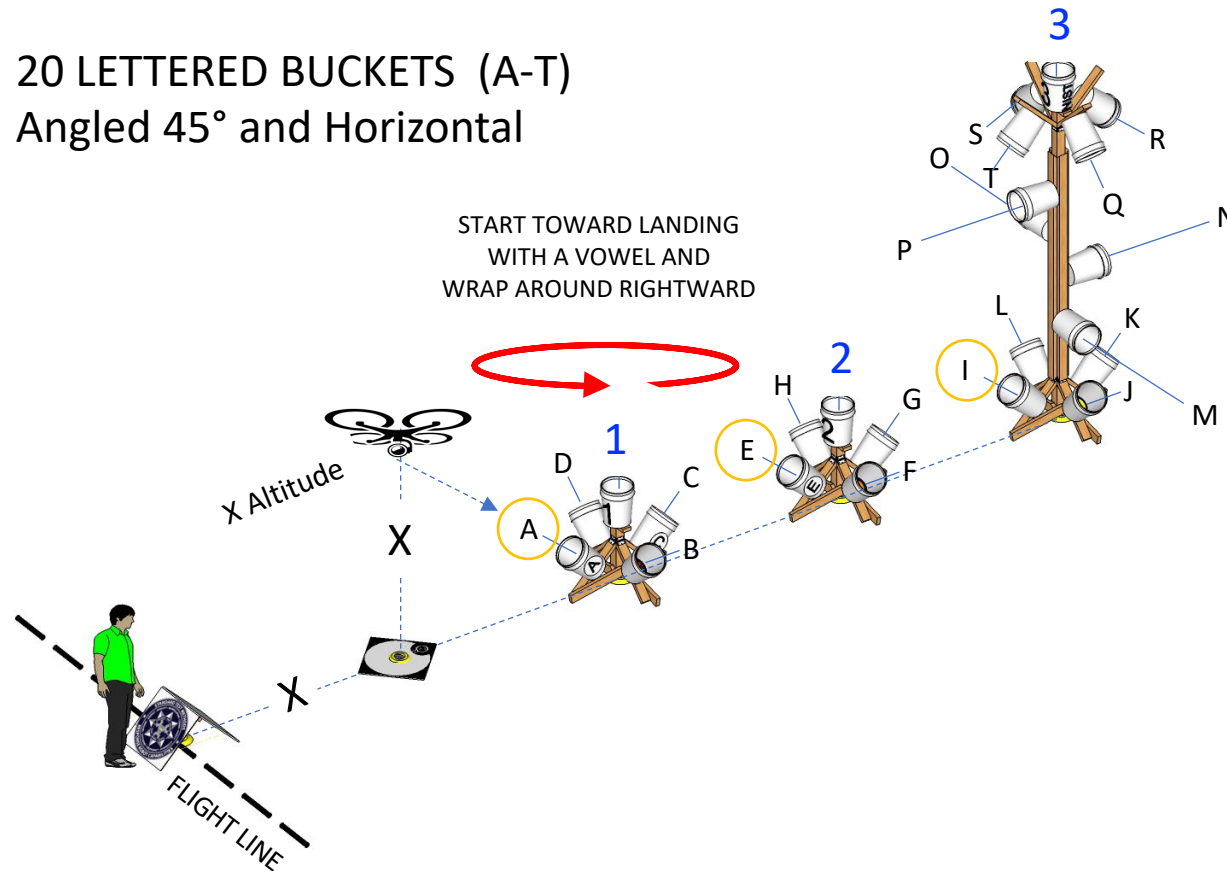
Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

3 NUMBERED BUCKETS (1-3)

Top Vertical

20 LETTERED BUCKETS (A-T)

Angled 45° and Horizontal



**MAN 1-5**

LETTER IDENTIFIERS



Align to see the entire inscribed ring inside each bucket. The letters are bucket identifiers.

**PAY 1-5**

VISUAL ACUITY TARGETS



Align and identify the acuity target inside each bucket with increasingly small concentric C gaps in one of eight directions.



# Bucket Details – Numbering and Lettering

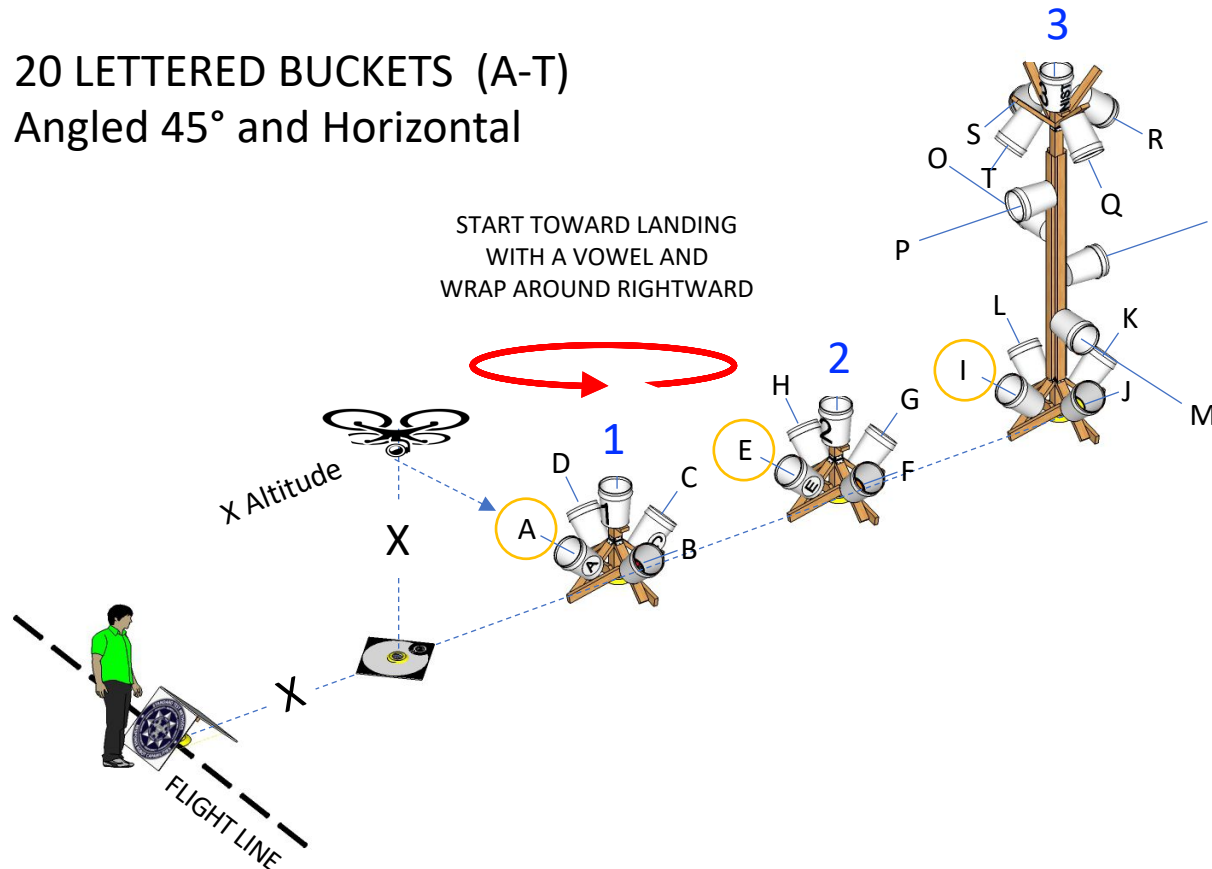
## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

3 NUMBERED BUCKETS (1-3)

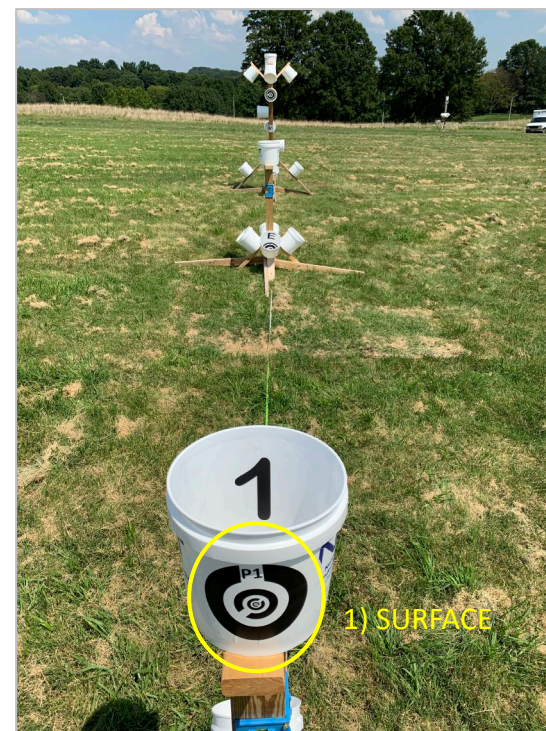
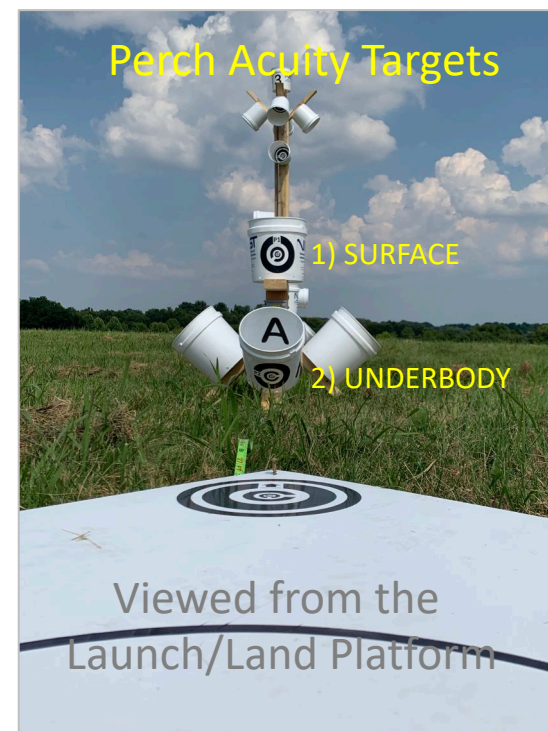
Top Vertical

20 LETTERED BUCKETS (A-T)

Angled 45° and Horizontal



Numbers and letters inside the buckets help guide the pilot.



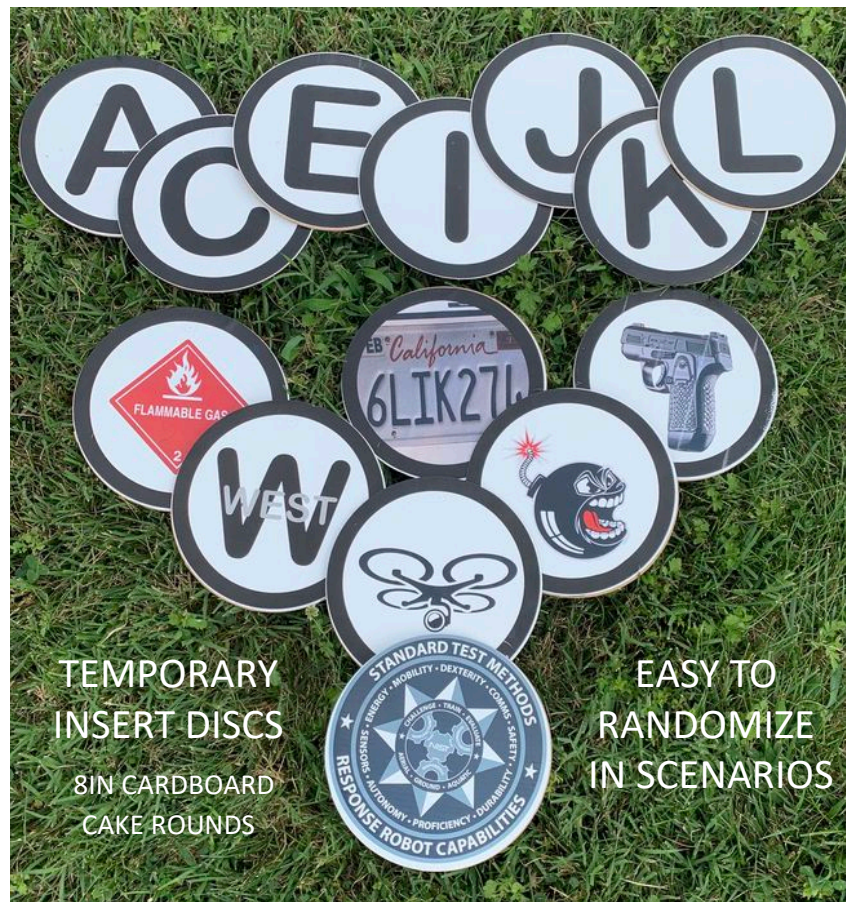
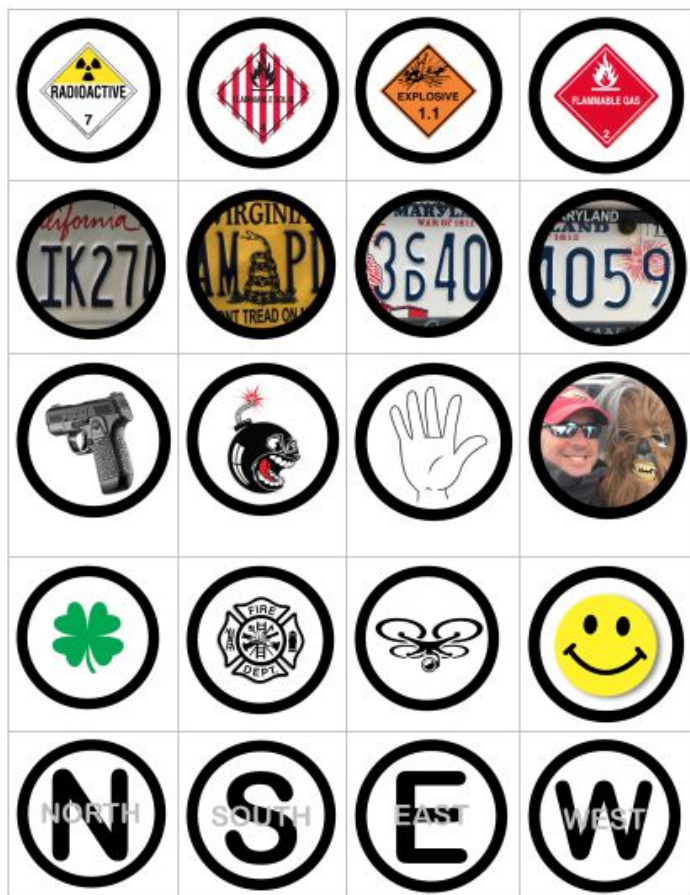
Perch acuity from the Launch/Land Platform  
benefit from accurate landings to apply full zoom capabilities



# Bucket Details - 2 Gallon (8in Diam) Sticker Files

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

Waterproof polyester stickers are preferred because they are easy to insert and adjust initially. They also survive the elements. Stickers can contain more than just numbers, letters, and acuity targets. More operationally significant or just random targets work too.



### All Basic Lane Buckets

<https://drive.google.com/open?id=1NQrHY3UH98fUeXKyffnQwt6-h5ewoeqU>

### Letters - INSERT DISCS FOR MAN

<https://drive.google.com/open?id=1FoQvoKkQu5jUC4bJJNM7TailCWWs-C3>

### Concentric Cs Black - SENSOR PANELS

[https://drive.google.com/open?id=1YxY1\\_26dn1KB0FHfleU4Xna\\_gxHzw98L](https://drive.google.com/open?id=1YxY1_26dn1KB0FHfleU4Xna_gxHzw98L)

### Concentric Cs Color - SCENARIOS

<https://drive.google.com/open?id=198sR8TzRB4TKtvZvHcAuXRWdgS35Thzi>

### Misc Hazmats, Directions, Plates, Images

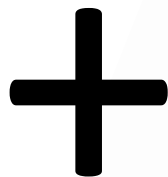
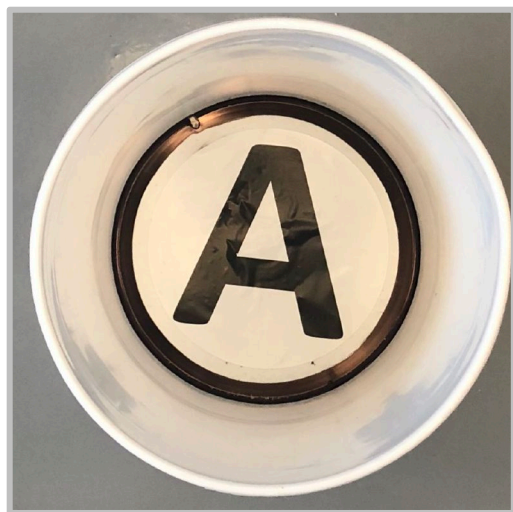
[https://drive.google.com/open?id=1nuHvZS9ARZ6Kkf\\_vJZKbhO6qwEo4UlkM](https://drive.google.com/open?id=1nuHvZS9ARZ6Kkf_vJZKbhO6qwEo4UlkM)

### Xtra Bucket Stands for Scenarios

<https://drive.google.com/open?id=1RklQazk4r8ZyUPJxidjNpVyF-ZNRCrn>

# Bucket Details – 5 Gallon (10in Diam) Inscribed Rings

Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)



- 2 gallon and 5 gallon buckets with inscribed rings and targets inside are essentially interchangeable. The larger bucket has only a slighter bigger diameter but at 20+ ft altitude this is negligible.
- 5 gallon white buckets with 10 in diameter inside bottoms require an inscribed ring plus a sticker.
- Use an extra large black marker to make a 5/8in inscribed ring.
- Tip: Press down using the thickest dimension of the marker tip and pull toward you in the bottom corner of the bucket. Then ROTATE THE BUCKET two revolutions.



# Choosing An Appropriate Lane Spacing

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

### MAN 1-5 LETTER IDENTIFIERS



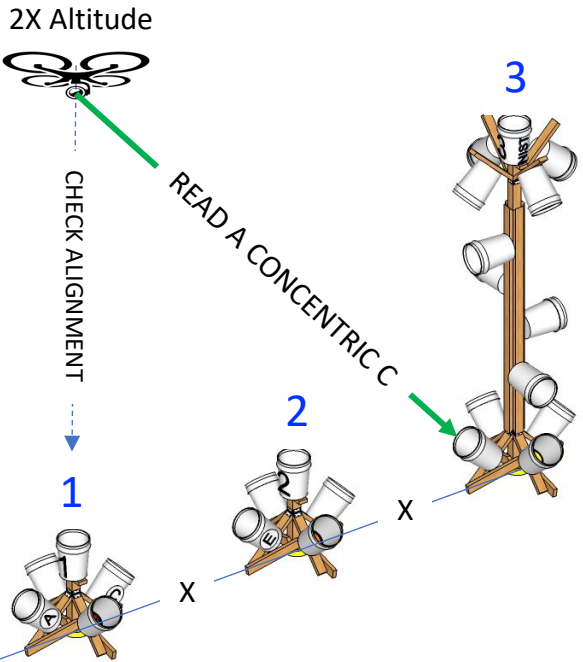
Align to see the entire inscribed ring inside the buckets. The letters are bucket identifiers.

NOT QUITE ALIGNED

### PAY 1-5 VISUAL ACUITY TARGETS



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



An appropriate lane spacing is when a 2X hover allows reading at least the outer ring of a concentric C target two stands away.



THIS SHOWS THE ANGLED BUCKETS ARE TOO FAR AWAY FOR THE OPTICS ON THIS AIRCRAFT  
---- MOVE TO A SHORTER LANE SPACING ----



THIS IS JUST BARELY CLOSE ENOUGH TO BE CERTAIN OF A COMPLETELY INSCRIBED RING (ROUGHLY 1 / 10 OF THE DISPLAY OR LARGER)



# Position Test Procedure

## Maneuvering (MAN 1) and Payload Functionality (PAY 1)

### MAN 1-5 LETTER IDENTIFIERS



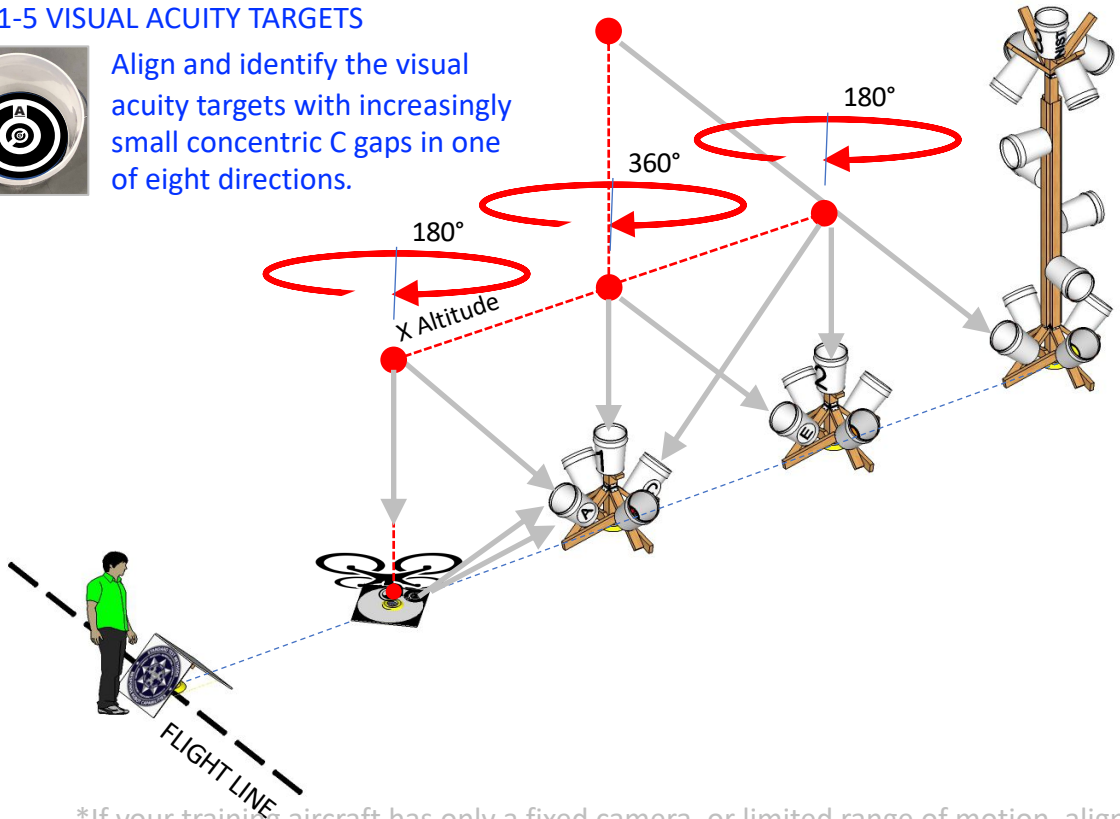
Align to see the entire inscribed ring inside the buckets. The letters are bucket identifiers.

NOT QUITE ALIGNED

### PAY 1-5 VISUAL ACUITY TARGETS



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



### FLIGHT PATH

### SCORING

MAN

PAY

START THE TIMER when the drone launches from the platform

- |                                      |          |          |
|--------------------------------------|----------|----------|
| 1. HOVER at X over Bucket 1          | Bucket E | Bucket 1 |
| 2. ROTATE RIGHT 360°                 | Bucket E | Bucket 1 |
| 3. ROTATE LEFT 360°                  | Bucket E | Bucket 1 |
| 4. CLIMB to 2X                       | Bucket I | Bucket 1 |
| 5. DESCEND to X                      | Bucket E | Bucket 1 |
| 6. FORWARD over Bucket 2             | Bucket I | Bucket 2 |
| 7. BACKWARD over Bucket 1            | Bucket E | Bucket 1 |
| 8. FORWARD/ROTATE 180° over Bucket 2 | Bucket C | Bucket 2 |
| 9. FORWARD/ROTATE 180° over Landing  | Bucket A | Landing  |
| 10. LAND CENTERED facing stands      | Centered | Perch 1  |
|                                      | Centered | Perch 2  |

MAN: 20 points, 10 Positions, 18 Alignments and a Landing (2pts)

PAY: 100 points, 10 Positions, 18 Bucket Targets and 2 Perch Targets

\*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.

# Position Test Form

## Maneuvering (MAN 1) and Payload Functionality (PAY 1)

### MAN 1-5 LETTER IDENTIFIERS



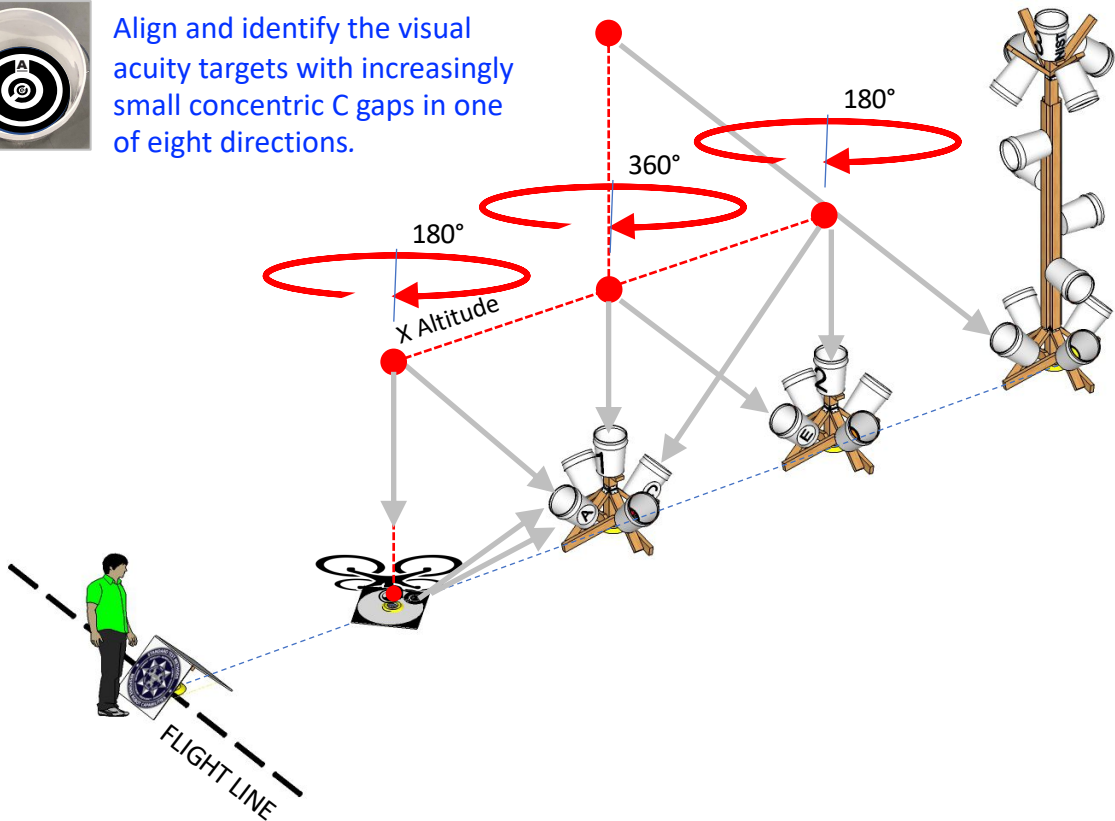
Align to see the entire inscribed ring inside the buckets to. The letters are bucket identifiers.

NOT QUITE ALIGNED

### PAY 1-5 VISUAL ACUITY TARGETS



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



### FORM FOR TRACKING YOUR PERFORMANCE OVER TIME

PROCEDURE   FLIGHT PATHS	Aligned   C's	Aligned   C's
1. HOVER at X over Bucket 1	<input type="checkbox"/> Bucket E	<input type="checkbox"/> Bucket 1
2. ROTATE RIGHT 360°	<input type="checkbox"/> Bucket E	<input type="checkbox"/> Bucket 1
3. ROTATE LEFT 360°	<input type="checkbox"/> Bucket E	<input type="checkbox"/> Bucket 1
4. CLIMB to 2X	<input type="checkbox"/> Bucket I	<input type="checkbox"/> Bucket 1
5. DESCEND to 1X	<input type="checkbox"/> Bucket E	<input type="checkbox"/> Bucket 1
6. FORWARD over Bucket 2	<input type="checkbox"/> Bucket I	<input type="checkbox"/> Bucket 2
7. BACKWARD over Bucket 1	<input type="checkbox"/> Bucket E	<input type="checkbox"/> Bucket 1
8. FORWARD/ROTATE 180° over Bucket 2	<input type="checkbox"/> Bucket C	<input type="checkbox"/> Bucket 2
9. FORWARD/ROTATE 180° over Landing	<input type="checkbox"/> Bucket A	<input type="checkbox"/> Landing
10. LAND ACCURATELY FACING STANDS	<input type="checkbox"/> Centered <input type="checkbox"/> Centered	Perch 1 Perch 2
<b>FAULTS:</b> X X X (circle for each)		
ELAPSED TIME: _____ MINUTES	TOTAL ALIGNED: _____ of 20	TOTAL C's: _____ of 100
<b>MAN 1 SCORE</b> 10 Positions, 20 Bucket Targets _____	<b>RELIABILITY</b> Aligned / Attempted _____	<b>EFFICIENCY</b> Aligned / Minute _____
<b>PAY 1 SCORE</b> 10 Positions, 20 Bucket Targets _____	<b>AVERAGE ACUITY</b> Total C's / Total Targets _____	<b>EFFICIENCY</b> Total Targets / Minute _____

### MAN and PAY TEST

Check mark the buckets when aligned for both MAN and PAY

### PAY TEST ONLY

Write the number of C's correctly identified

### RESULTS

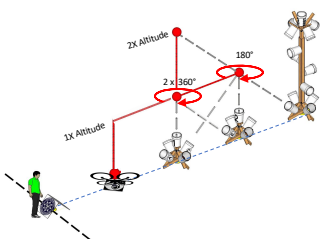
- Total aligned buckets
- Total C's identified
- Faults
- Elapsed time of trial

### METRICS (in order)

1. Score
2. Reliability/Acuity
3. Efficiency

# Comprehensive Flight Paths in a Single Lane

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)



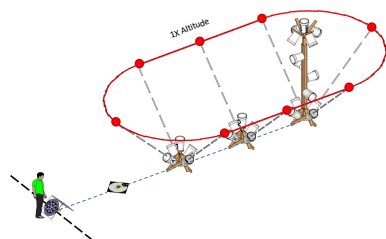
### Position

MAN 1 / PAY 1

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

MAN: Align only

PAY: Align and Identify



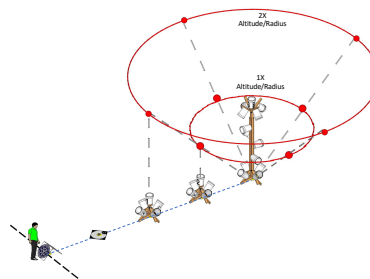
### Traverse

MAN 2 / PAY 2

- Sideways along a line
- Left and right directions
- Landing accuracy
- 20 tasks in 2 laps

MAN: Align only

PAY: Align and Identify



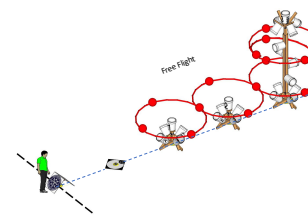
### Orbit

MAN 3 / PAY 3

- Orbit identifications
- Left and right directions
- X and 2X altitudes
- 20 tasks in 4 laps

MAN: Align only

PAY: Align and Identify



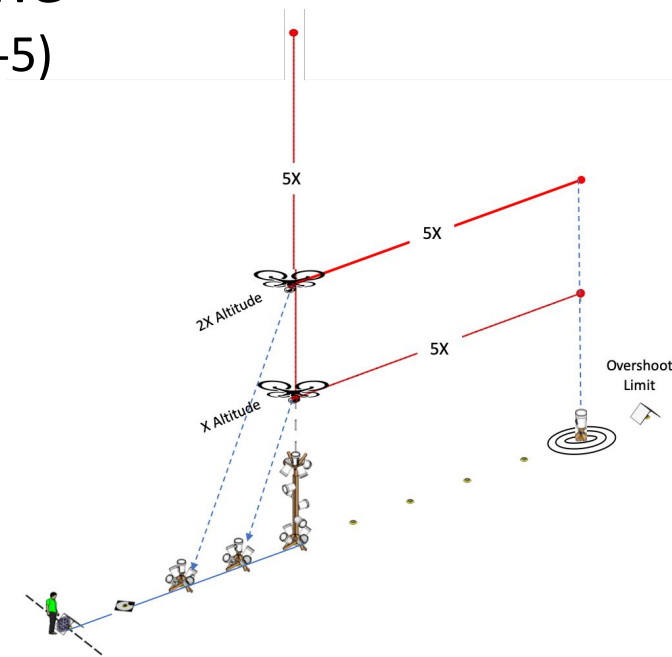
### Spiral

MAN 4 / PAY 4

- Free flight inspections
- Any proximity
- Any altitude
- 20 tasks in 1 lap

MAN: Align only

PAY: Align and Identify



### Sustain Speed/Deliver Accurately

MAN 5 / PAY 5

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

MAN: Follow paths

PAY: Deliver Payload Accurately

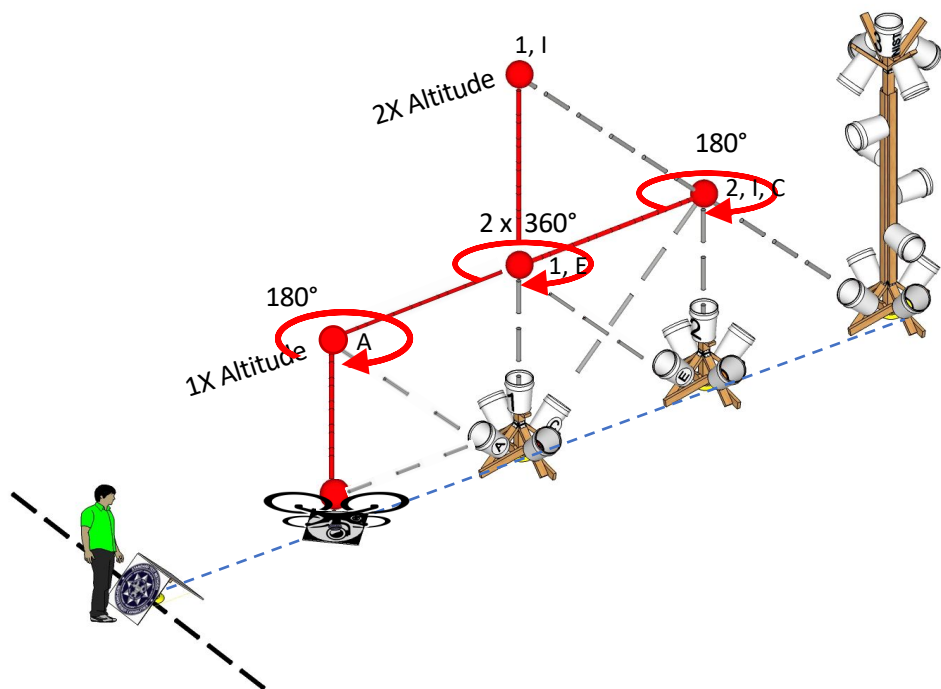


# Evaluate System Capabilities or Pilot Proficiency

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

### Position (Version D)

MAN 1 / PAY 1



START POSITION



Bucket  
Targets

### MANEUVERING 1 (MAN 1)

- 10 positions in 1 lap
- 18 bucket alignments and 1 landing (2pts)
- 1 point each
- **20 points maximum**



### PAYLOAD FUNCTIONALITY 1 (PAY 1)

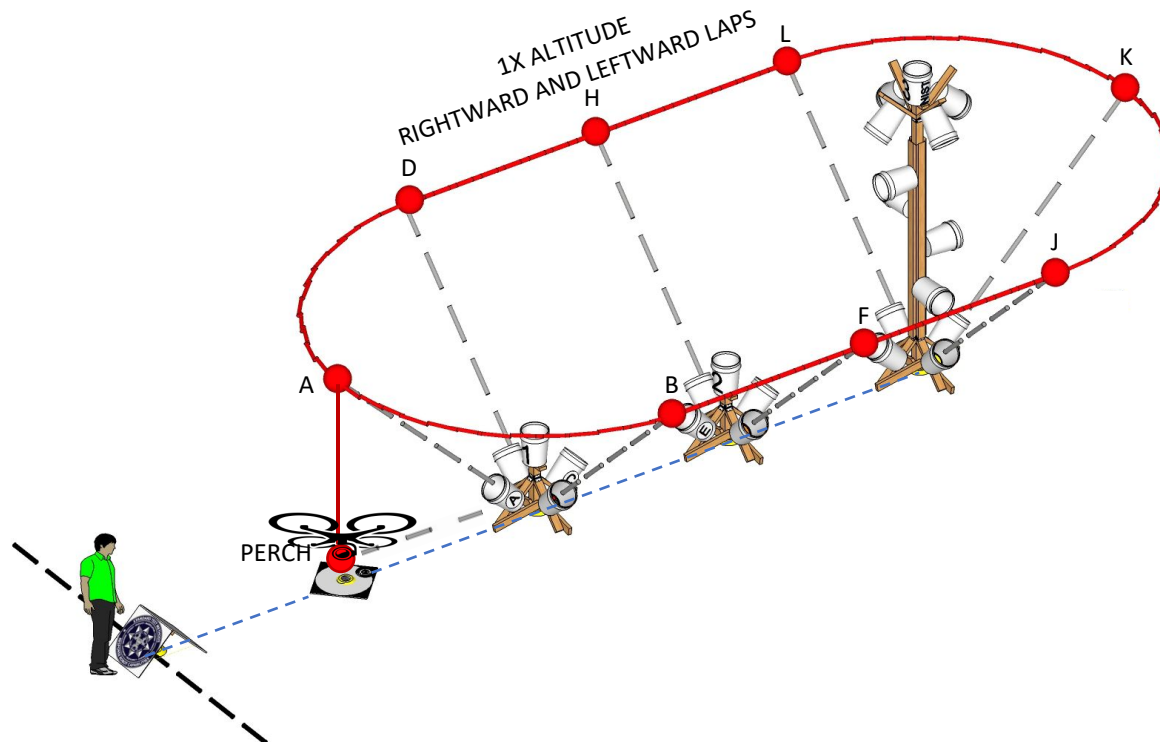
- 10 positions in 1 lap
- 18 bucket targets and 2 perch targets
- 5 concentric Cs per target
- **100 points maximum per lap**

# Evaluate System Capabilities or Pilot Proficiency

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

### Traverse

MAN 2 / PAY 2



START POSITION



Bucket  
Targets

#### MANEUVERING 2 (MAN 2)

- 20 alignments in 2 laps (rightward/leftward)
- 18 bucket alignments and 2 landings
- 1 point each
- **20 points maximum**



#### PAYLOAD FUNCTIONALITY 2 (PAY 2)

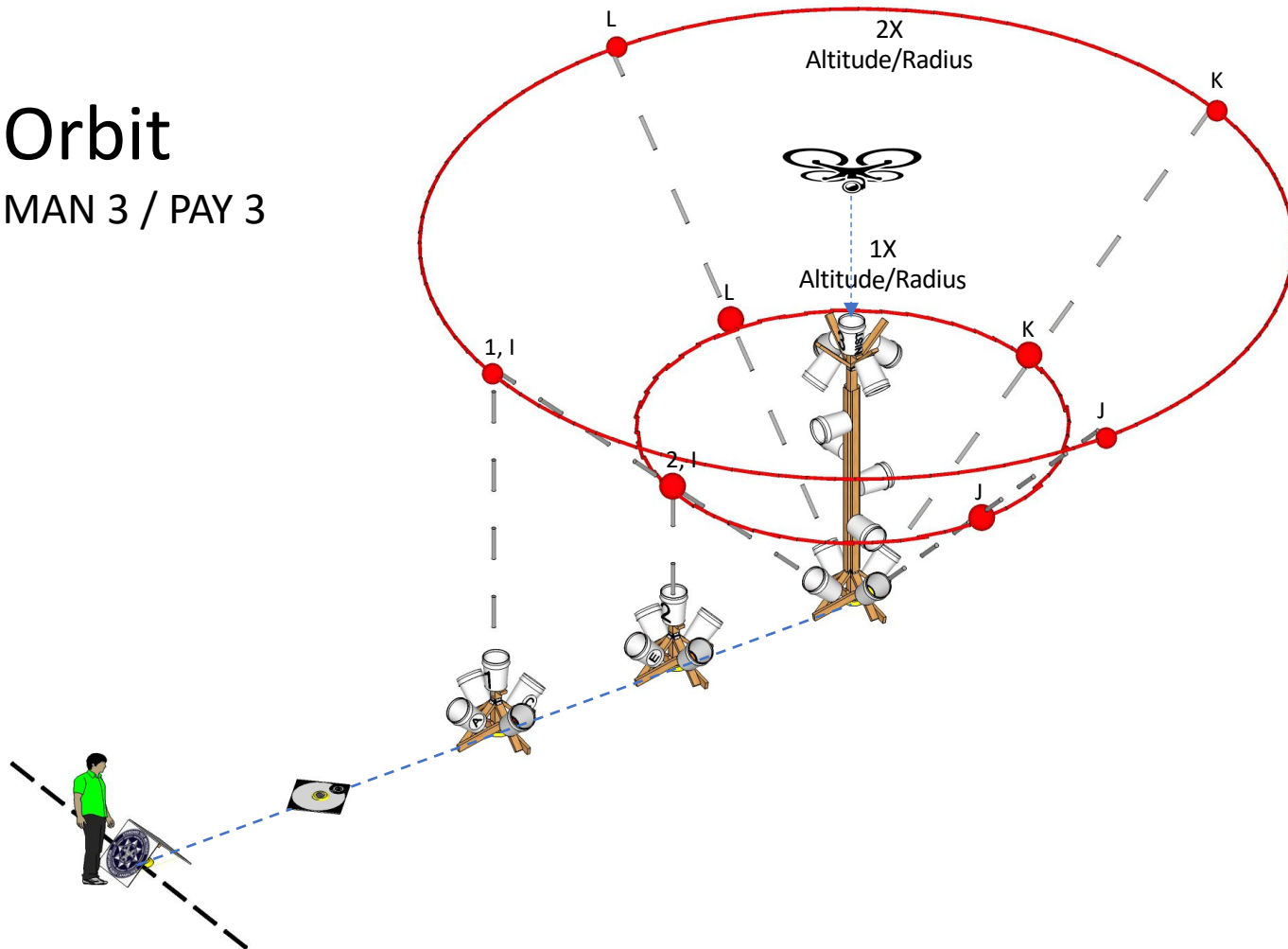
- 20 targets in 2 laps (rightward/leftward)
- 18 bucket targets and 2 perch targets
- 5 concentric Cs per target
- **100 points maximum**

# Evaluate System Capabilities or Pilot Proficiency

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

### Orbit

MAN 3 / PAY 3



START POSITION



Bucket  
Targets



### MANEUVERING 3 (MAN 3)

- 20 alignments in 4 orbits (rightward & leftward, 1X & 2X)
- Each orbit has 4 buckets toward center and 1 downward radius
- 1 point each
- **20 points maximum**

### PAYLOAD FUNCTIONALITY 3 (PAY 3)

- 20 targets in 4 orbits (rightward & leftward, 1X & 2X)
- Each orbit has 4 buckets toward center and 1 downward radius
- 5 concentric Cs per target
- **100 points maximum**

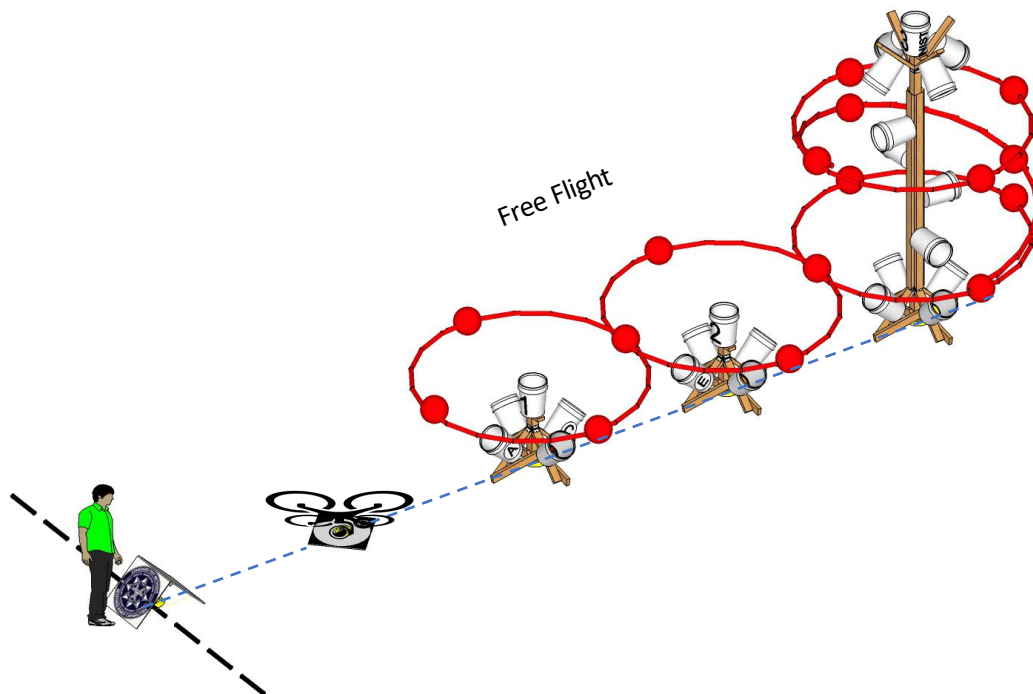


# Evaluate System Capabilities or Pilot Proficiency

Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

## Spiral

MAN 4 / PAY 4



START POSITION



### MANEUVERING 4 (MAN 4)

- 20 bucket alignments in 1 lap
- 1 Point Each
- **20 Points Maximum**

Bucket  
Targets



### PAYLOAD FUNCTIONALITY 4 (PAY 4)

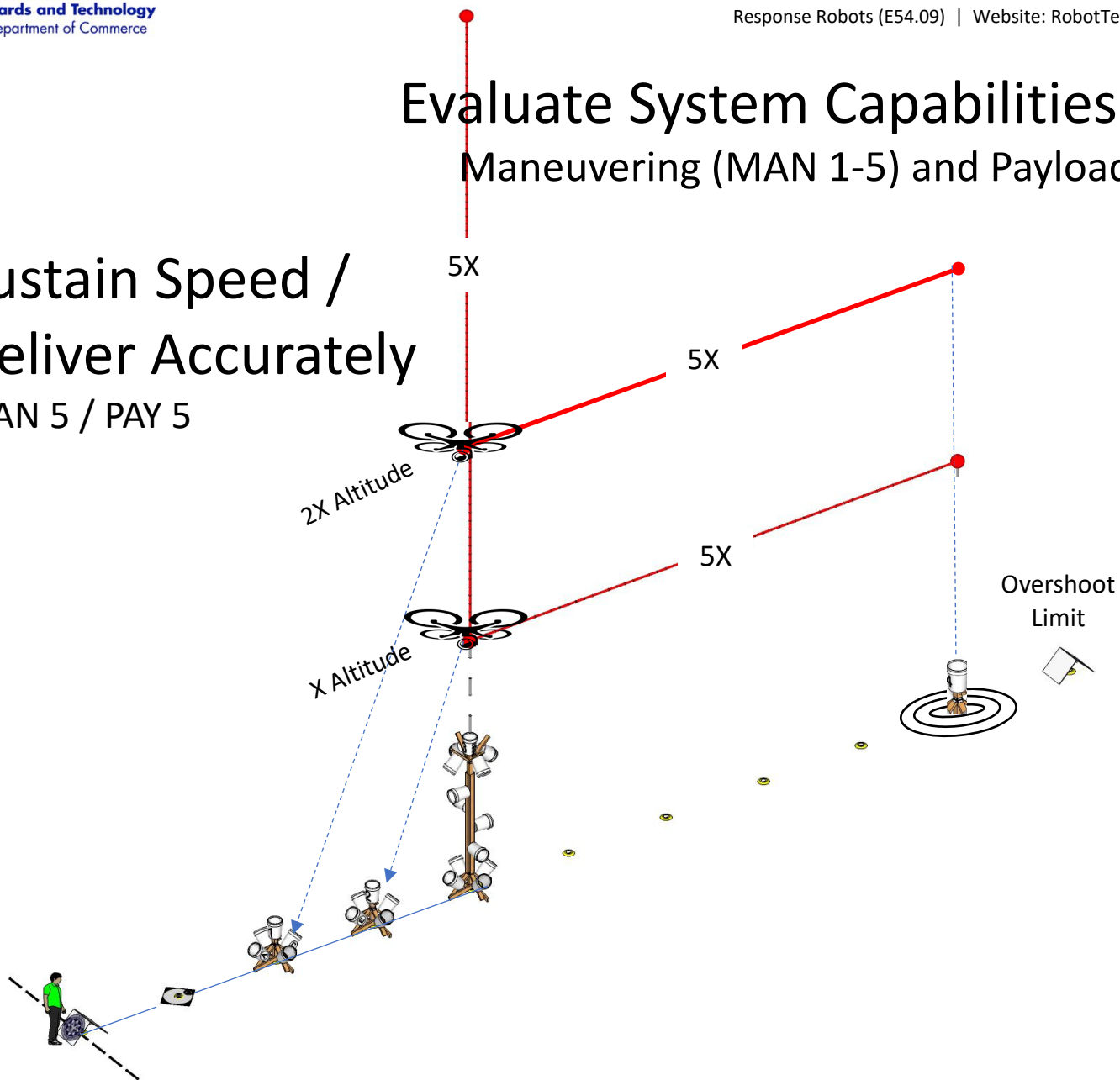
- 20 targets in 1 lap
- 5 concentric Cs per target
- **100 Points Maximum**

# Evaluate System Capabilities or Pilot Proficiency

Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

Sustain Speed /  
Deliver Accurately

MAN 5 / PAY 5



START POSITION



## MANEUVERING 5 (MAN 5)

- 5 laps
- 4 flight path (2 horizontal, 2 vertical)
- 1 Point Each
- **20 Points Maximum**



## PAYLOAD FUNCTIONALITY 5 (PAY 5)

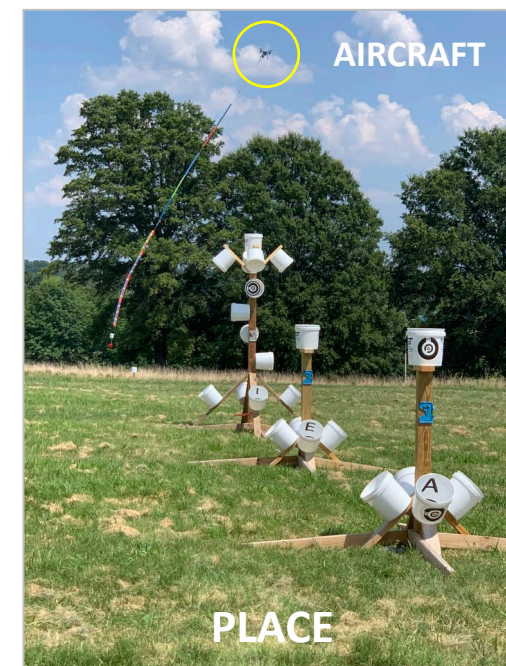
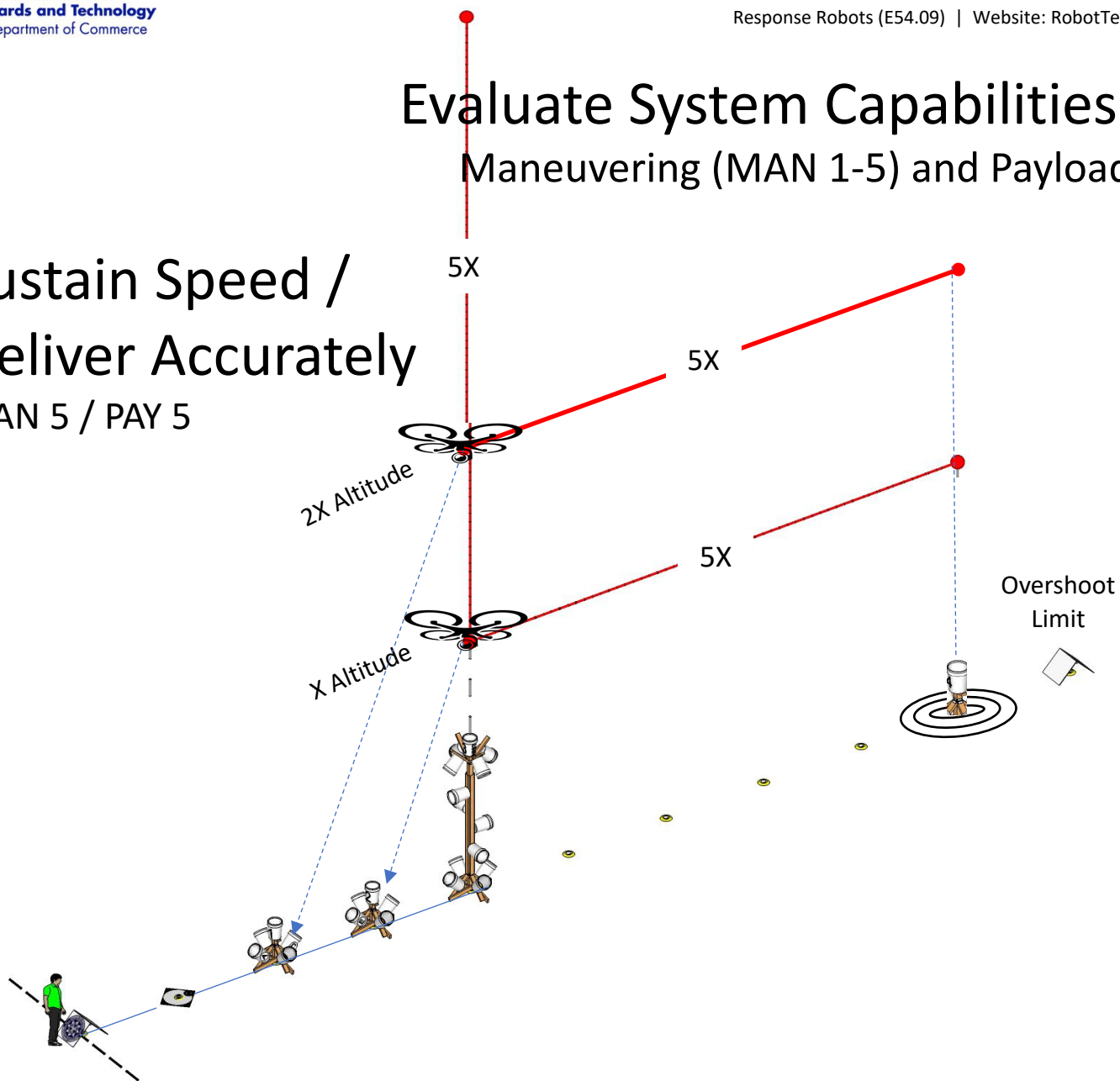
- 5 placements or drop from 2X altitude
- 20 points for diameters from 4-20ft
- **100 Points Maximum**  
(max weight object)

# Evaluate System Capabilities or Pilot Proficiency

Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

Sustain Speed /  
Deliver Accurately

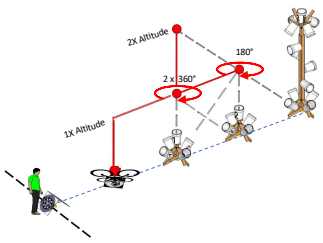
MAN 5 / PAY 5





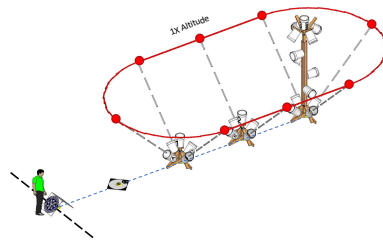
# Circuit Training with Scores

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)



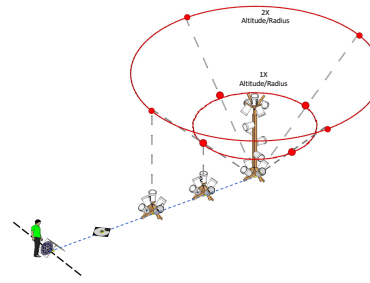
**Position**  
MAN 1 / PAY 1

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



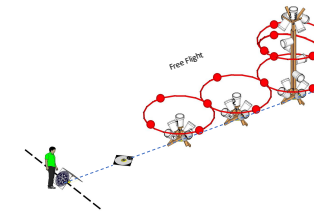
**Traverse**  
MAN 2 / PAY 2

- Sideways along a line
- Left and right directions
- Landing accuracy
- 20 tasks in 2 laps



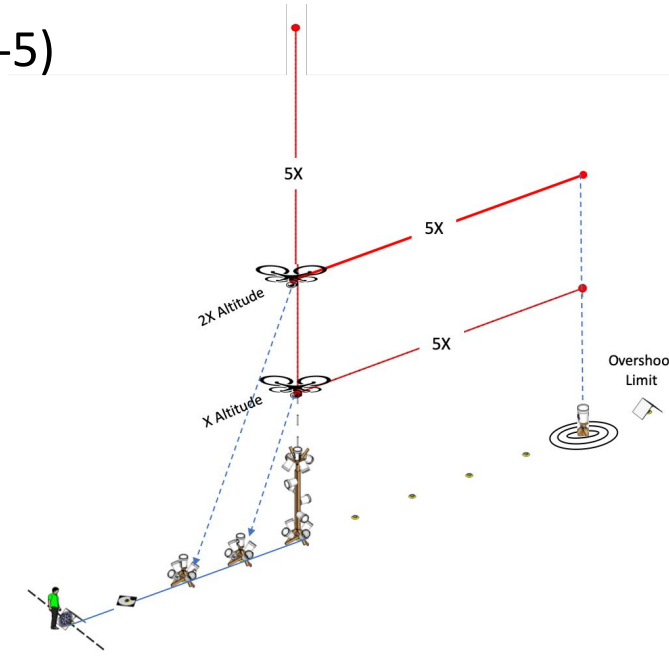
**Orbit**  
MAN 3 / PAY 3

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



**Spiral**  
MAN 4 / PAY 4

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



**Sustain Speed / Deliver Accurately**  
MAN 5 / PAY 5

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

# Circuit Training with Scores

## Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

20 points per test  
**100 points total**

**LETTER IDENTIFIERS MAN 1-5**  
See the entire inscribed ring inside the buckets to evaluate successful alignments. The letters are bucket identifiers.



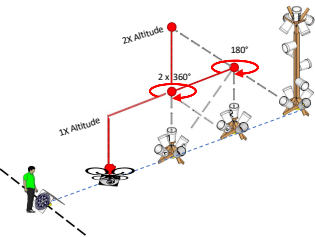
NOT QUITE  
ALIGNED



ALIGNED

**PAY 1-5 VISUAL ACUITY TARGETS**  
Align and identify the visual acuity targets with increasingly small concentric C gaps in one of eight directions.

100 points per test  
**500 points total**

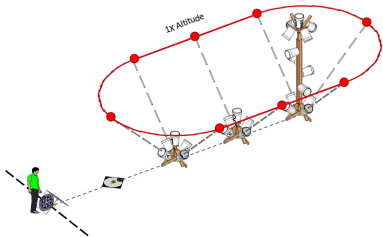


**Position**  
MAN 1 / PAY 1

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

MAN: Align only  
20 points max

PAY: Align and Identify  
100 points max

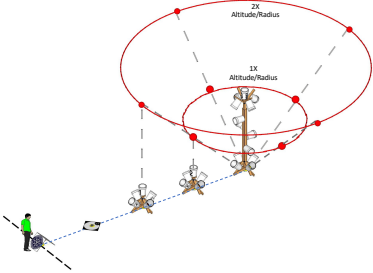


**Traverse**  
MAN 2 / PAY 2

- Sideways along a line
- Left and right directions
- Landing accuracy
- 20 tasks in 2 laps

MAN: Align only  
20 points max

PAY: Align and Identify  
100 points max

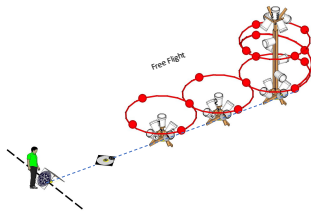


**Orbit**  
MAN 3 / PAY 3

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

MAN: Align only  
20 points max

PAY: Align and Identify  
100 points max

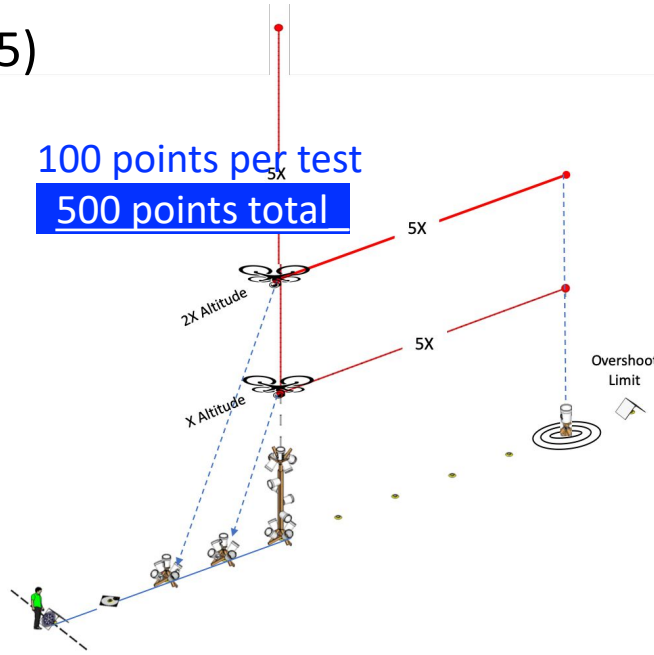


**Spiral**  
MAN 4 / PAY 4

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

MAN: Align only  
20 points max

PAY: Align and Identify  
100 points max



**Sustain Speed / Deliver Accurately**  
MAN 5 / PAY 5

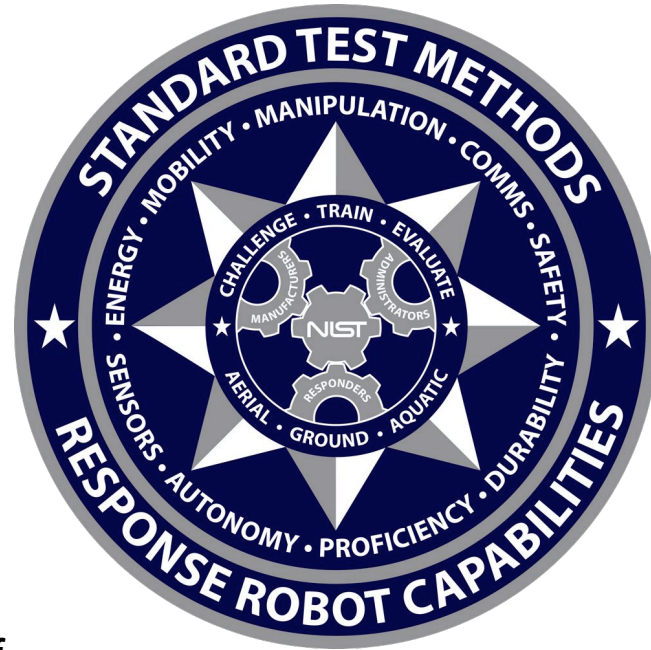
- Max speed following a line
- 5X distance
- X altitude
- 20X distance per lap

MAN: Follow the flight paths  
20 points max

PAY: Deliver accurately  
100 points max

# Training and Embedding into Scenarios

## Maneuvering (MAN 1) and Payload Functionality (PAY 1)



*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](http://RobotTestMethods.nist.gov)

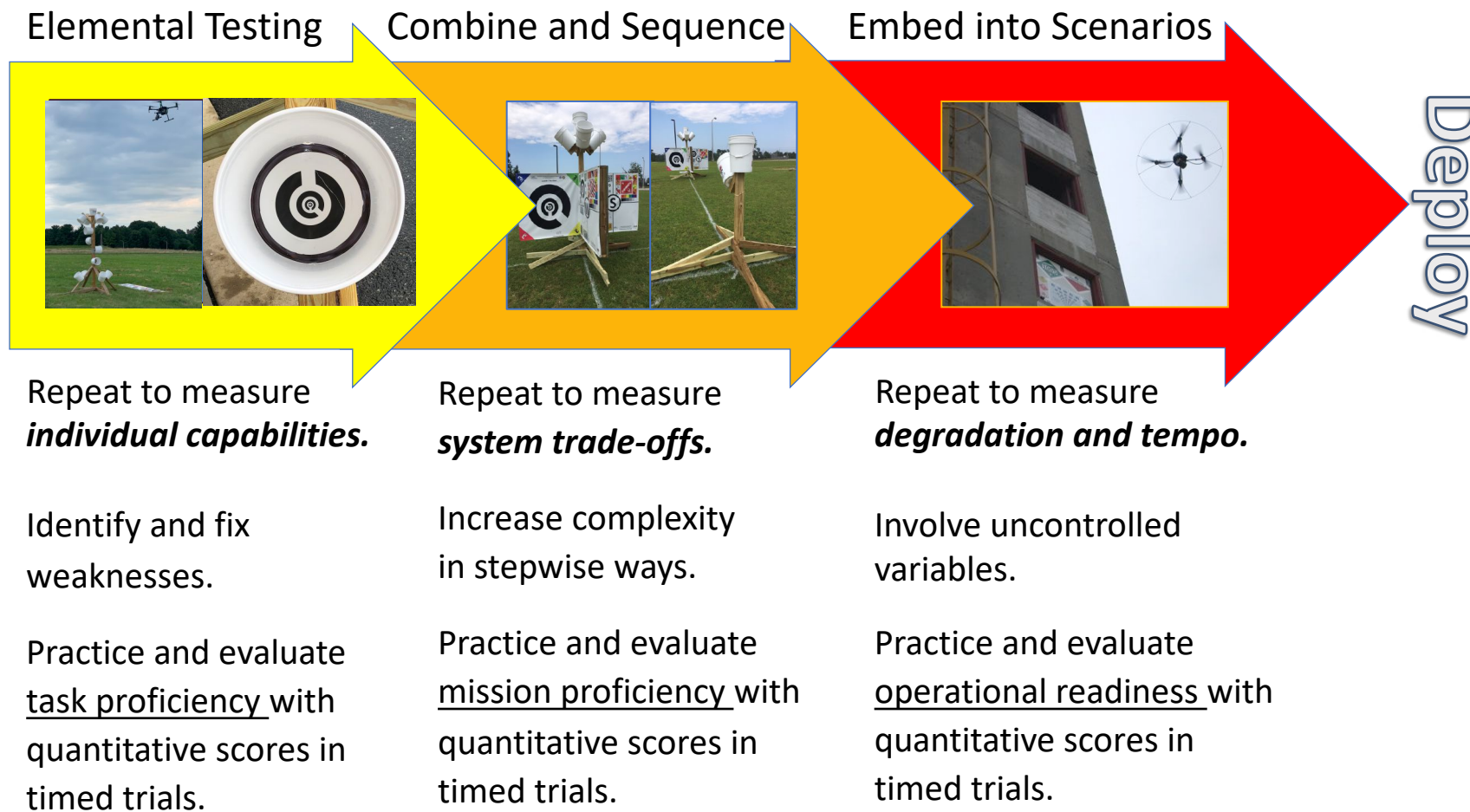


Email  
[RobotTestMethods@nist.gov](mailto:RobotTestMethods@nist.gov)



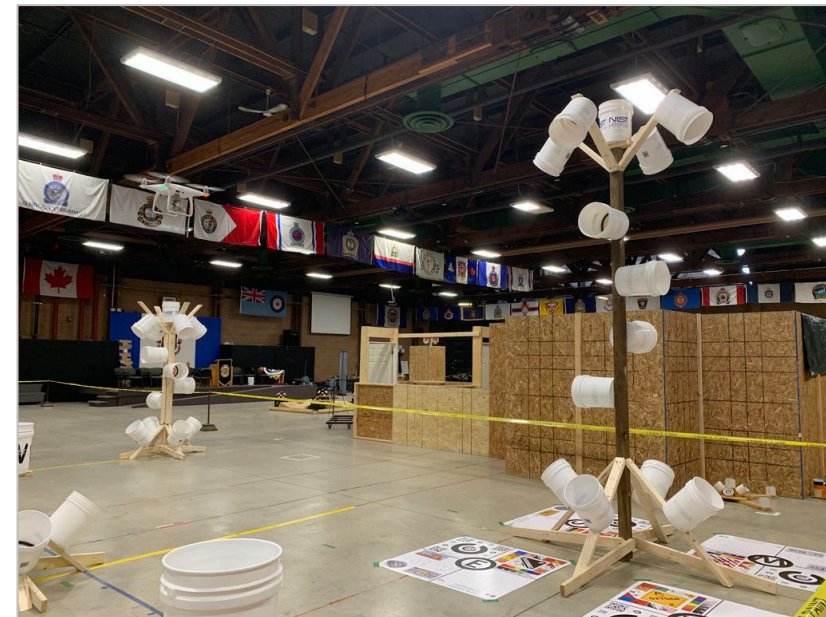
# Using Standard Test Methods

## Safety | Capabilities | Proficiency



# Concurrent Test Lanes

## Training and Evaluation

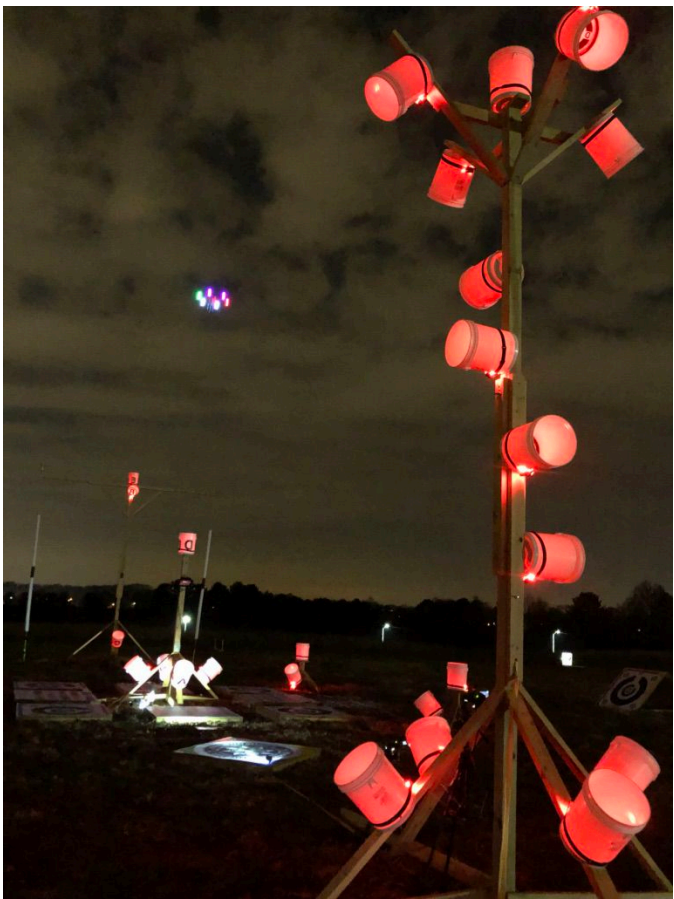


Ceiling height determines maximum safe hover altitude (2X)

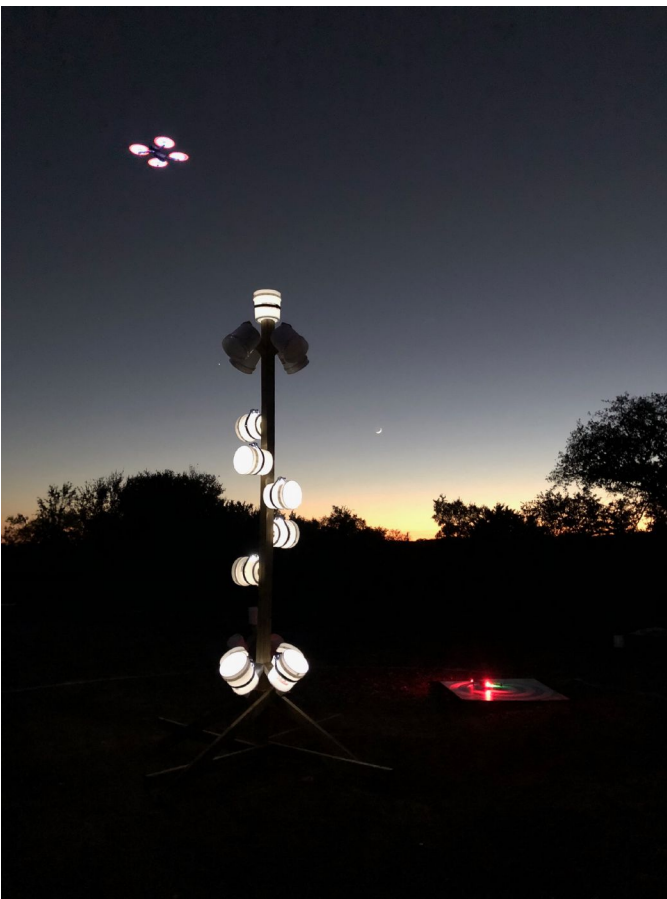


# Night Operations Training and Evaluation

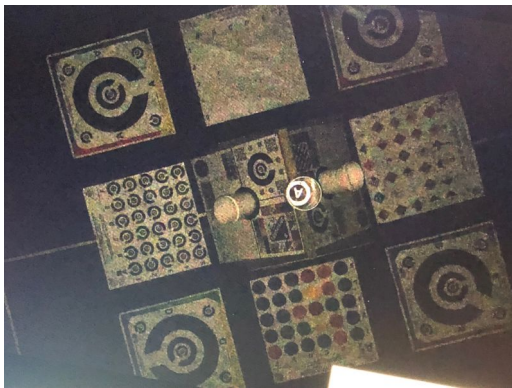
Headlamps wrapped around  
the buckets pointed inward!



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



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



Identify objects  
lighted from the aircraft



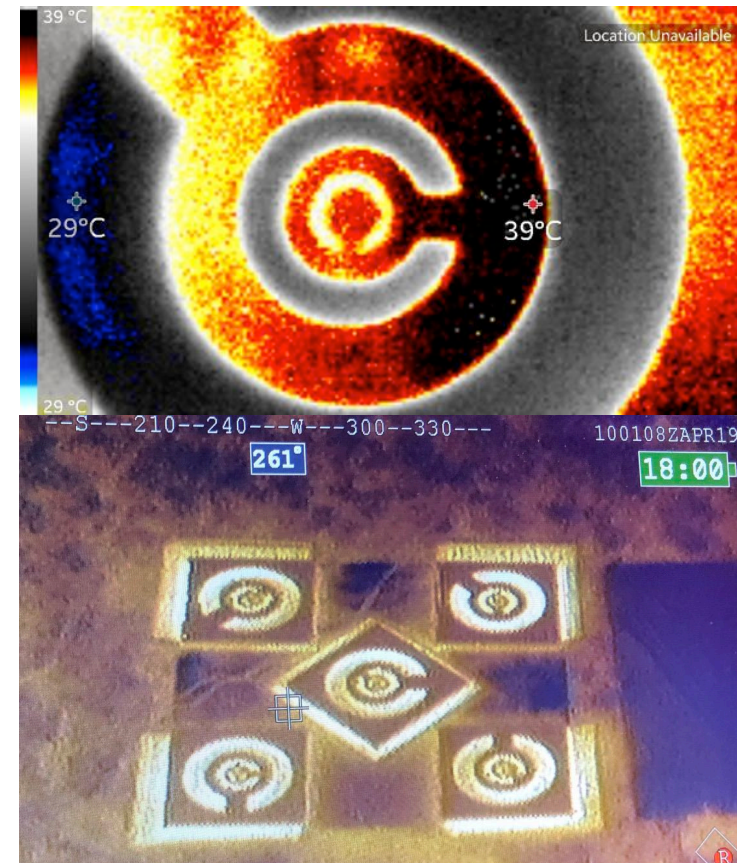
Measure additional  
sensor capabilities

*NIST and Reveille Peak Ranch, Burnet, TX*



# Thermal Targets

## Training and Evaluation





# Embed 20 Targets into ANY Scenario

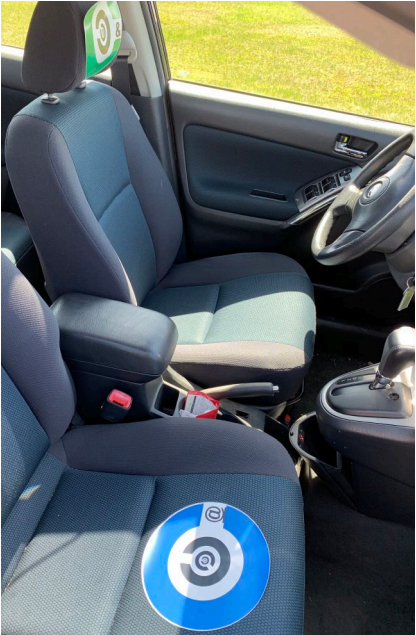
## Training and Evaluation

DOWNLOAD THE 8IN ROUND STICKER FILE

20 Visual/Color Acuity Targets x 5 Concentric Cs = 100 Points

[https://drive.google.com/file/d/15G1NUarr1\\_vOdf\\_1gYgJellA8HuqJngT/view?usp=sharing](https://drive.google.com/file/d/15G1NUarr1_vOdf_1gYgJellA8HuqJngT/view?usp=sharing)

4	#	ROOF STAND – TOP BUCKET	Any unique number to identify the scenario feature
A	A	ROOF STAND – ANGLED BUCKET	Front of the vehicle
B	B	ROOF STAND – ANGLED BUCKET	Driver side
C	C	ROOF STAND – ANGLED BUCKET	Rear
D	D	ROOF STAND – ANGLED BUCKET	Passenger side
E	E	FRONT	License plate
F	F	FRONT	Vehicle ID number
G	G	DRIVER SIDE	Window profile of driver
H	H	DRIVER SIDE	Other location of interest
I	I	DRIVER SIDE	Other location of interest
J	J	DRIVER SIDE	Other location of interest
K	K	REAR	License plate
L	L	REAR	Other location of interest
M	M	PASSENGER SIDE	Other location of interest
N	N	PASSENGER SIDE	Other location of interest
O	O	PASSENGER SIDE	Other location of interest
P	P	PASSENGER SIDE	Window profile of passenger
Q	Q	CAB INTERIOR	Passenger headrest face view
R	R	CAB INTERIOR	Passenger seat with object
S	S	CAB INTERIOR	Driver seat with object
T	T	CAB INTERIOR	Driver headrest face view





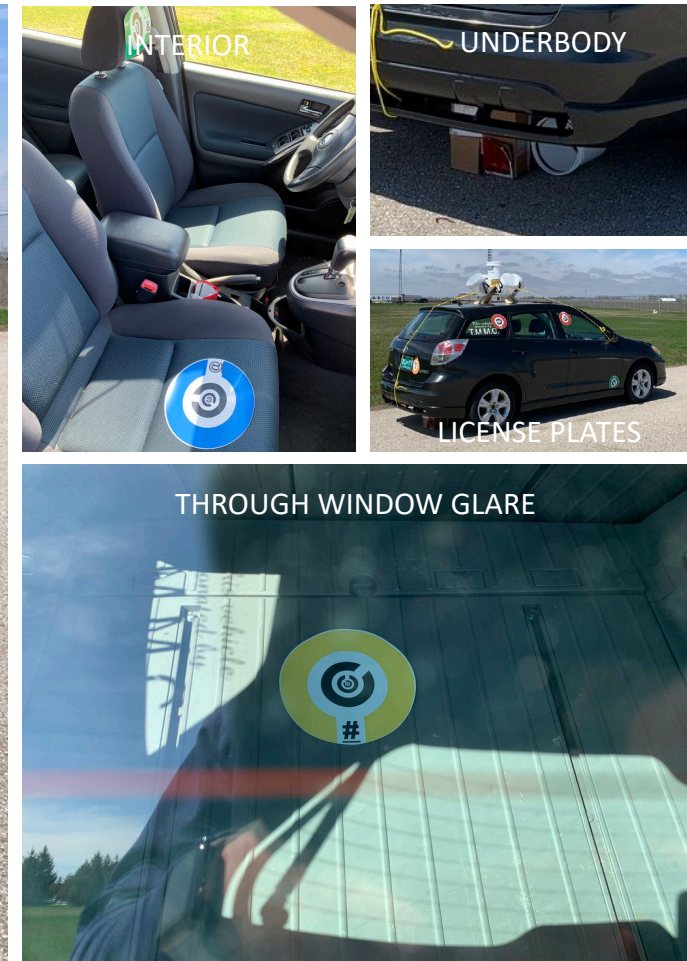
# Sedan Inspection Training and Evaluation

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

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

Spiral inspect all sides and interior.

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





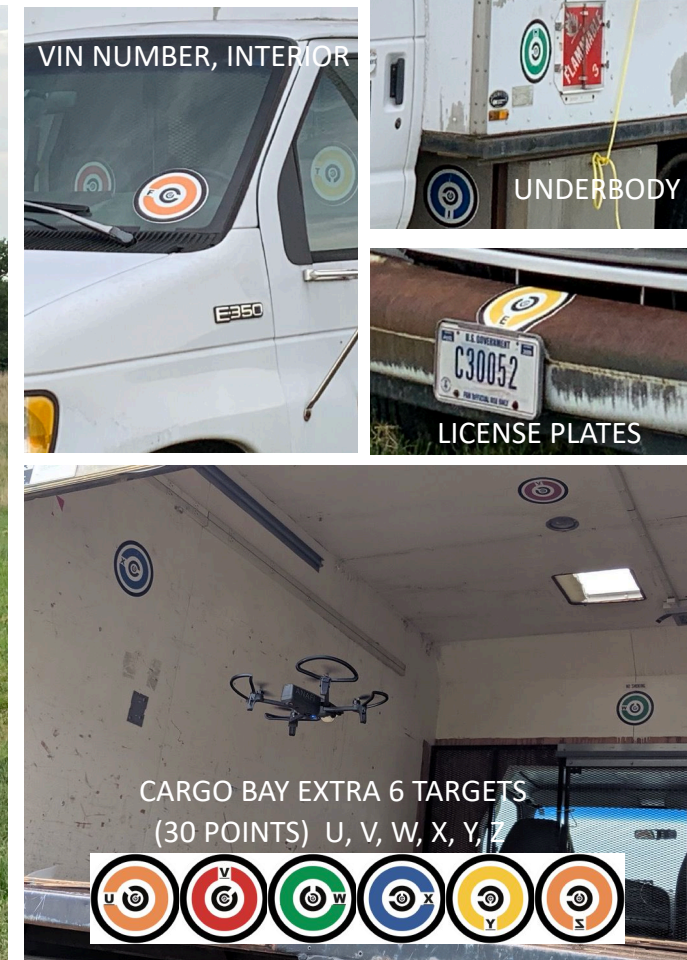
# Box Truck Inspection Training and Evaluation

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

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

Spiral inspect all sides and interior.

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





# Fuel Truck / Rail Car Inspection Training and Evaluation

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

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

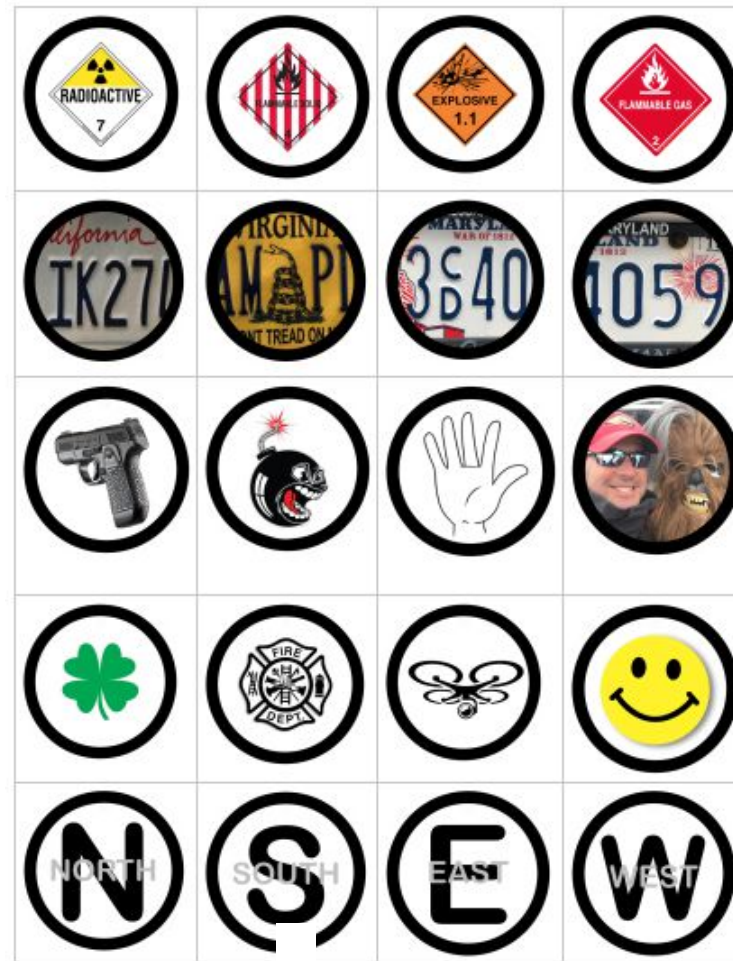
Spiral inspect all sides and interior.

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



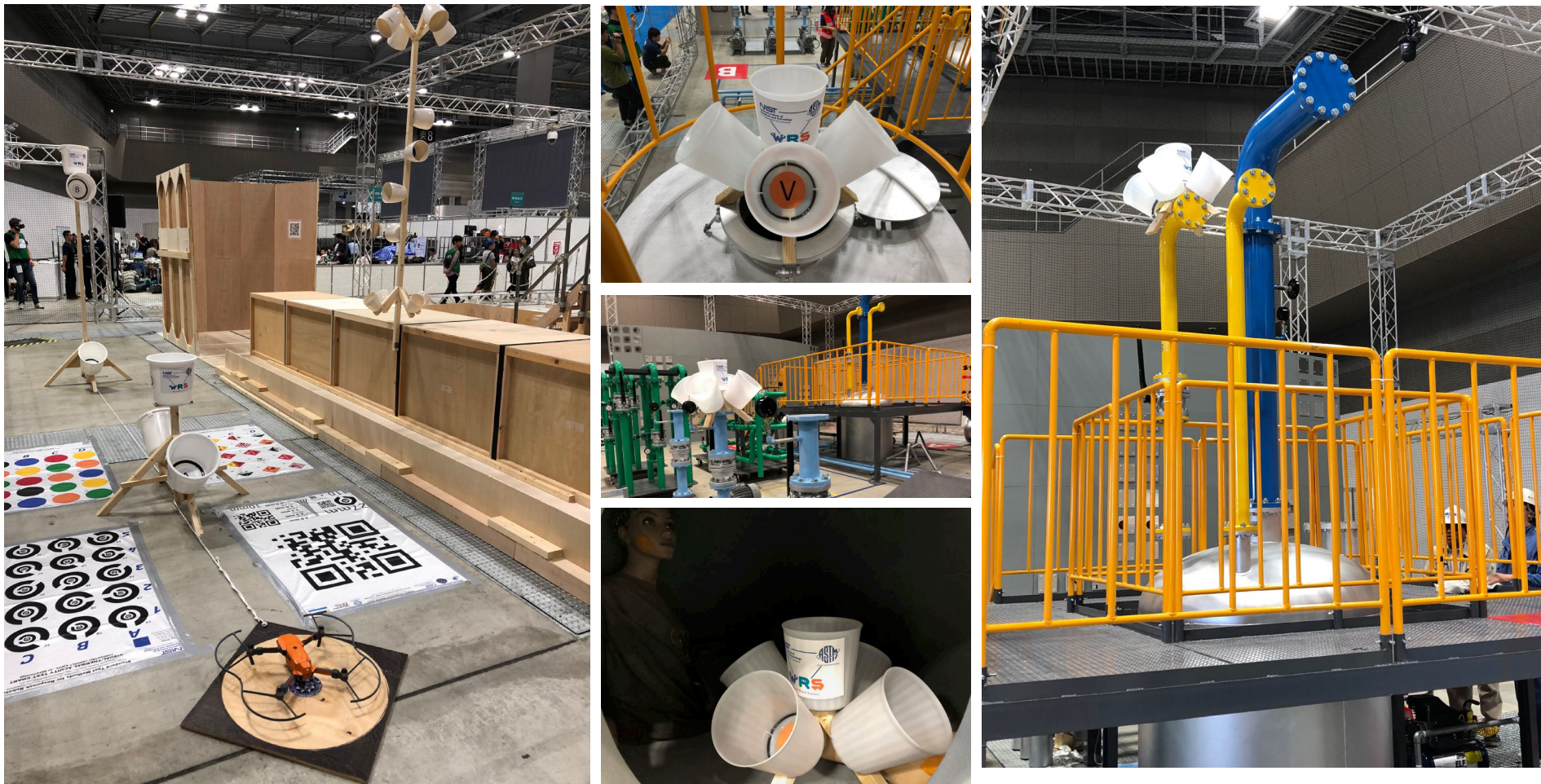


# Wide Area Search Training and Evaluation





# Indoor Search Training and Evaluation



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

# Measure and Track Performance, Then Set Thresholds Training and Evaluation

Roles for Standards  
Organizations and Others



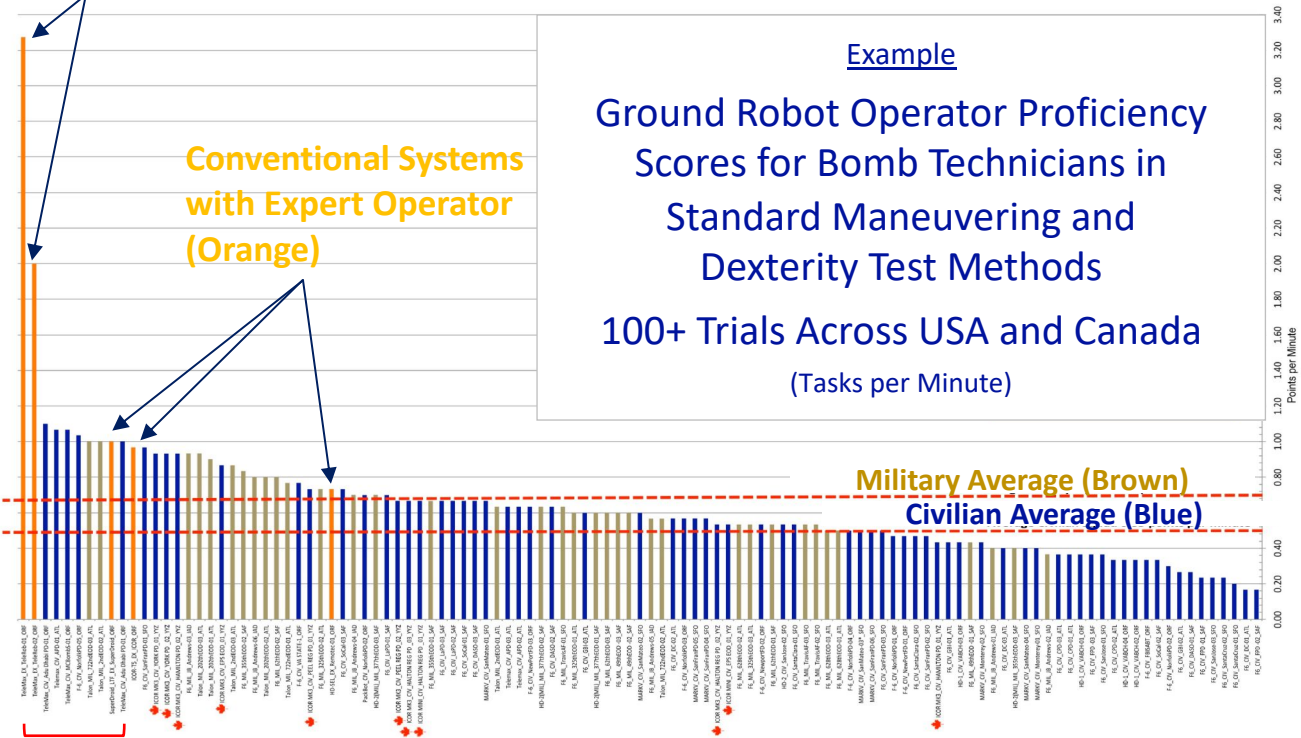
Select standard  
tests that define  
readiness for  
mission tasks.

Set thresholds  
or adopt averages



Develop standard  
test methods and  
collect robot  
capability and  
reliability data with  
“expert” operators

Technical Improvement  
Best-In-Class System with Expert Operators  
(Orange)



Top 6 of the top 10 responder operators using the best-in-class system  
(Ease of Use Indicator)

# Supporting NFPA 2400 Job Performance Requirements

Safety | Capabilities | Proficiency

## *Chapter 5 excerpts:*

- “Perform aerial maneuvers.... so that the **pilot demonstrates positive aircraft control....**”
- “Perform payload functionality... so that the **sUAS is maneuvered in a manner that avoids obstacles and demonstrates payload drop, payload application, or data acquisition at targeted locations...**”

## *Appendix A:*

### **Maneuvering Test Methods**

- *Maintain Position and Rotate*
- *Fly Straight and Level*
- *Move and Rotate*
- *Avoid Obstacles*
- *Land Accurately*

### **Payload Functionality Test Methods**

- *Point and Zoom Cameras*
- *Identify Objects*
- *Inspect Objects*
- *Map Wide Areas*
- *Drop Accurately*



# Supporting ASTM F38 Practical Skills Requirement

Safety | Capabilities | Proficiency

*“Standard Guide for Training for Remote Pilot in Command of UAS Endorsement”*

Qualitative Task Performance Levels:

**4) PROFICIENT**

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

**3) COMPETENT**

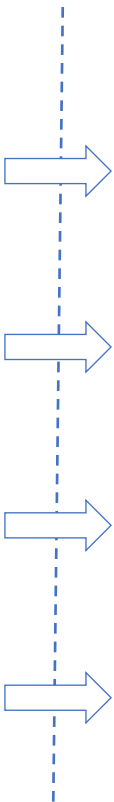
Can do all parts of the task.  
Needs only a spot check of completed work.

**2) PARTIALLY PROFICIENT**

Can do most parts of the task.  
Needs only help on hardest parts.

**1) LIMITED**

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



Quantitative Thresholds

(Examples, You May Set Your Own)

**80-100%**



**60-79%**



**40-59%**



**20-39%**



Benefits

Scores captured  
in standard tests.

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

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

Provides clear thresholds for  
self-evaluation.

# APPARATUS FABRICATION

# Short Bucket Leveling Stand Fabrication

## Optional Hinges for Stowing/Transportation

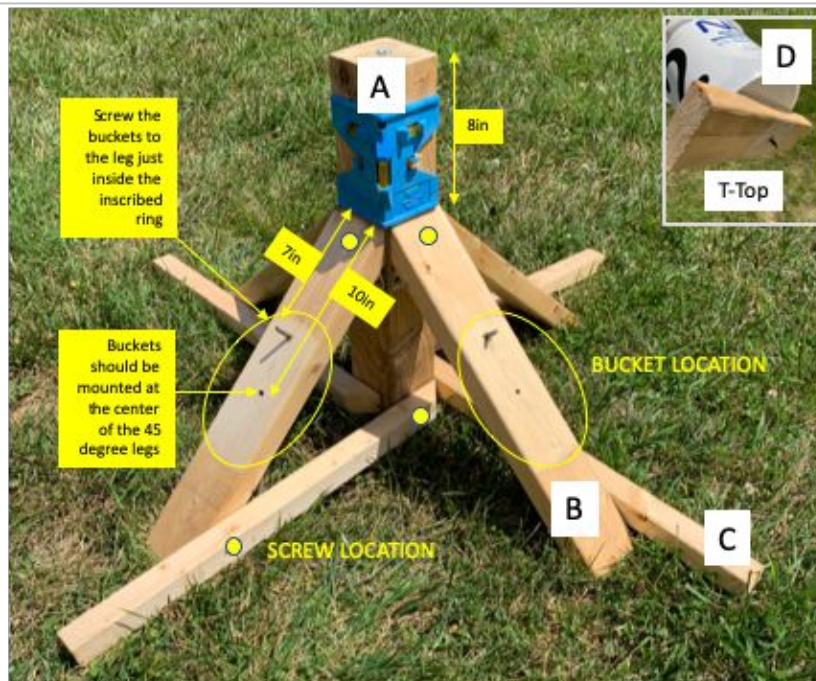
### Short Bucket Leveling Stand

#### Cut list:

- |   |     |  |
|---|-----|--|
| A | [1] | 4x4x20in post  |
| B | [4] | 2x4x20in legs with 45degree cuts on both ends (opposing) |
| C | [4] | 2x2x24in outriggers with 45 degree cut on one end        |
| D | [1] | 2x4x12in T-top   |

#### Notes:

- 1) The shoulder joint is 7 inches from the top of the post to ensure the post doesn't touch the ground when assembled. Four ground contacts only.
- 2) Screw the pieces together using a single 2-1/2 or 3in screws at every joint.
- 3) The outriggers should be at least 36in long for taller spiral post assemblies.
- 4) The outriggers rotate on a single screw into the post and then are affixed to the legs when vertical.
- 5) The hardware shown is optional, including 4in gate hinges under the legs, hanger bolts and wing nuts to hold the buckets on, wood nuts in top and bottom of the post to attach/remove the T-Top.

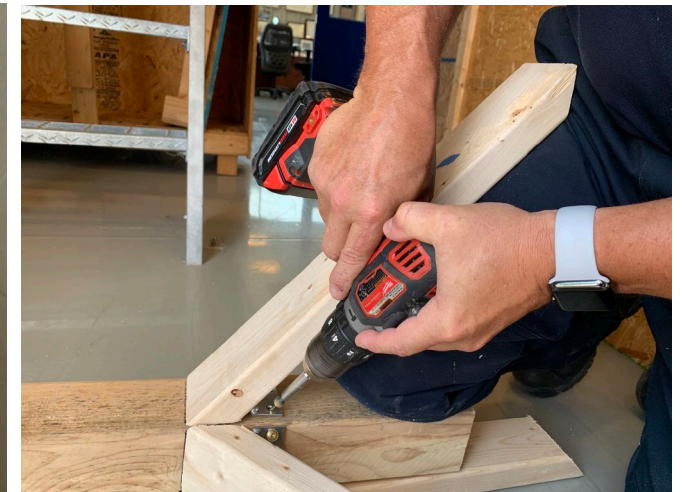
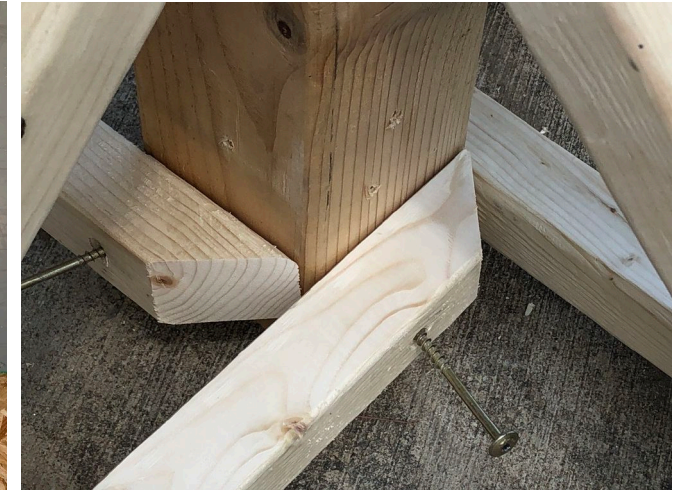


The advantage of this bucket leveling stand design is that they can be used **WITHOUT THE OUTRIGGERS** (shown here as either 2x2s or 2x4s) on flat surfaces indoors and in parking lots. The outriggers allow some leveling capacity in grass or elsewhere. This is best done by resting the center post on a block of wood. This lifts all four legs off the ground at the same time so the center post can be leaned to vertical in any direction while all four legs pivot on one screw to touch the ground before being secured with a second screw. The block can remain there or be removed.



# Short Bucket Leveling Stand Fabrication

## Optional Hinges for Stowing/Transportation





# Tall Bucket Leveling Stand Fabrication

## Three Piece Assembly for Stowing/Transportation



### Online Apparatus Set Up Videos

[NIST-ASTM-NFPA 2400 Test Methods for sUAS: Deploying a 2ft Bucket Leveling Stand for Flat Terrain.](https://vimeo.com/325054438)

<https://vimeo.com/325054438>

[NIST-ASTM-NFPA 2400 Test Methods for sUAS: Stowing a 2ft Bucket Leveling Stand for Flat Terrain.](https://vimeo.com/325052953)

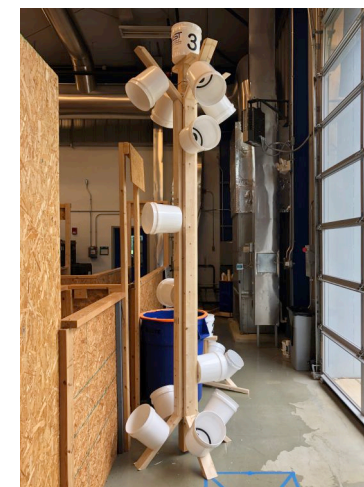
<https://vimeo.com/325052953>

[NIST-ASTM-NFPA 2400 Test Methods for sUAS: Deploying a 4ft Bucket Leveling Stand for Uneven Terrain.](https://vimeo.com/320053684)

<https://vimeo.com/320053684>

[NIST-ASTM-NFPA 2400 Test Methods for sUAS: Deploying a 10ft Spiral Inspect Post \(stowable/transportable in three pieces\).](https://vimeo.com/327968250)

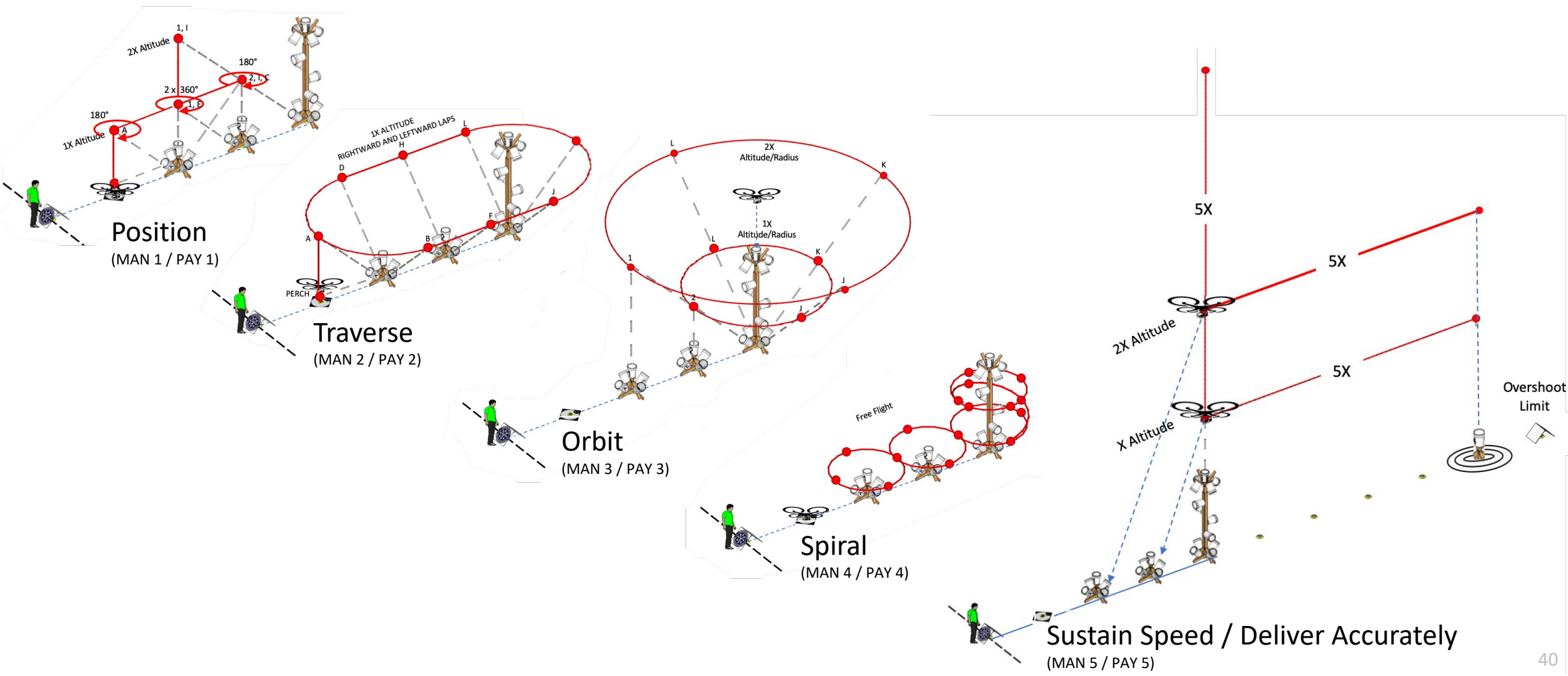
<https://vimeo.com/327968250>





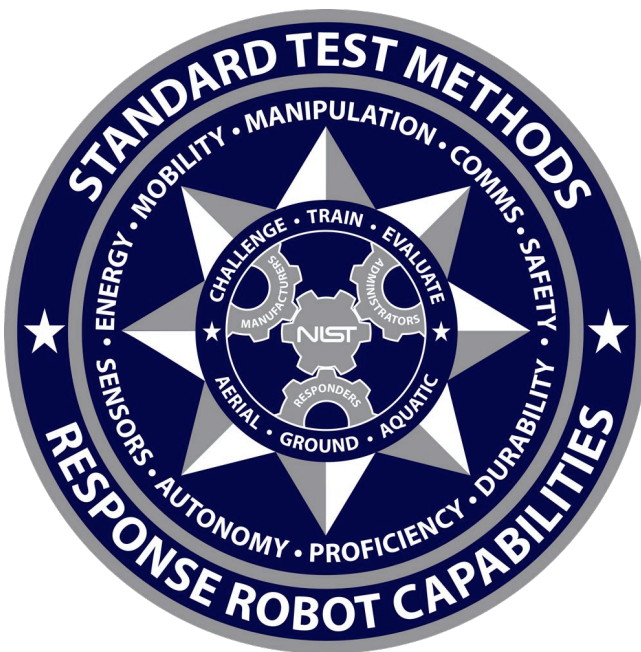
# Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

## Comprehensive Flight Paths in a Single Lane



# Test Method Procedures and Flight Paths

## Maneuvering (MAN 1) and Payload Functionality (PAY 1)



WATCH THE VIDEO VERSION WITH  
TEST METHOD FLY THROUGHS

<https://vimeo.com/354145833>

*Test Director:*

**Adam Jacoff**

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

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Internet  
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Email  
[RobotTestMethods@nist.gov](mailto:RobotTestMethods@nist.gov)