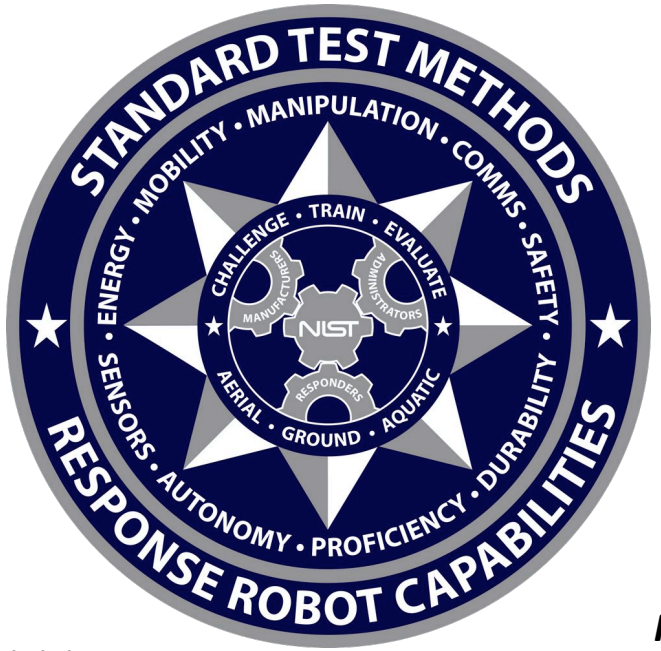
Measuring and Comparing Small Unmanned Aircraft System Capabilities and Remote Pilot Proficiency

Version: 2019-09-12



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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, 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, 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

Al Frazier, Grand Forks County Sheriff's Dept., ND

Ben Miller, CDPS COE for Aerial Technology Fire Fighting, CO

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Andy Olesen, Canadian Explosives Technicians Assoc., Canada

Tom Prentice, Reveille Peak Ranch, Burnet, TX

Michael Leo, Fire Department of New York City, NY

Luke Bergan, New South Whales Police Dept., Sydney, Australia

Katie Thielmeyer, Woodlawn Fire Dept. OH

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

Project Overview

Objective

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

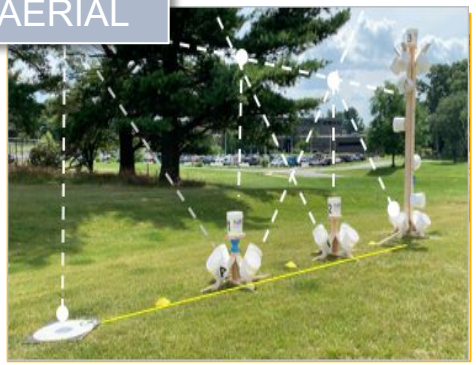
Outcomes:

Test methods, performance metrics, and data collection tools to help apply emerging technologies toward mission tasks.

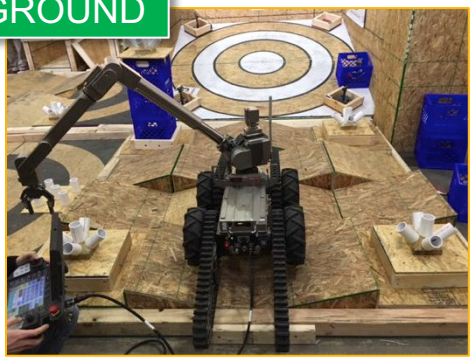
Impacts:

- Quantitative data help compare systems, specify purchases, and train with measures of proficiency.
- Objective test methods help researchers and manufacturers push the state of the science by measuring progress and highlighting breakthroughs.

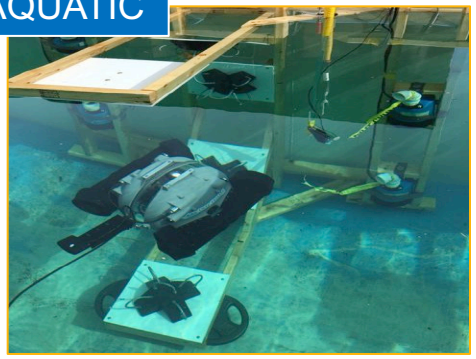
AERIAL



GROUND



AQUATIC

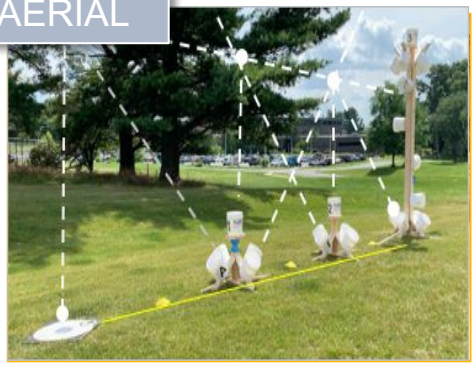


Project Approach

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 technological 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 local, regional, or national averages.

AERIAL



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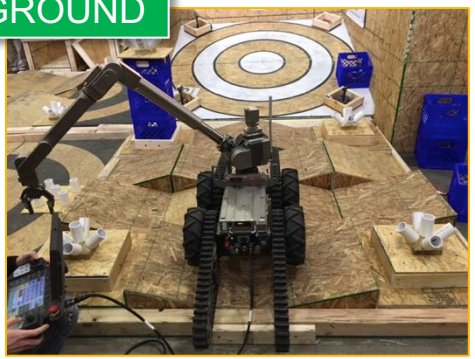

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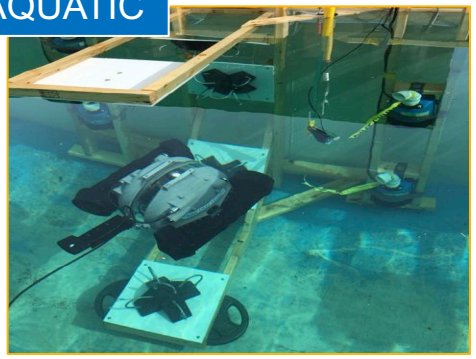


Comprehensive Suites of 50 Test Methods

Ground, Aerial, and Aquatic Systems

Mobility

Dexterity

Endurance

Sensors

Radio Comms

Durability

Logistics

Safety

Autonomy

Proficiency

Test Methods for VTOL Systems

Safety | Capabilities | Proficiency

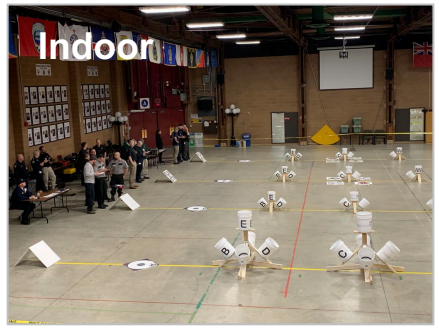
Although some tests apply to forward fly aircraft when scaled up to the appropriate orbit radius.

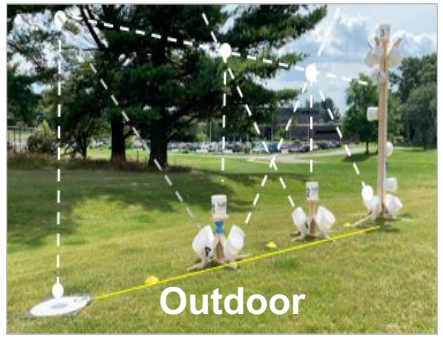
List of Test Methods Being Developed

Safety | Capabilities | Proficiency

Sensing

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





Basic Pilot Proficiency Tests

Maneuvering & Payload Functionality

1. Position Alignments & Identifications
   - Maintain Position and Rotate
   - Climb and Descend
   - Fly Straight and Level
   - Move and Rotate
   - Land Accurately
2. Traverse Alignments & Identifications
3. Orbit Alignments & Identifications
4. Spiral Alignments & Identifications
5. Sustain Speed / Deliver Payload

Maneuvering & Payload Funct. (cont.)

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

Energy/Power

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

Radio Communications

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

Safety

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

Durability

- Rain Tolerance

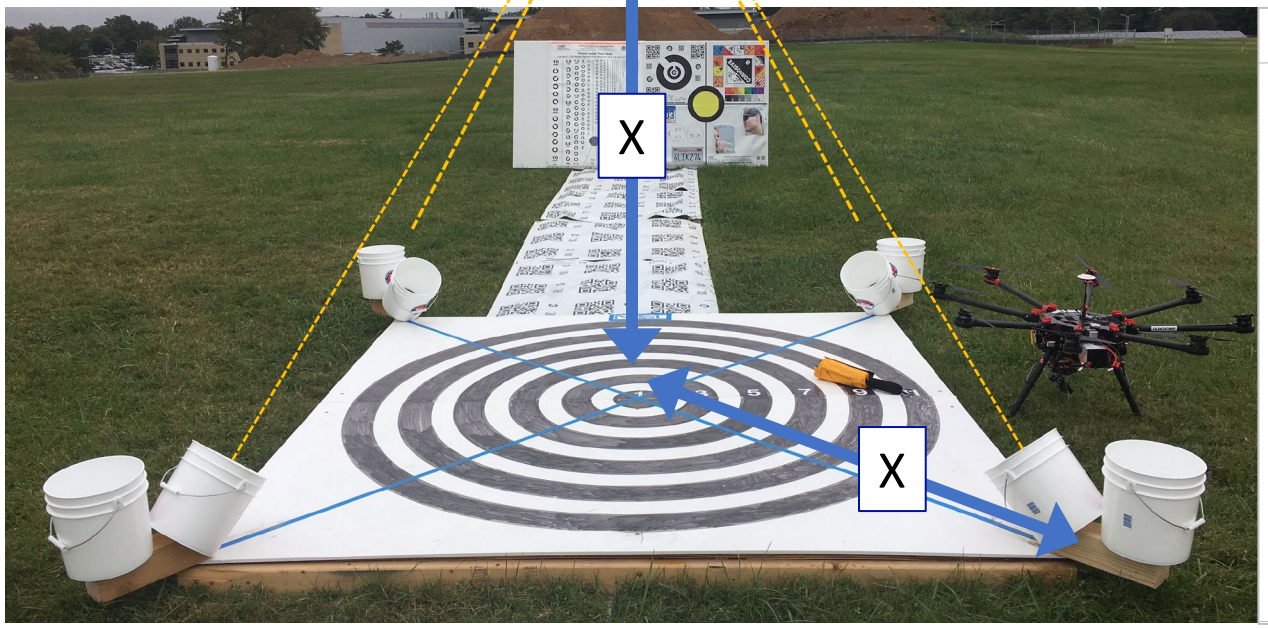
Logistics

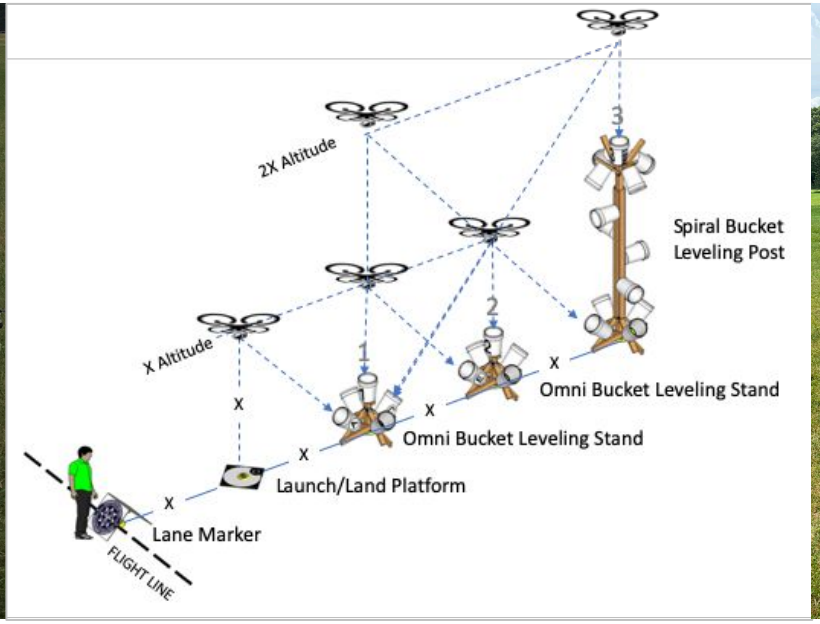
- Configuration Identification, Packaging & Setup Time

Defining Points In Space

Safety | Capabilities | Proficiency

Designated hover altitudes are scalable. They are equal to the ground distance between the drone and the 45 degree bucket targets. Move the bucket targets apart for higher hover altitudes.





Recessed Bucket Targets
Align to Points in Space

Successful Alignment is a
Complete Outer Ring

Example: Sensing Tests with Precise Range to Target

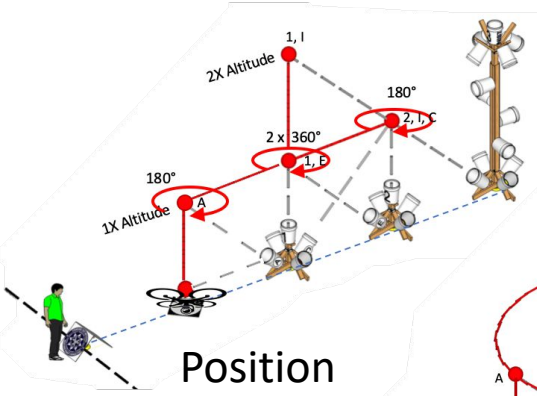
Safety | Capabilities | Proficiency

Visual, Color, Motion, Thermal Acuity
Measured as Live, Streamed, and Recovered Files

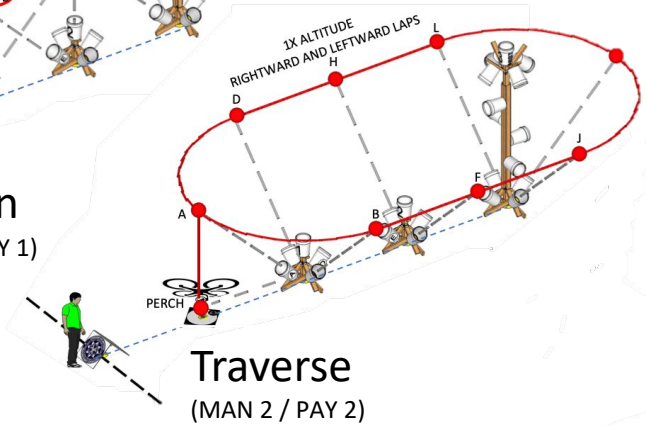
Video Latency Using a Flashing Light

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

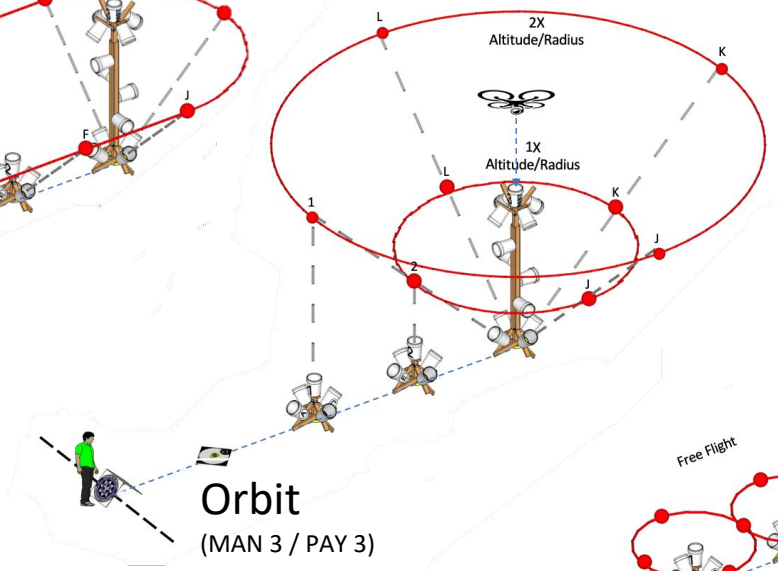
Comprehensive Flight Paths in a Single Lane



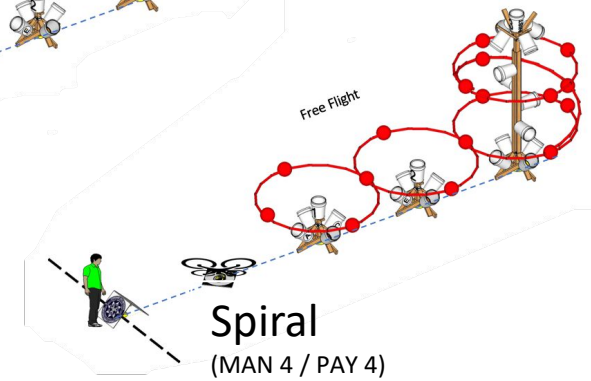
Position
(MAN 1 / PAY 1)



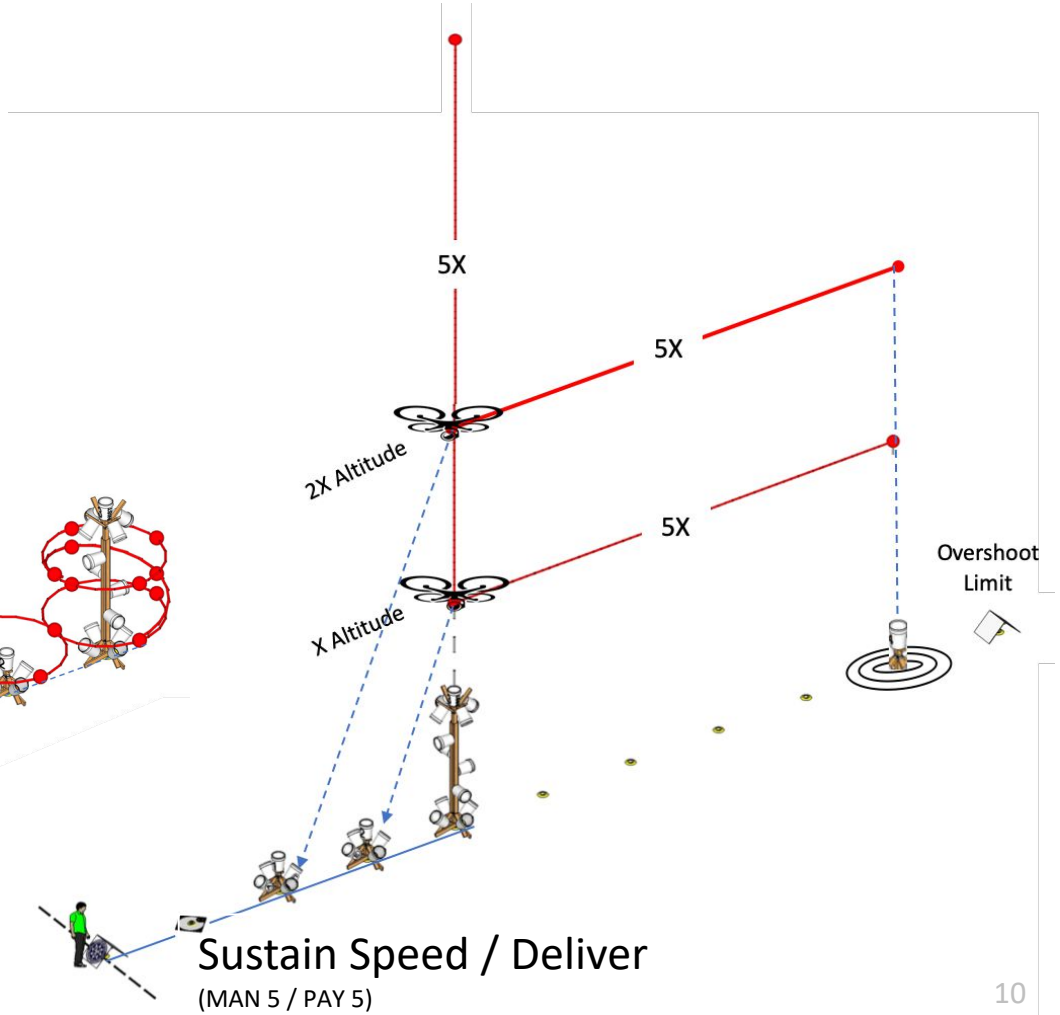
Traverse
(MAN 2 / PAY 2)



Orbit
(MAN 3 / PAY 3)



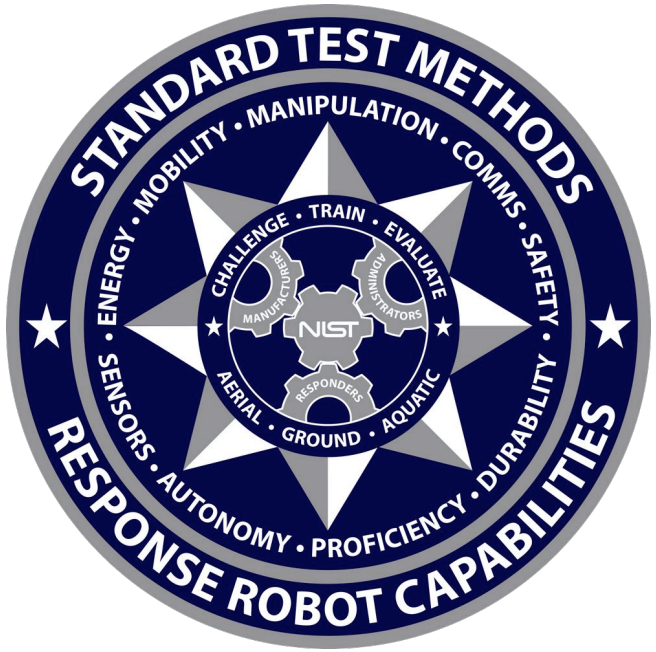
Spiral
(MAN 4 / PAY 4)



Sustain Speed / Deliver
(MAN 5 / PAY 5)

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

Quick Start Guide



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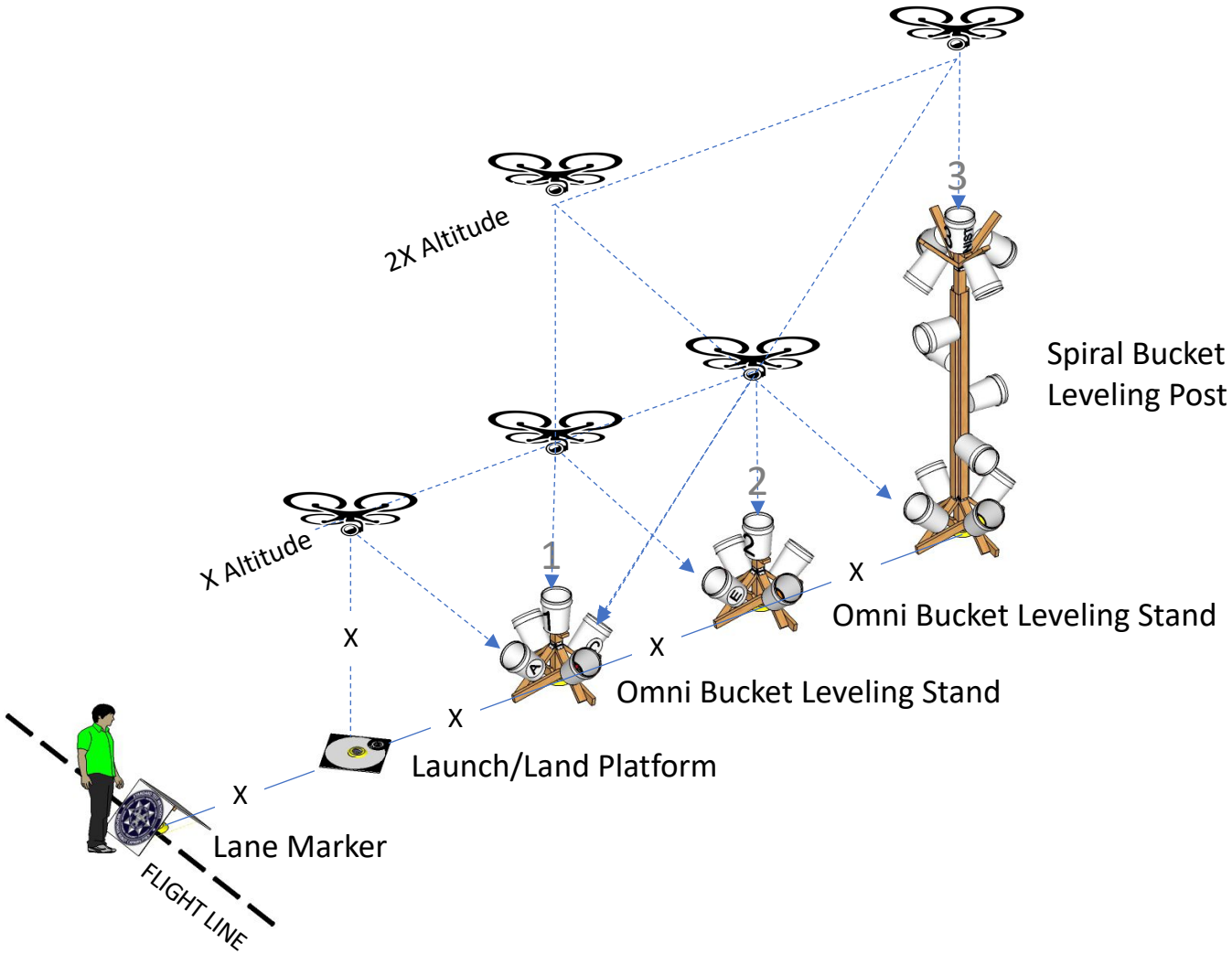
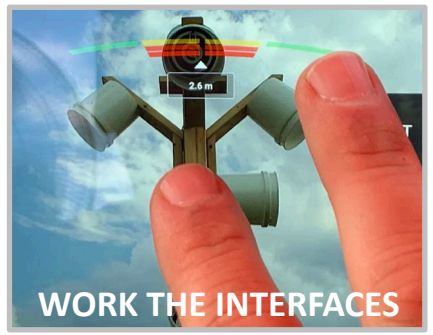
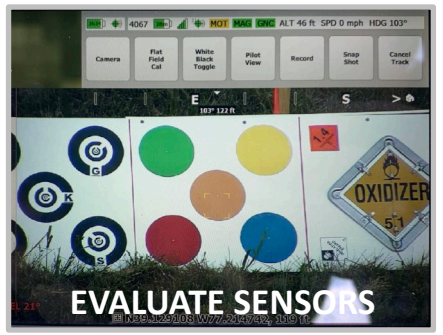
Scalable Test Lane

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



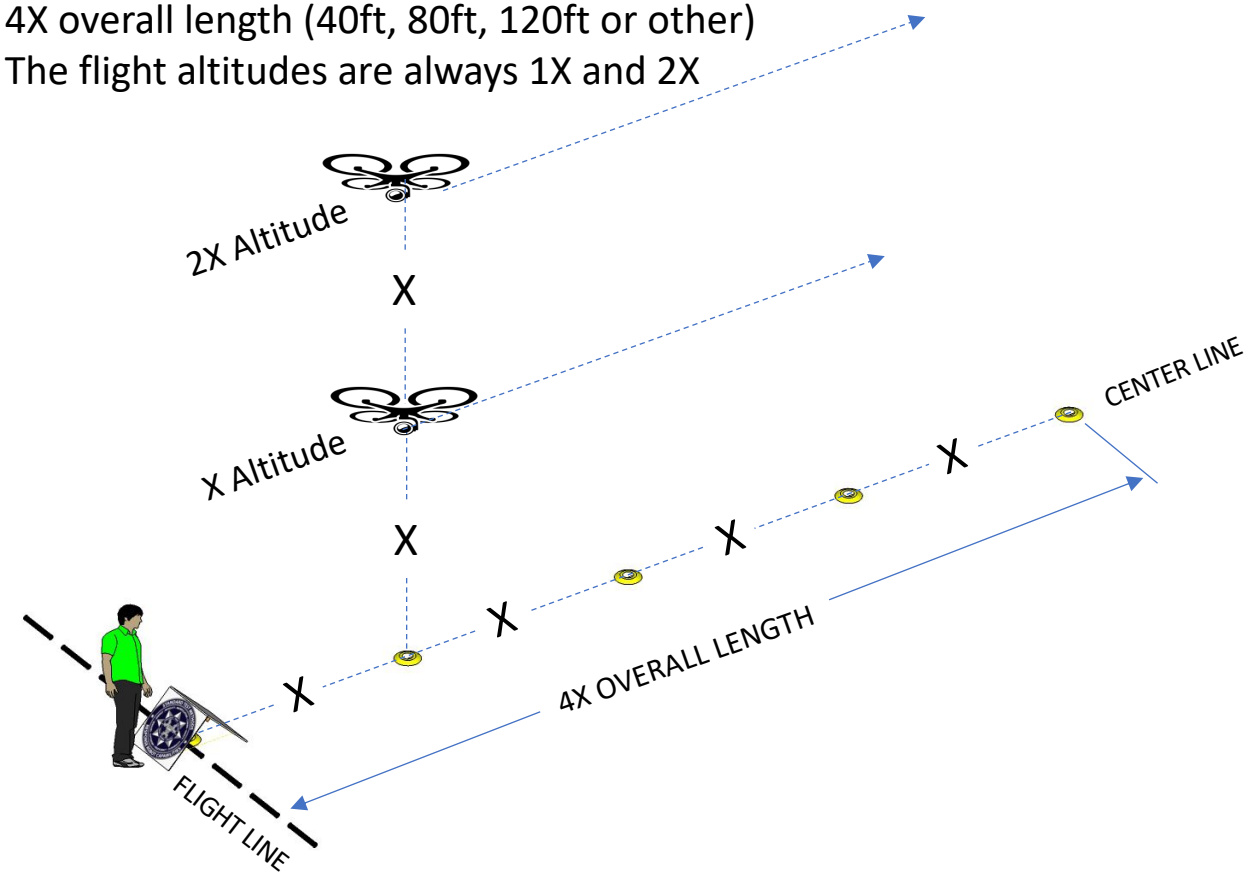


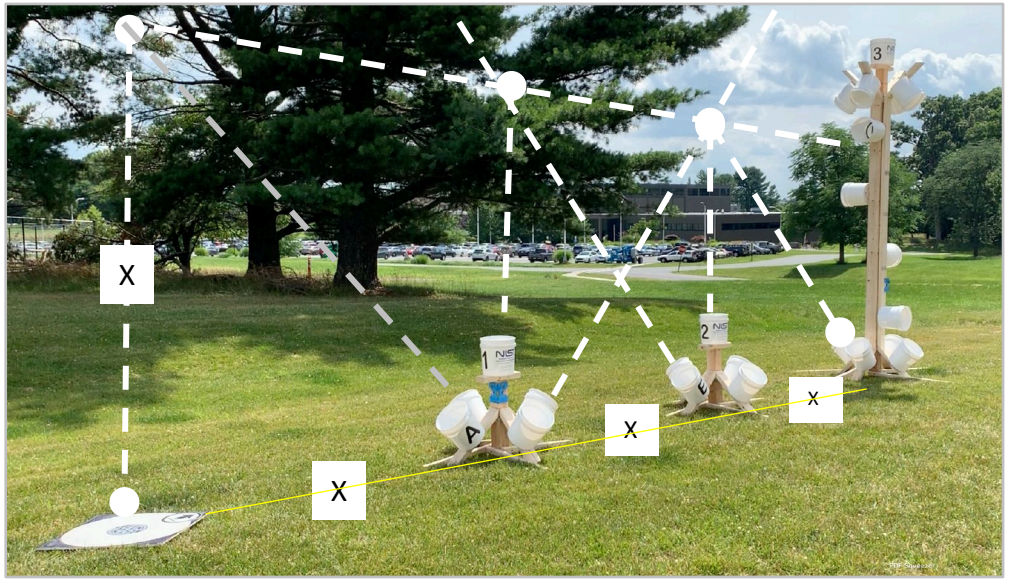


Test Lane Layout

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

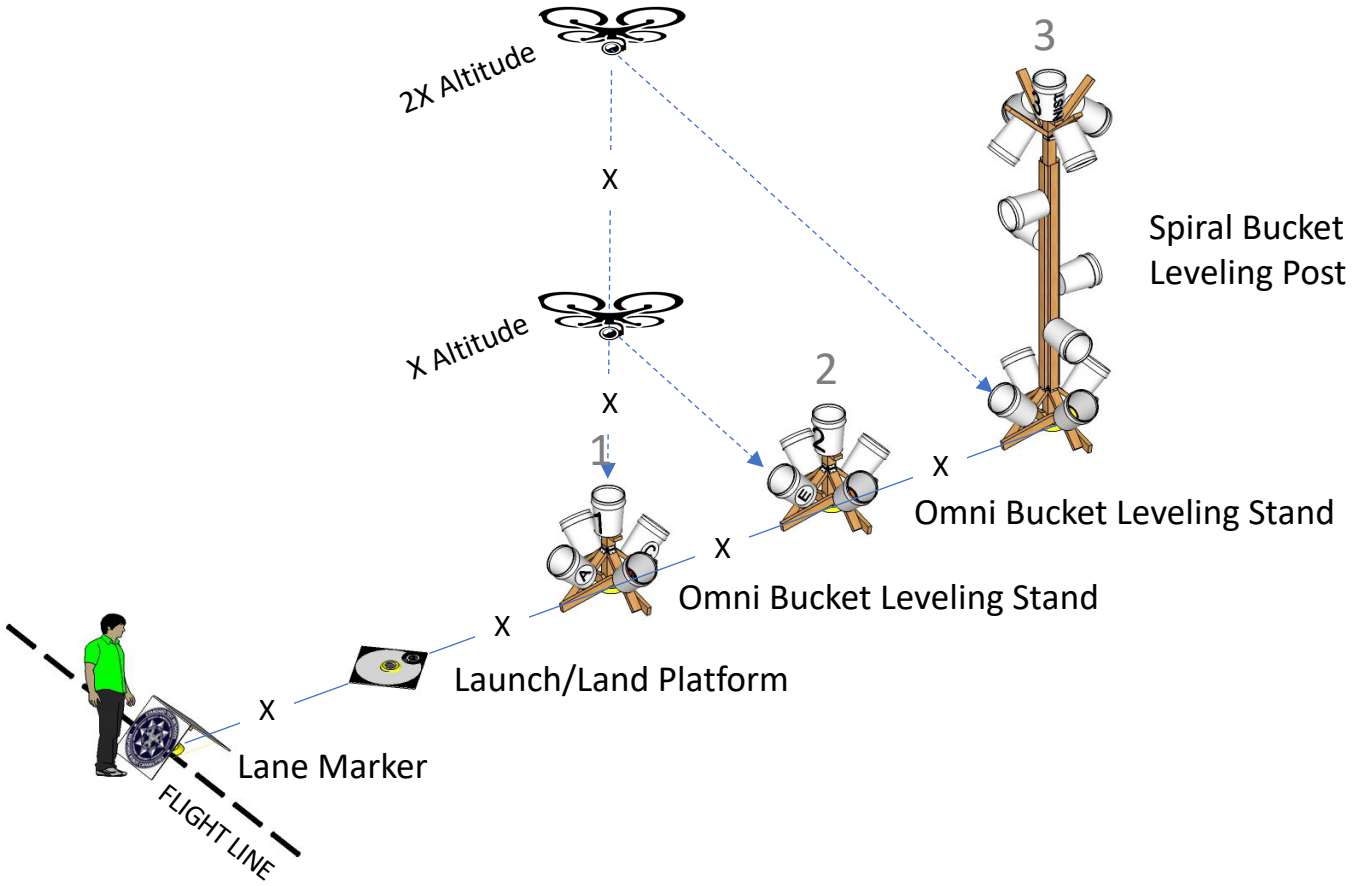


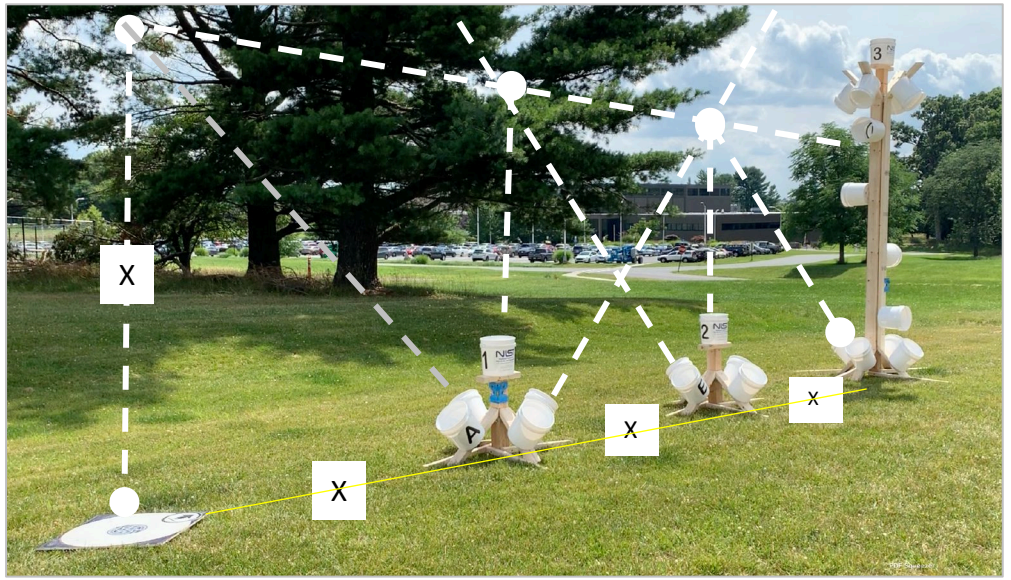


Inside each bucket is a 1in (25mm) inscribed ring to evaluate alignment. Center targets can be letters, visual/color/thermal acuity charts, hazmat labels, or other items.

Test Lane Layout

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





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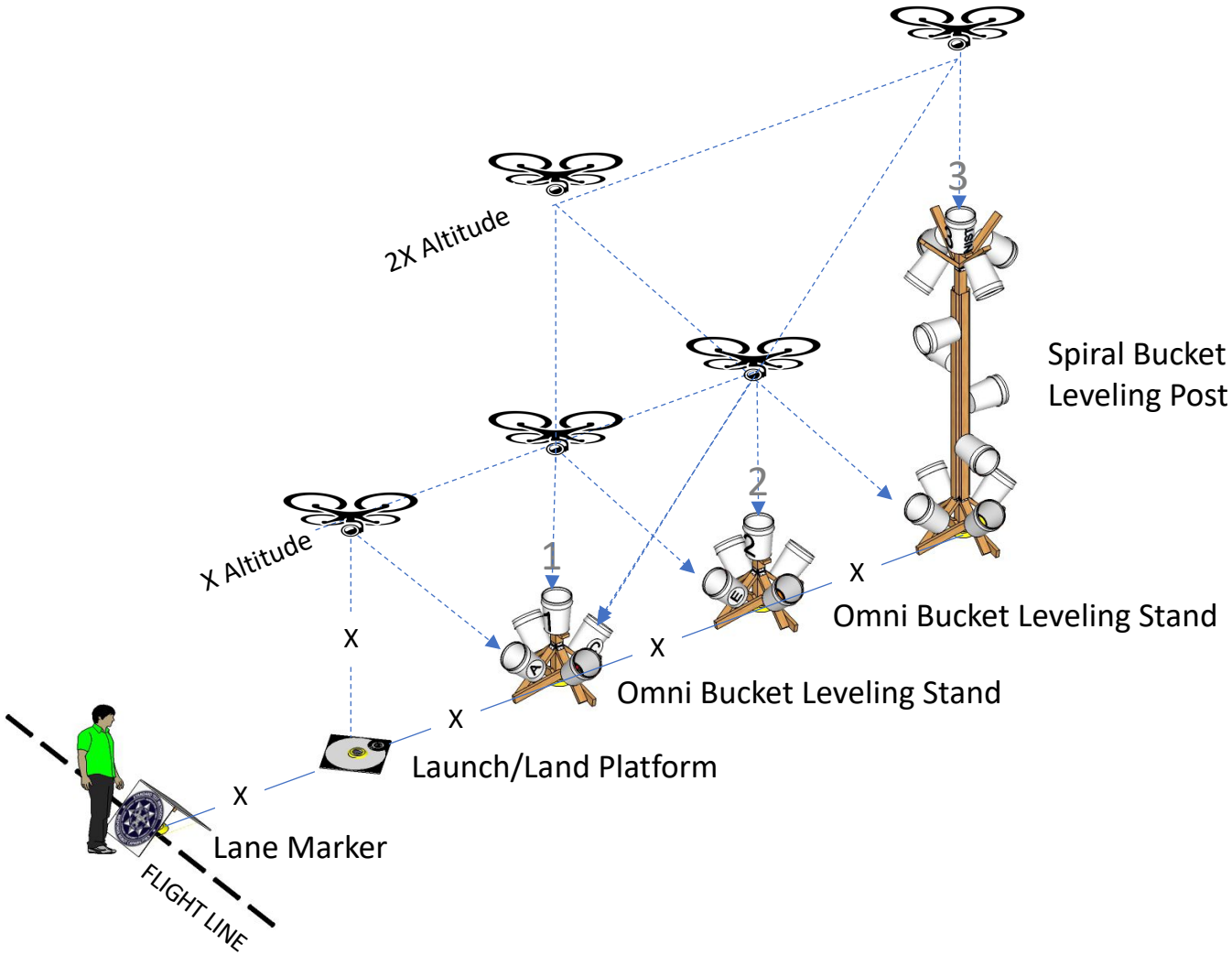
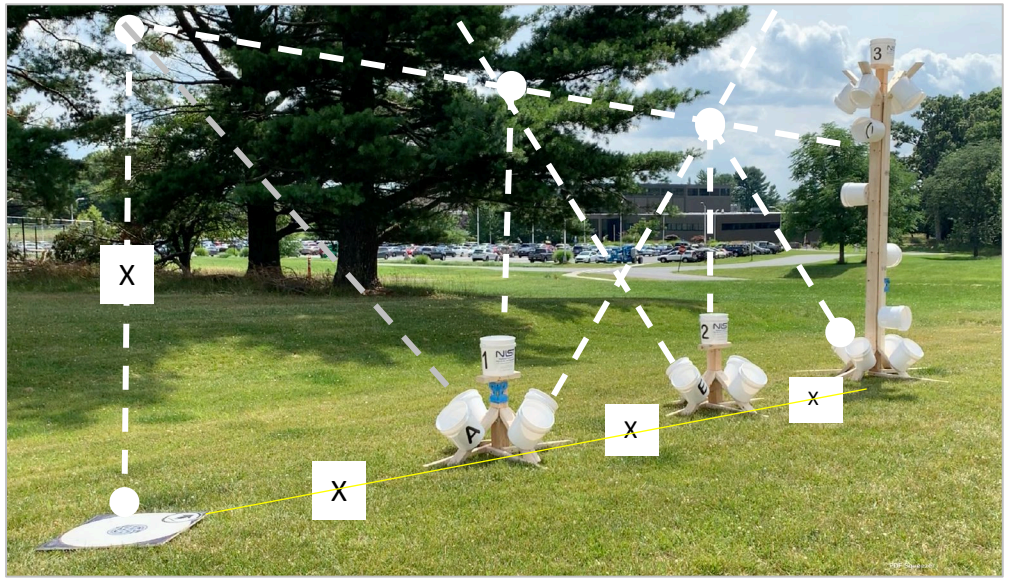
Test Lane Layout

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





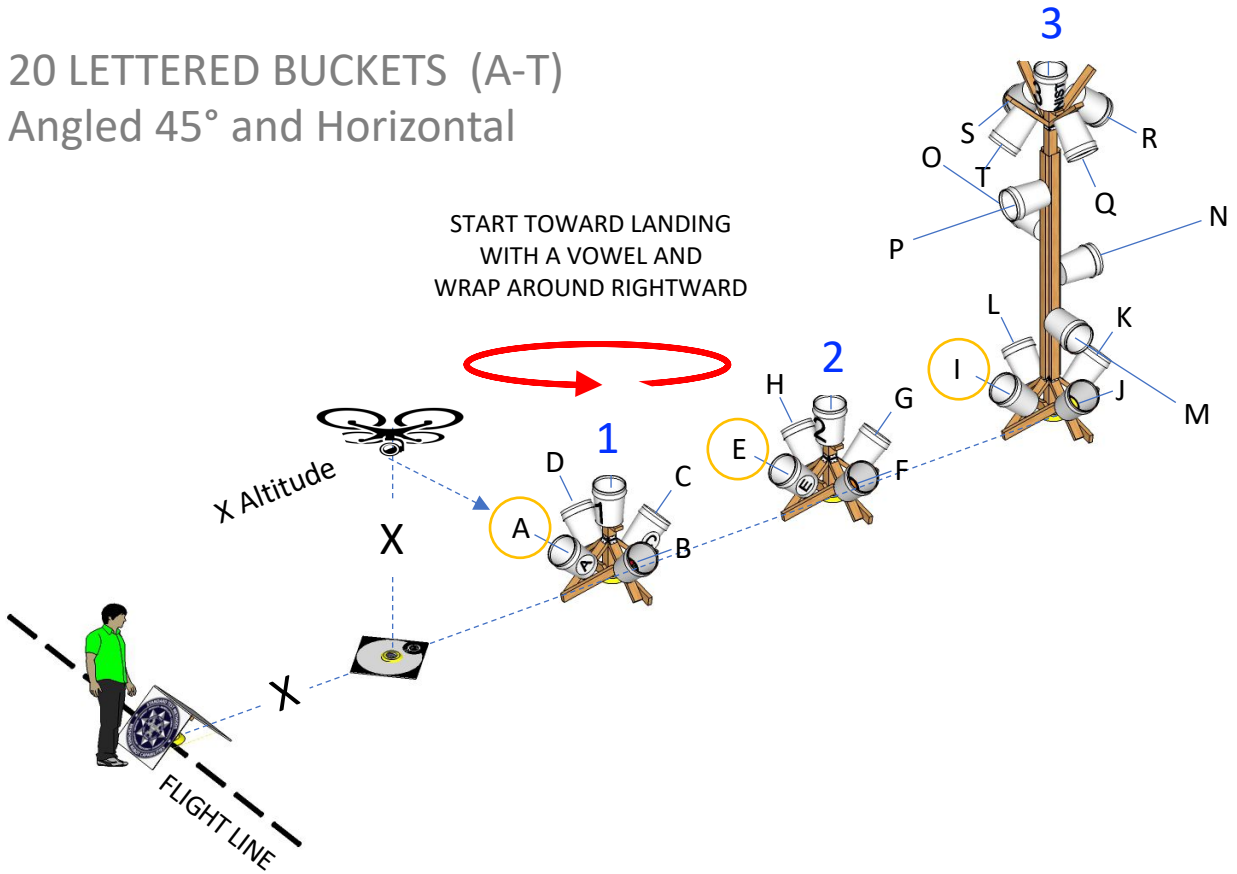
Inside each bucket is a 1in (25mm) inscribed ring to evaluate alignment. Center targets can be letters, visual/color/thermal acuity charts, hazmat labels, or other items.

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

ACUITY TARGETS

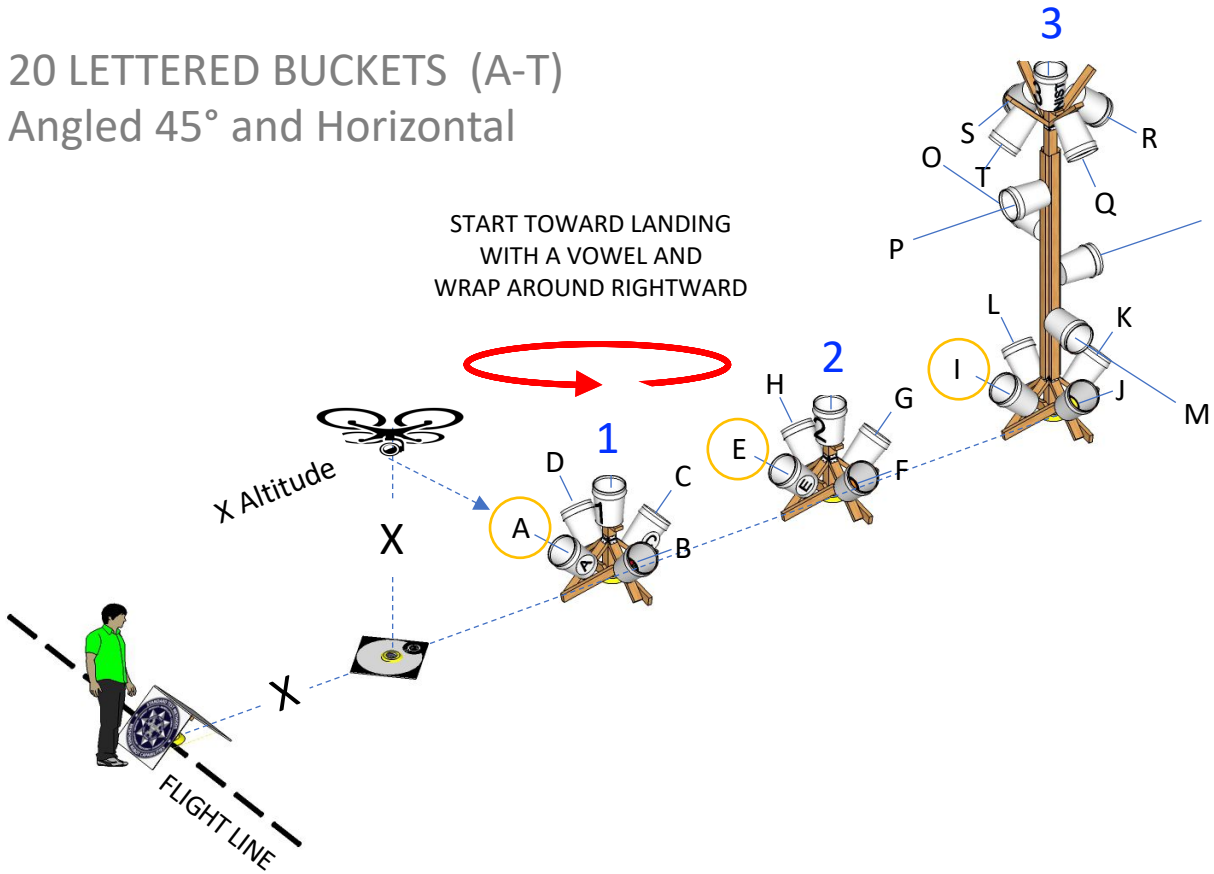
Align and identify the acuity target inside each bucket with increasingly small concentric C gaps in one of eight directions.

Bucket Details – Numbering and Lettering

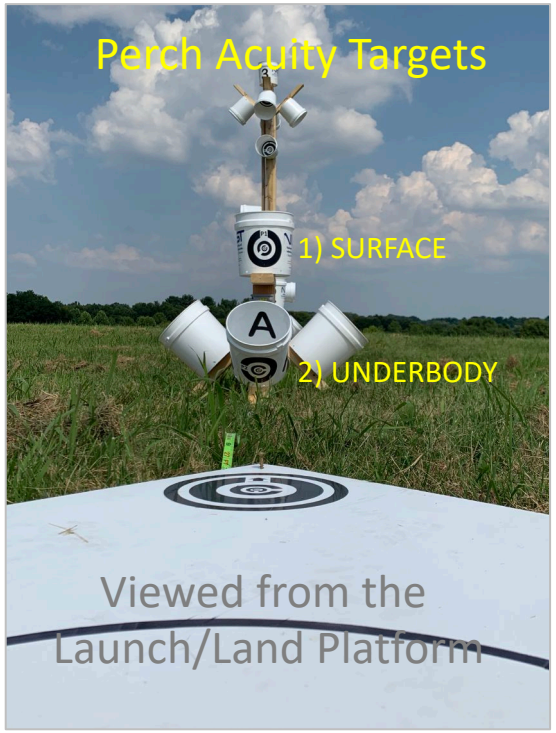
Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)

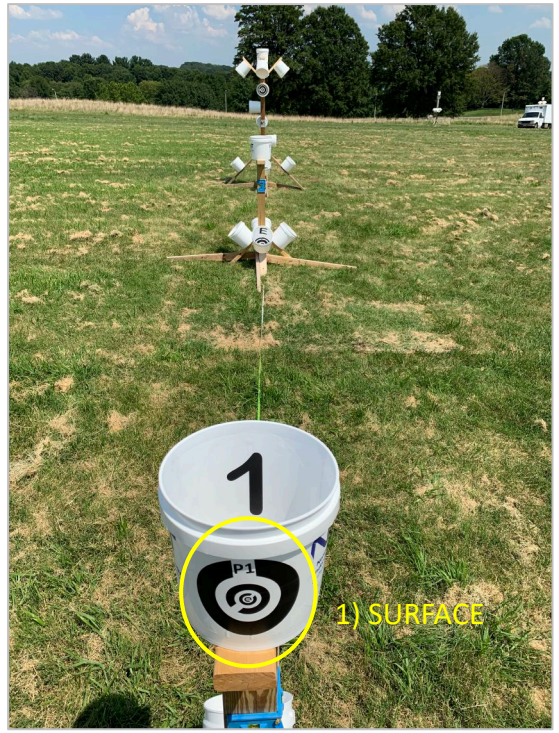
3 NUMBERED BUCKETS (1-3)
Top Vertical

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

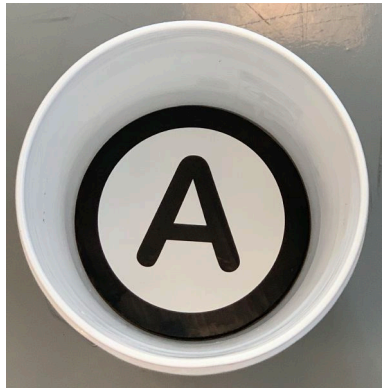
Concentric Cs Color - SCENARIOS
https://drive.google.com/open?id=198sR8TzRB4TKtvZvHcAuXRWdgS35Thzi

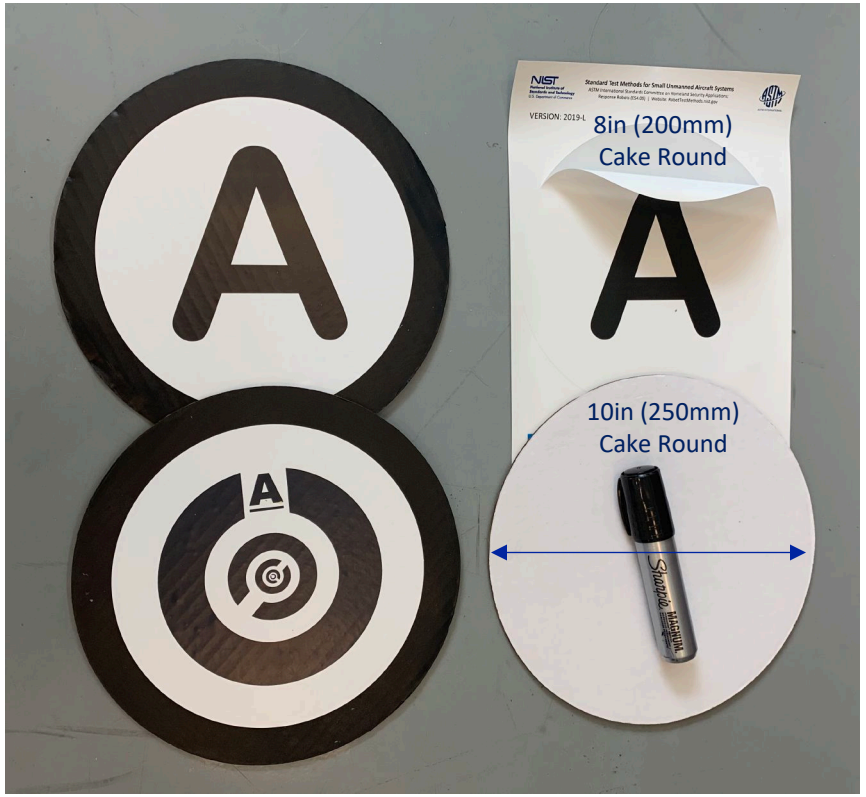
Misc Hazmats, Directions, Plates, Images
https://drive.google.com/open?id=1nuHvZS9ARZ6KkF_vJZKbhO6qwEo4UlkM

Xtra Bucket Stands for Scenarios
https://drive.google.com/open?id=1RklQazk4r8ZyUPJxidjlNpVyF-ZNRCrn

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

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





10in (250mm) cake round colored black with 8in (200mm) white sticker fits in the bottom of 5 gallon bucket.

- 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 10in (250mm) cake rounds colored black with 8in (200mm) white sticker targets in the center.
- Or use an extra large black marker to make a 1in (25mm) inscribed ring inside the bucket. 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

ALIGNED

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

PAY 1-5 VISUAL ACUITY TARGETS

NOT ALIGNED

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)

Example: Position Test Procedure

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

MAN 1-5 LETTER IDENTIFIERS

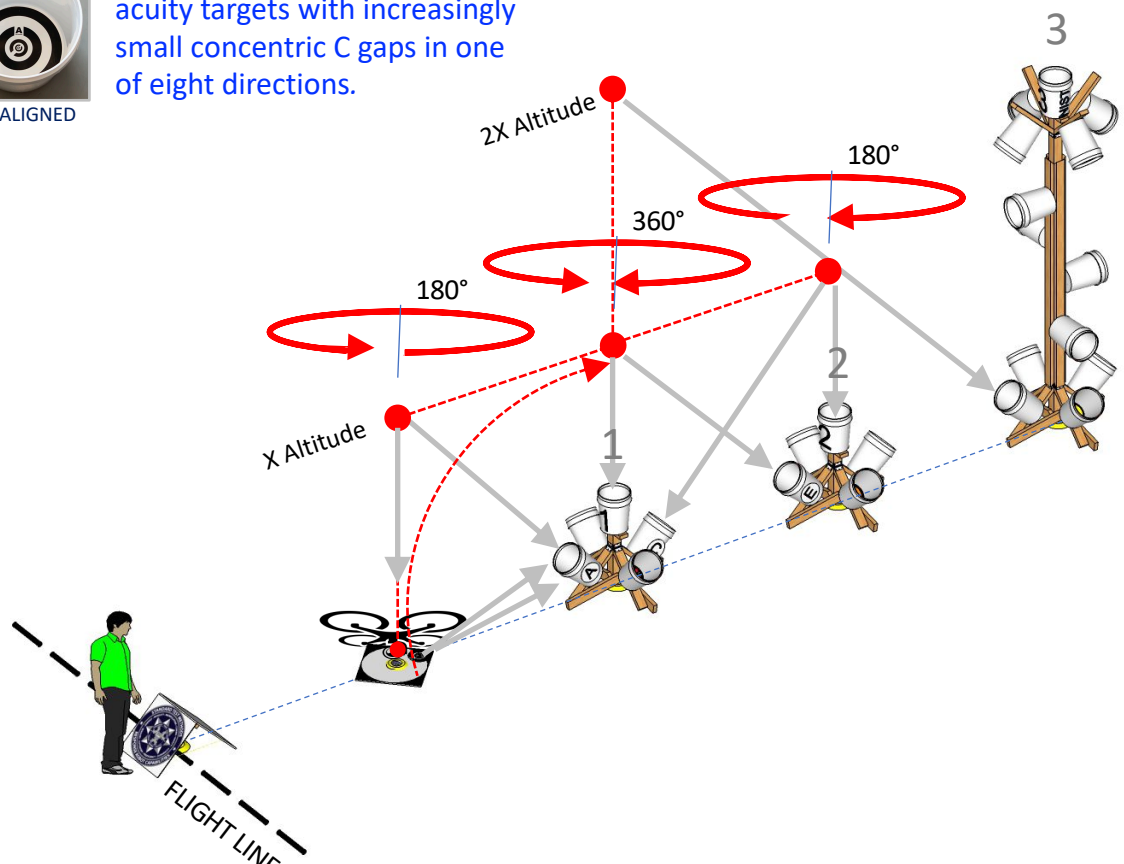
ALIGNED

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

PAY 1-5 VISUAL ACUITY TARGETS

NOT ALIGNED

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.	LAUNCH TO X OVER BUCKET 1 ----------	Bucket 1 Bucket 2E
2.	ROTATE RIGHT 360° ----------	Bucket 1 Bucket 2E
3.	ROTATE LEFT 360° ----------	Bucket 1 Bucket 2E
4.	CLIMB TO 2X ----------	Bucket 1 Bucket 3I
5.	DESCEND TO X ----------	Bucket 1 Bucket 2E
6.	FORWARD OVER BUCKET 2 ----------	Bucket 2 Bucket 3I
7.	BACKWARD OVER BUCKET 1 ----------	Bucket 1 Bucket 2E
8.	FORWARD/ROTATE 180° OVER BUCKET 2	Bucket 2 Bucket 1C
9.	FORWARD/ROTATE 180° OVER LANDING	Bucket 1A 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.

Example: Position Test Form

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

MAN 1-5 LETTER IDENTIFIERS

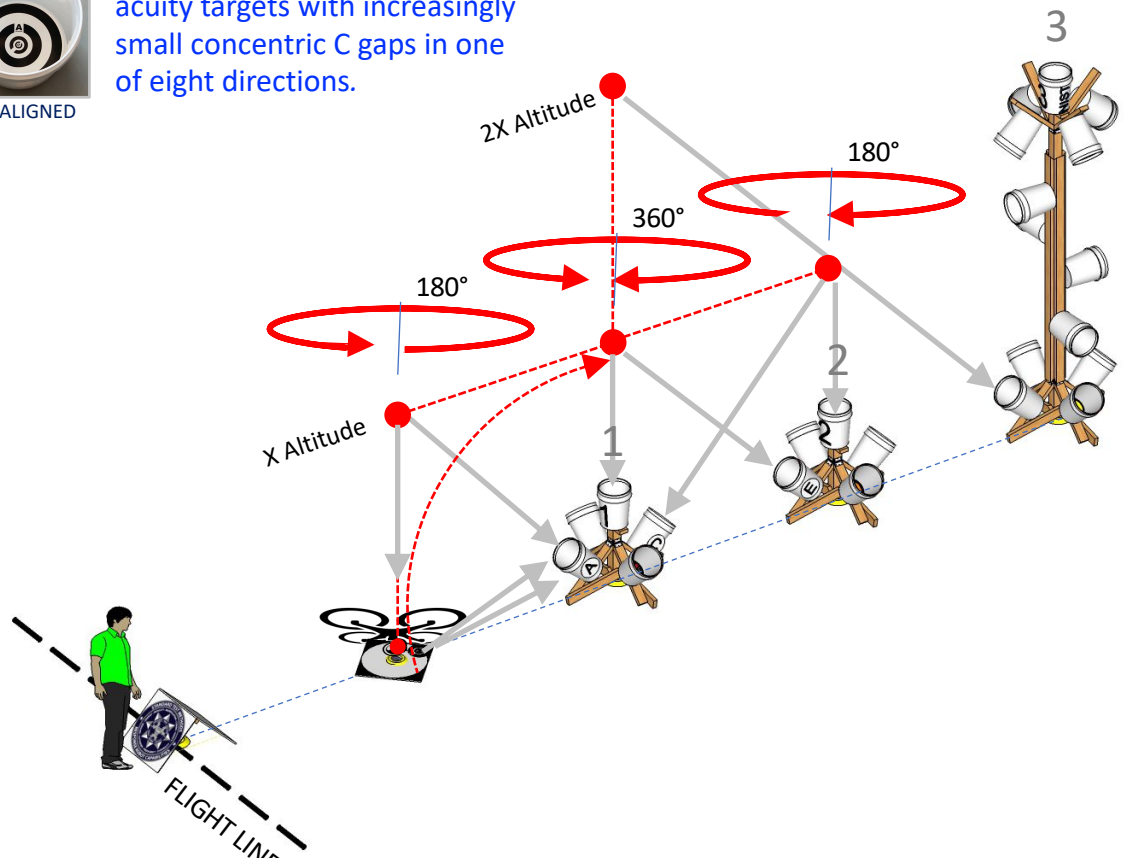
ALIGNED

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

PAY 1-5 VISUAL ACUITY TARGETS

NOT ALIGNED

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 | 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

MAN and PAY TEST

Circle the green identifiers when successfully aligned for both MAN and PAY.

PAY TEST ADDITION

Circle the blue concentric C gap direction when correct.

RESULTS

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

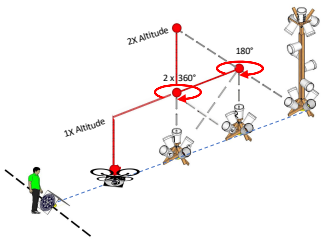
METRICS (in order)

1. Score
2. Reliability/Acuity
3. Efficiency

*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.

Comprehensive Flight Paths in a Single Lane

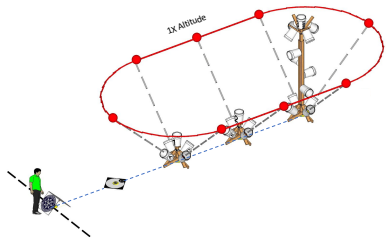
Maneuvering (MAN 1-5) and Payload Functionality (PAY 1-5)



Position
MAN 1 / PAY 1

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

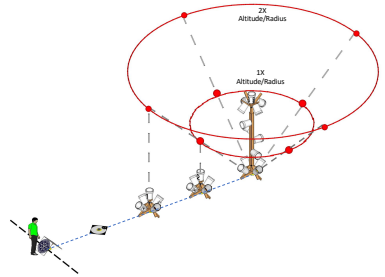
MAN: Align only
PAY: Align and Identify



Traverse
MAN 2 / PAY 2

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

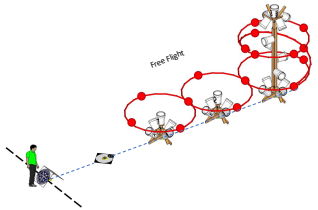
MAN: Align only
PAY: Align and Identify



Orbit
MAN 3 / PAY 3

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

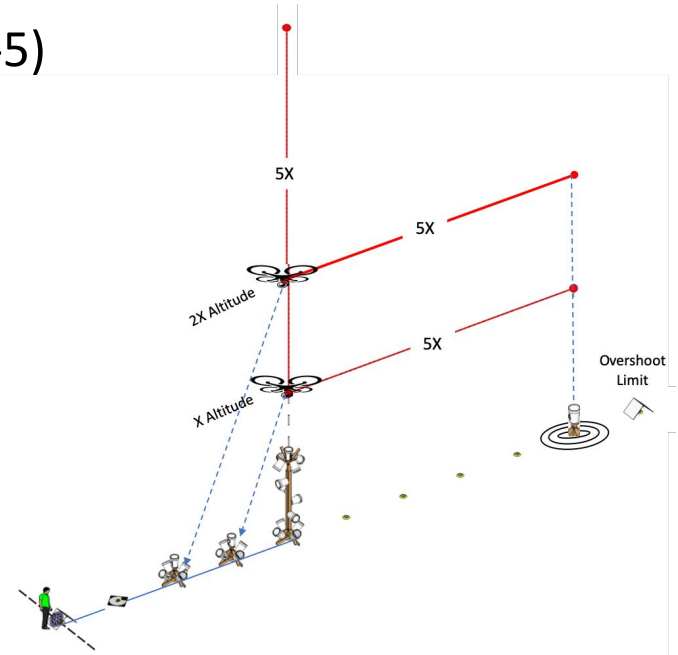
MAN: Align only
PAY: Align and Identify



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

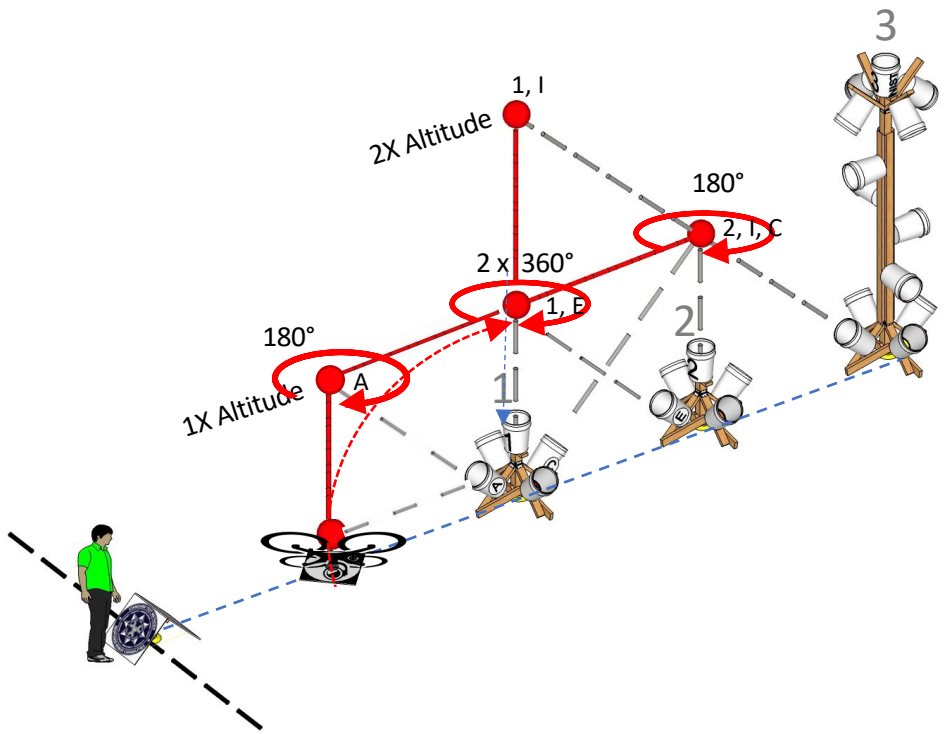
*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Performance is never compared across aircraft anyway.

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

ALIGNED

Bucket Targets

MANEUVERING 1 (MAN 1)

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

NOT ALIGNED

PAYOAD 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**

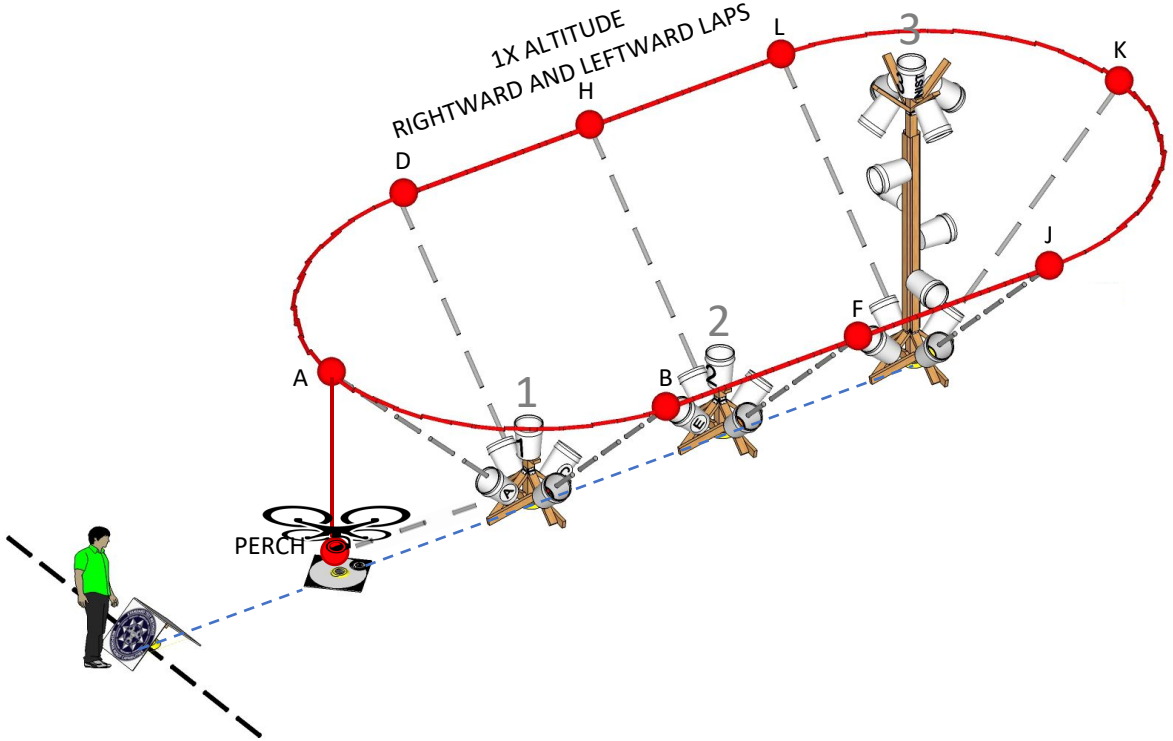
*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Performance is never compared across aircraft anyway.

Evaluate System Capabilities or Pilot Proficiency

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

Traverse

MAN 2 / PAY 2



START POSITION

ALIGNED

Bucket Targets

NOT ALIGNED

MANEUVERING 2 (MAN 2)

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

PAYOAD 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**

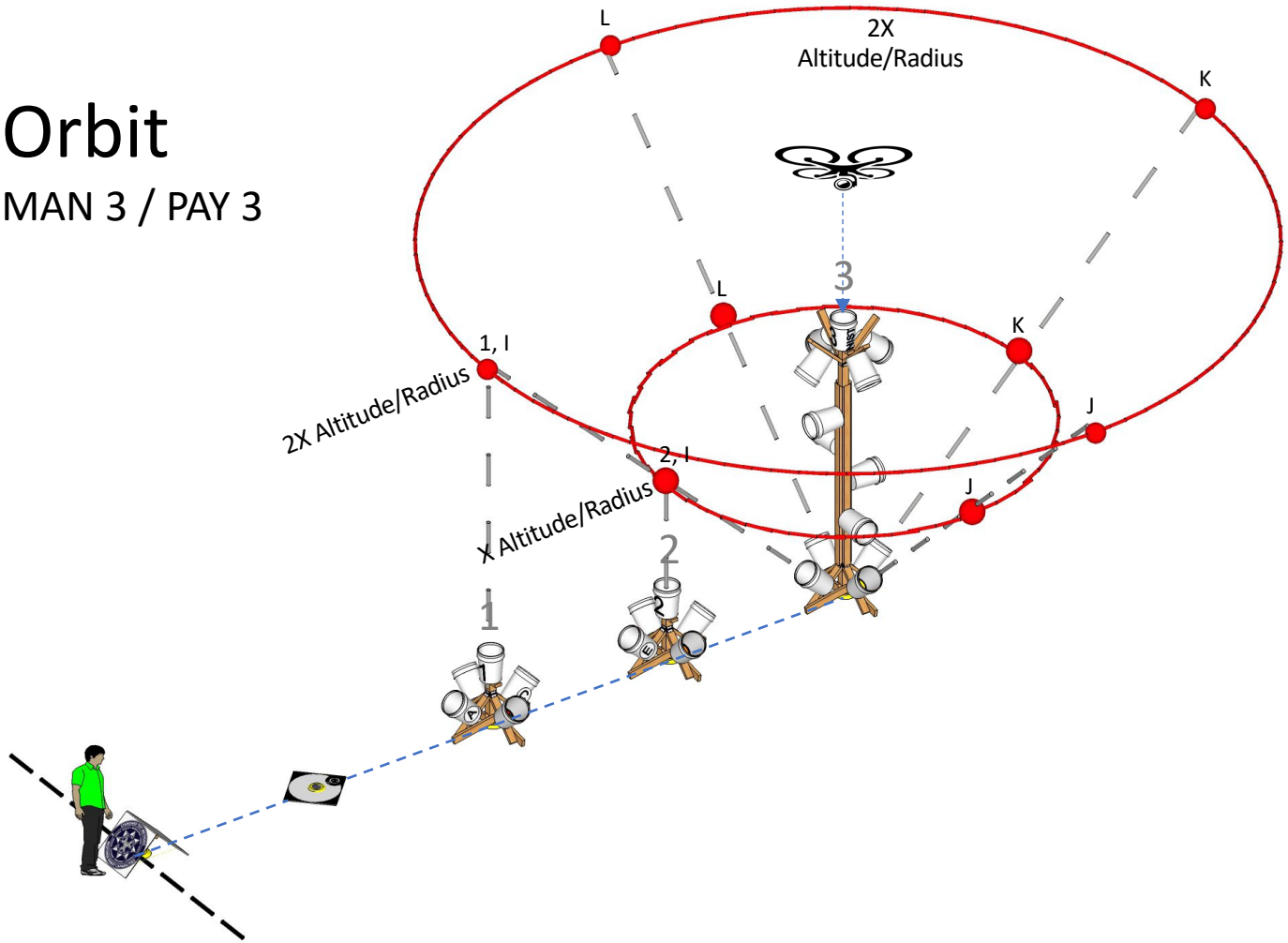
*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Performance is never compared across aircraft anyway.

Evaluate System Capabilities or Pilot Proficiency

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

Orbit

MAN 3 / PAY 3



START POSITION

ALIGNED

Bucket Targets

NOT ALIGNED

MANEUVERING 3 (MAN 3)

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

PAYOAD FUNCTIONALITY 3 (PAY 3)

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

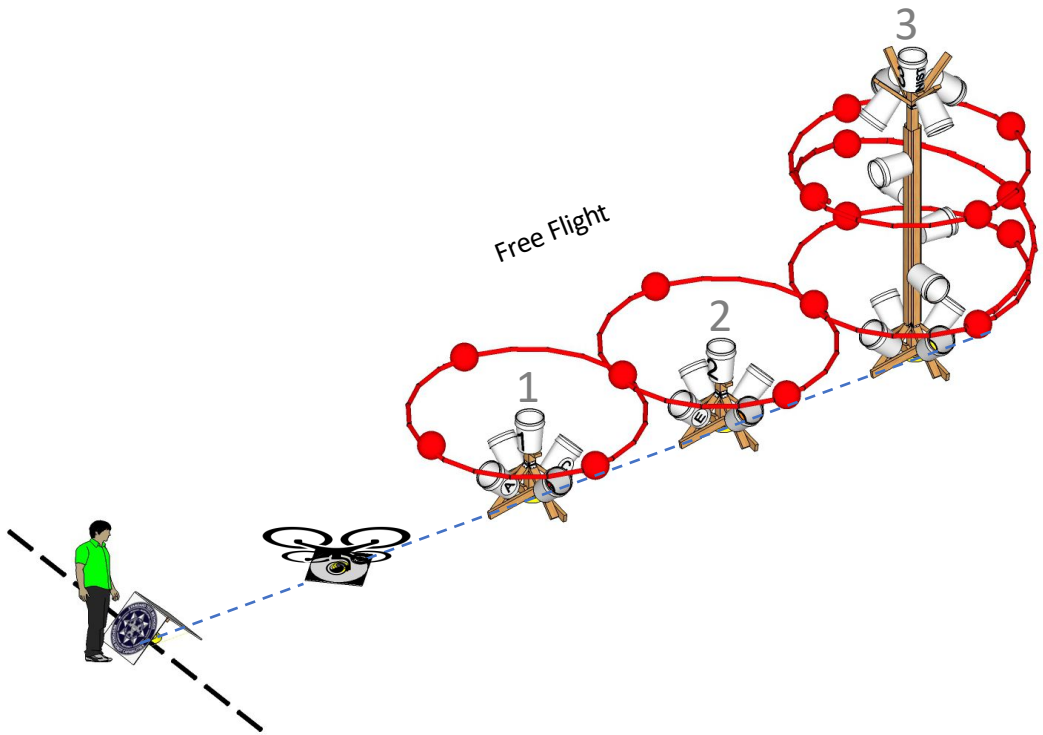
*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Performance is never compared across aircraft anyway.

Evaluate System Capabilities or Pilot Proficiency

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

Spiral

MAN 4 / PAY 4



START POSITION

ALIGNED

Bucket Targets

MANEUVERING 4 (MAN 4)

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

NOT ALIGNED

PAYOAD FUNCTIONALITY 4 (PAY 4)

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

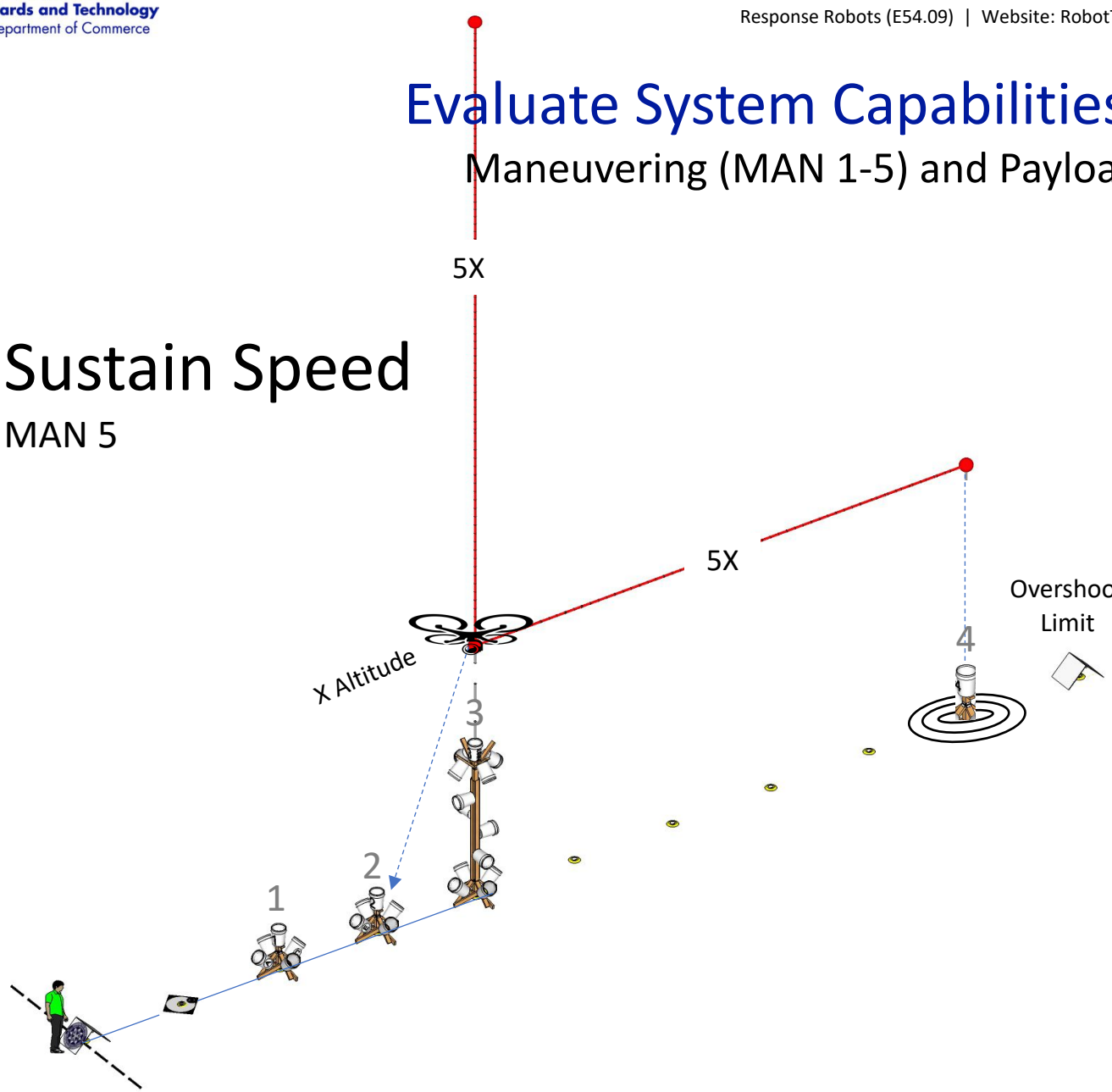
*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Performance is never compared across aircraft anyway.

Evaluate System Capabilities or Pilot Proficiency

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

Sustain Speed

MAN 5



START POSITION

ALIGNED

MANEUVERING 5 (MAN 5)

- 5 laps with 20 flight paths of 5X
- 4 flight paths per lap with 2 horizontal and 2 vertical
- 100X total distance
- Start and end horizontal and vertical flight paths aligned over Bucket 3
- 1 point for each flight path
- **20 Points Maximum**

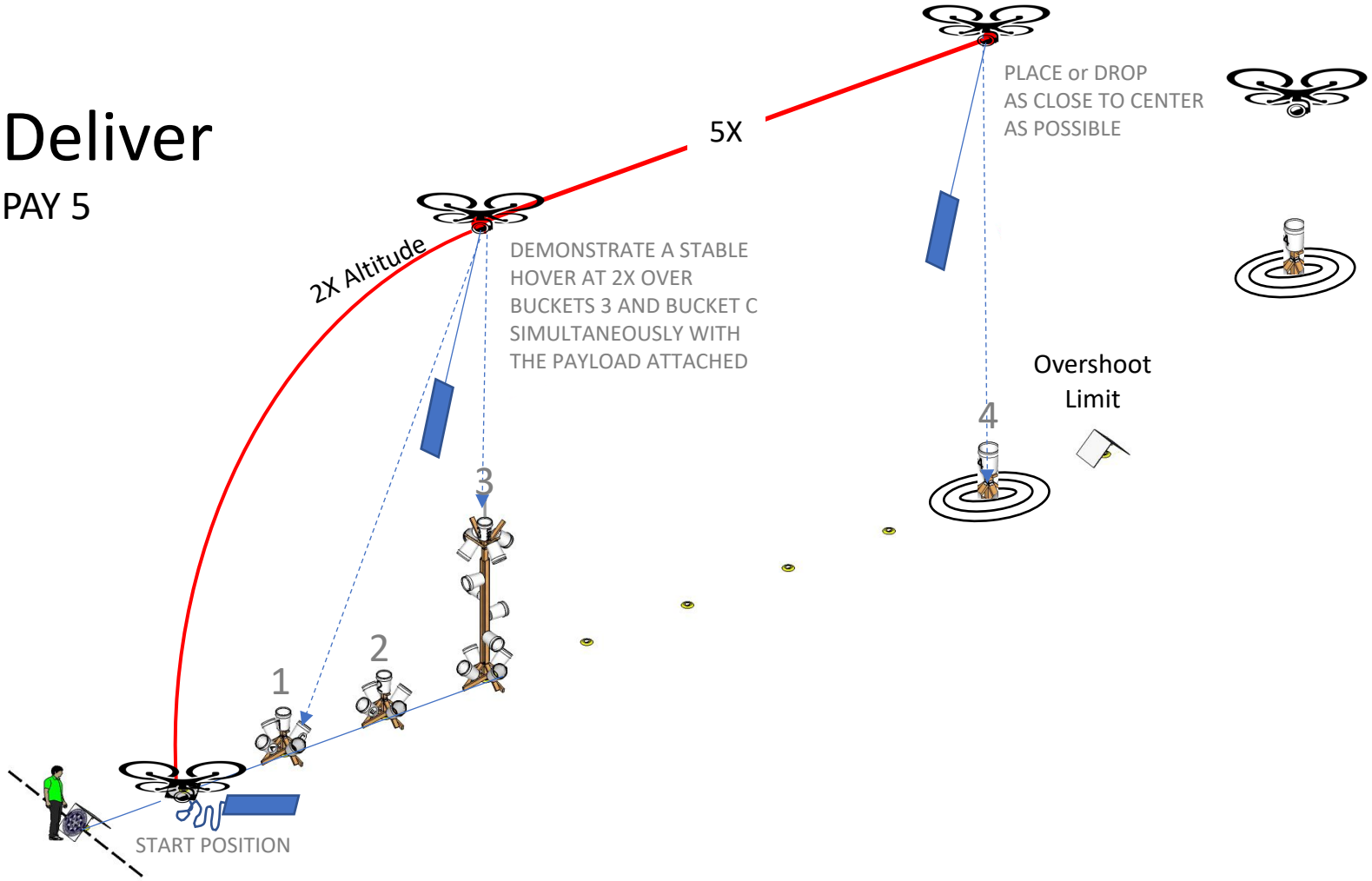
*If your training aircraft has only a fixed camera, or limited range of motion, align with as many buckets as possible. Performance is never compared across aircraft anyway.

Evaluate System Capabilities or Pilot Proficiency

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

Deliver

PAY 5



START POSITION

PAYOAD FUNCTIONALITY 5 (PAY 5)

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

Scoring: 100 points maximum

- 20 points for a 4ft diameter (2ft radius)
- 16 points for a 8ft diameter (4ft radius)
- 12 points for a 12ft diameter (6ft radius)
- 8 points for a 16ft diameter (8ft radius)
- 4 points for a 20ft diameter (10ft radius)

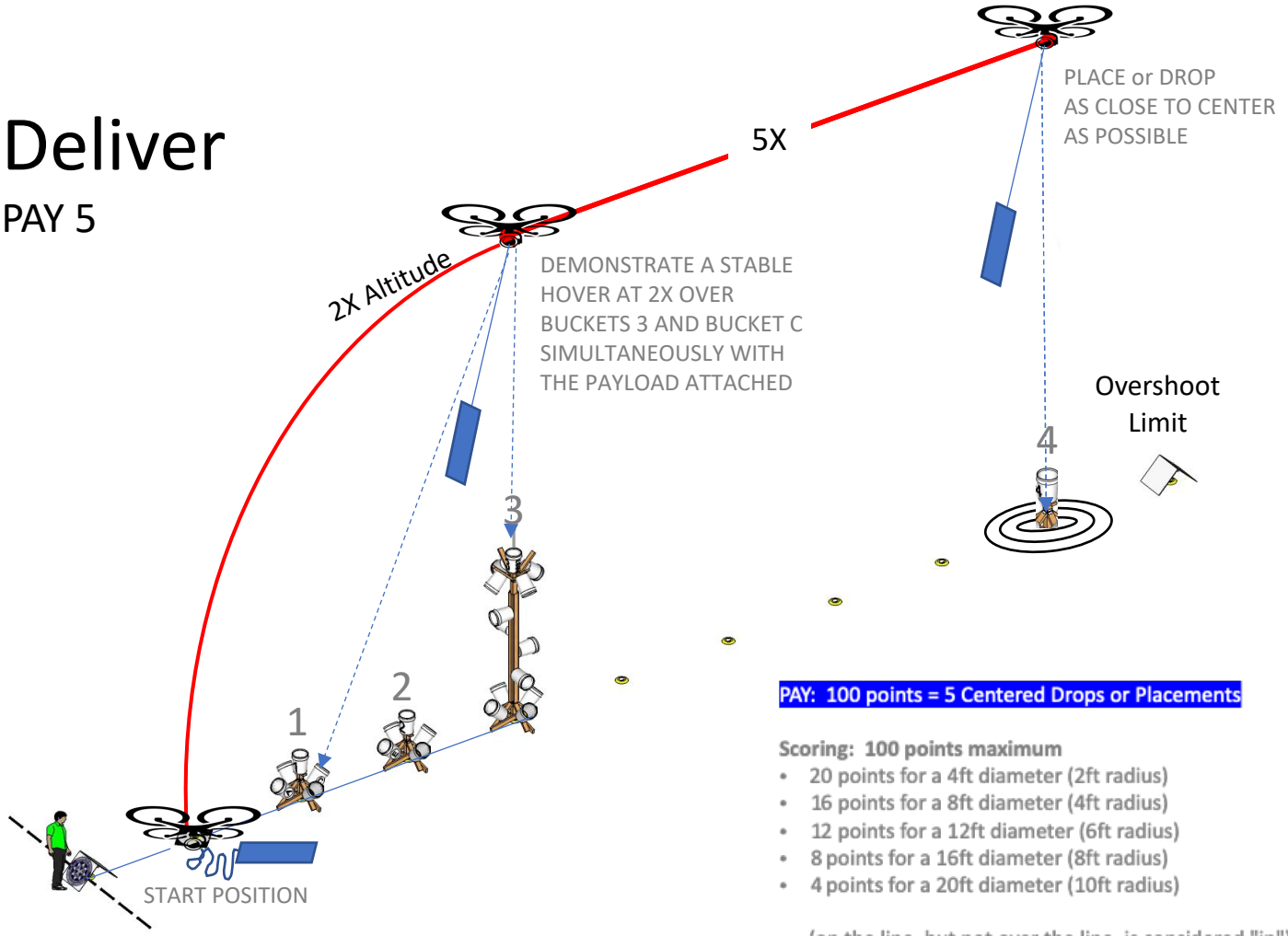
(On the line, but not over, is considered "in")

Evaluate System Capabilities or Pilot Proficiency

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

Deliver

PAY 5

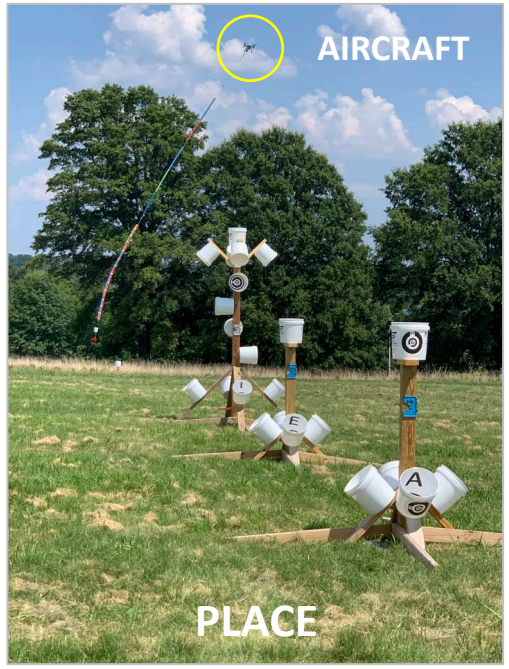


PAY: 100 points = 5 Centered Drops or Placements

Scoring: 100 points maximum

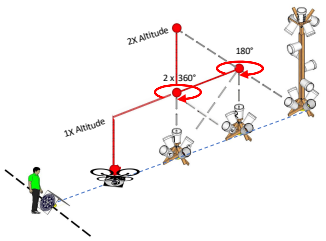
- 20 points for a 4ft diameter (2ft radius)
- 16 points for a 8ft diameter (4ft radius)
- 12 points for a 12ft diameter (6ft radius)
- 8 points for a 16ft diameter (8ft radius)
- 4 points for a 20ft diameter (10ft radius)

(on the line, but not over the line, is considered "in")



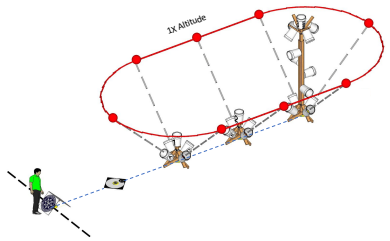
Circuit Training with Scores

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



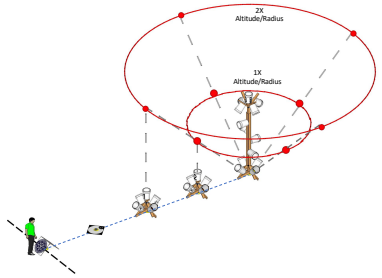
Position
MAN 1 / PAY 1

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



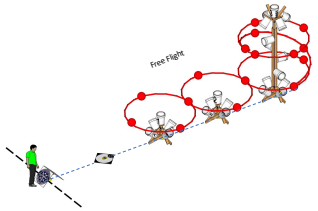
Traverse
MAN 2 / PAY 2

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



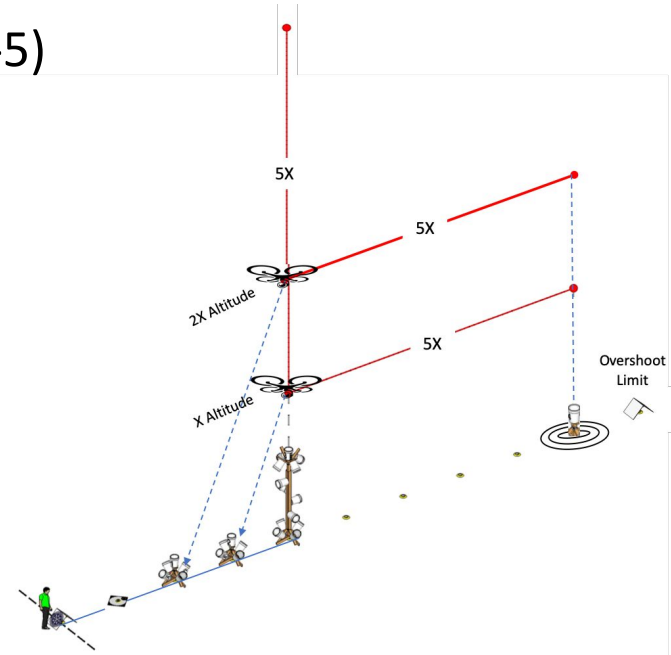
Orbit
MAN 3 / PAY 3

- 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
MAN 5 / PAY 5

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

*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.

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.

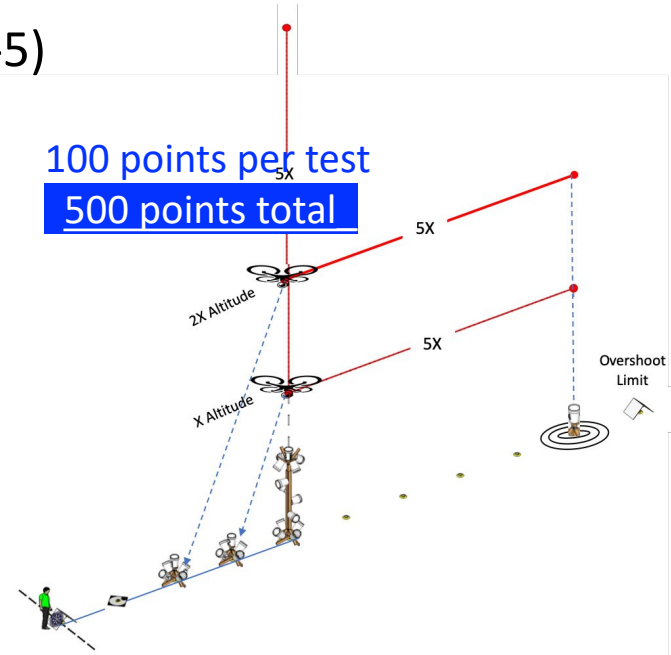
NOT QUITE ALIGNED

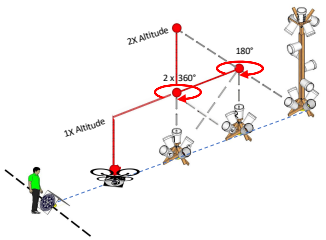
PAY 1-5

ALIGNED

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



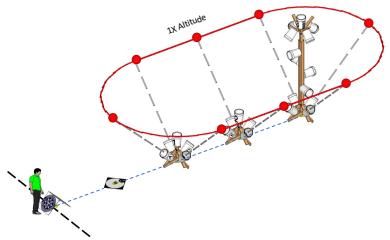


Position
MAN 1 / PAY 1

- 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

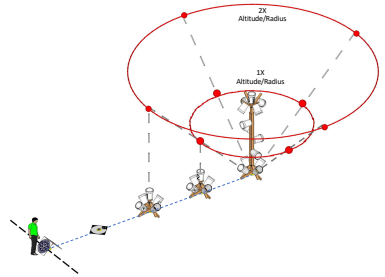


Traverse
MAN 2 / PAY 2

- 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

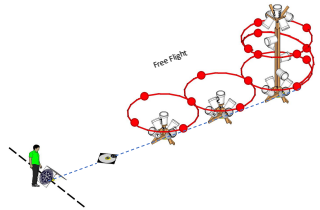


Orbit
MAN 3 / PAY 3

- 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
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

*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.

Comprehensive Pilot Skills Evaluation

Sequential Mini-Trials In Order (time/battery limited or not)

LETTER IDENTIFIERS MAN 1-5

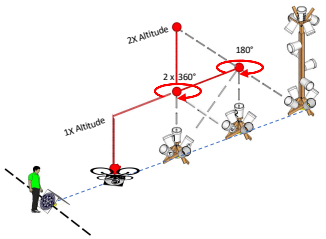
See the entire inscribed ring inside the buckets to evaluate successful alignments. The letters are bucket identifiers.

NOT QUITE ALIGNED

PAY 1-5 VISUAL ACUITY TARGETS

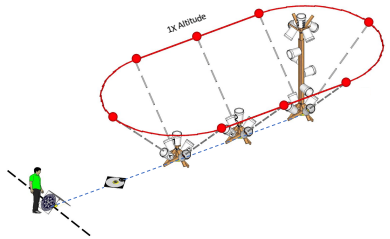
Align and identify the visual acuity targets with increasingly small concentric C gaps in one of eight directions.

ALIGNED



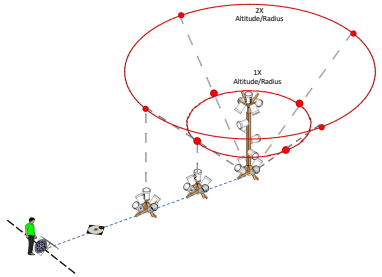
Position
MAN 1 / PAY 1

- 20 tasks in 1 lap
- Perform a complete trial



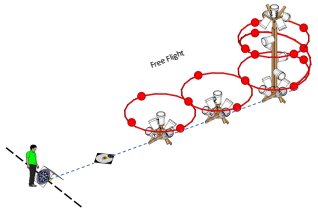
Traverse
MAN 2 / PAY 2

- 20 tasks in 2 laps
- Perform a complete trial



Orbit
MAN 3 / PAY 3

- 8 tasks in 2 laps
- 2X altitude orbit only
- Inward angled buckets only



Spiral
MAN 4 / PAY 4

- 12 tasks in 1 lap
- Spiral post buckets only
- Downward, forward, upward

ONLY DIFFERENCE

Orbit
2 orbits to identify at 2X altitude only (8 center buckets)

Spiral
Free flight to inspect the tall pole only (12 buckets)

MAN: Align only 20 points max	MAN: Align only 20 points max	MAN: Align only 8 points max	MAN: Align only 12 points max
PAY: Align and Identify 100 points max	PAY: Align and Identify 100 points max	PAY: Align and Identify 40 points max	PAY: Align and Identify 60 points max

60 points total

300 points total

*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.

Trial Forms for Tests an Scenarios

Track and Compare Performance In Different Locations or Over Time

WEBSITE: DOWNLOAD FORMS AND STICKER FILES HERE

SCORE SUMMARY ON COVER

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

Basic Maneuvering and Payload Functionality

Safety | Capabilities | Proficiency

Forms Version: 2019-G

Make: _____

Model: _____

Config: _____

Pilot Code: _____ VO Code: _____

Date: _____

Facility: _____

Location: _____

Event: _____

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

MAN 1-5 TOTAL SCORE
100 Points Max

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

PAY 1-5 TOTAL SCORE
500 Points Max

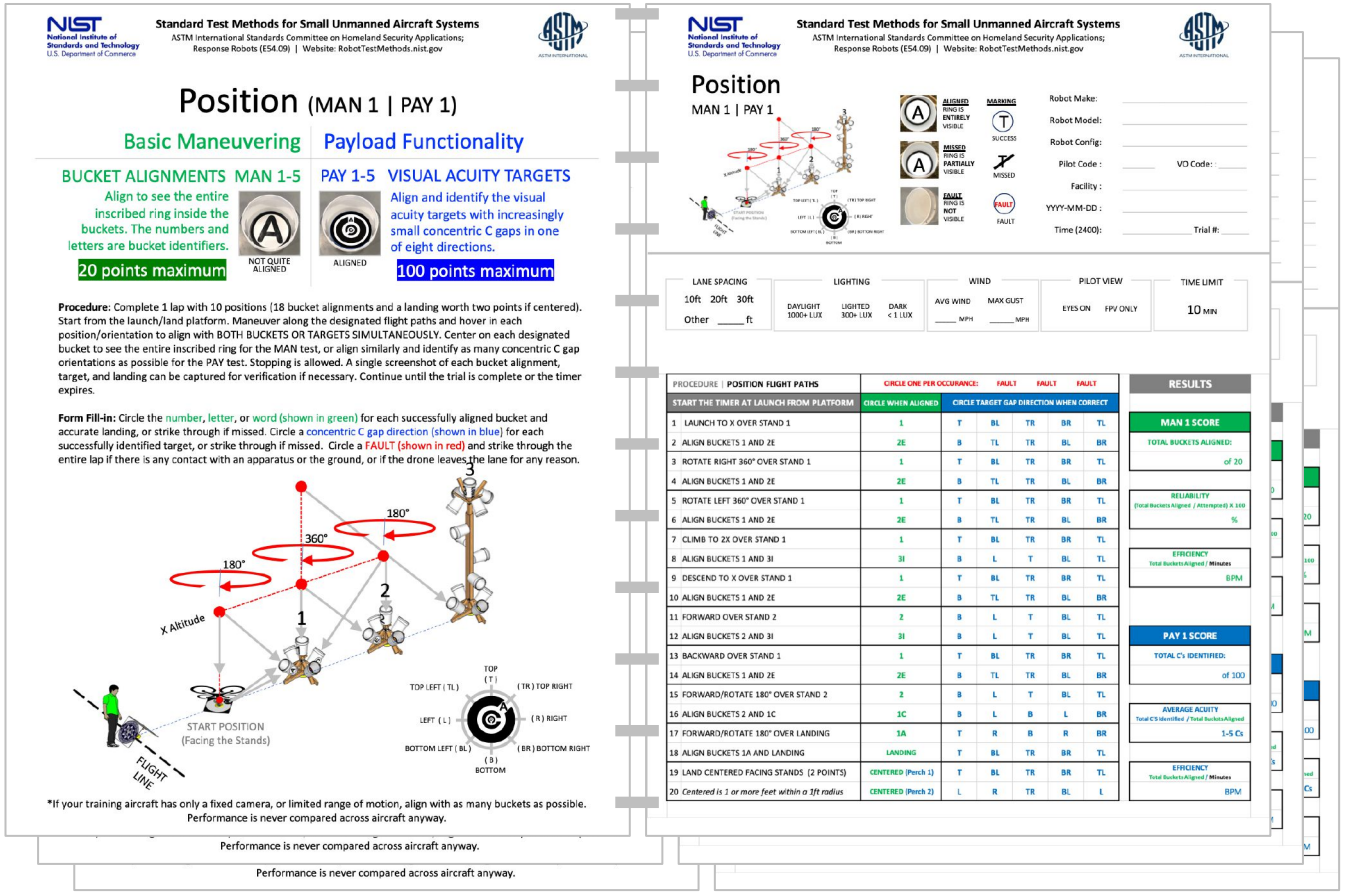
Test Director:
Adam Jacoff
Intelligent Systems Division
National Institute of Standards and Technology
U.S. Department of Commerce

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

Internet
RobotTestMethods.nist.gov

Email
RobotTestMethods@nist.gov

PILOT BOOKLET WITH INSTRUCTIONS, FORMS, SCENARIOS, ETC.



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
Align to see the entire inscribed ring inside the buckets. The numbers and letters are bucket identifiers.
20 points maximum
NOT QUITE ALIGNED

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

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.

Position
MAN 1 | PAY 1

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

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

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

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

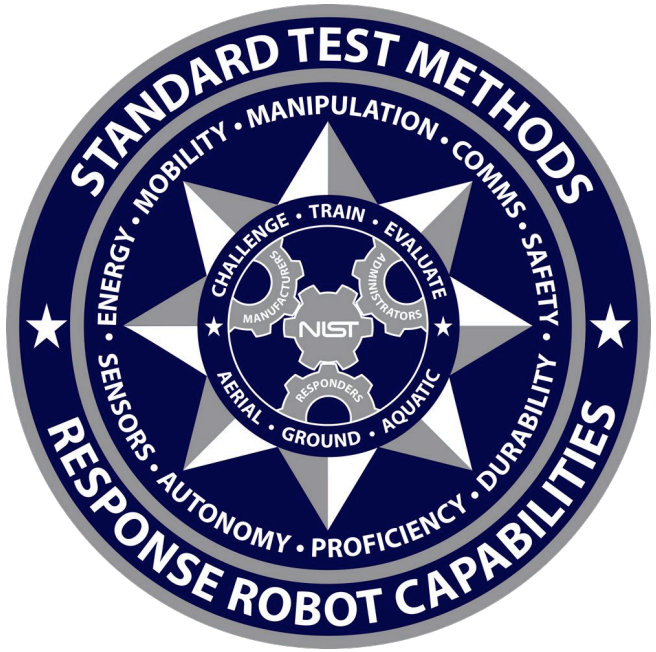
RESULTS
MAN 1 SCORE
TOTAL BUCKETS ALIGNED: of 20
RELIABILITY (Total Buckets Aligned / Attempted) X 100 %
EFFICIENCY Total Buckets Aligned / Minutes BPM
PAY 1 SCORE
TOTAL C's IDENTIFIED: of 100
AVERAGE ACUITY Total C's Identified / Total Buckets Aligned 1-5 Cs
EFFICIENCY Total Buckets Aligned / Minutes BPM

Performance is never compared across aircraft anyway.

Performance is never compared across aircraft anyway.

Training and Embedding into Scenarios

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



WEBSITE: WATCH THE VIDEO VERSION WITH FLY THROUGH ANIMATIONS HERE

WEBSITE: DOWNLOAD FORMS AND STICKER FILES HERE

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

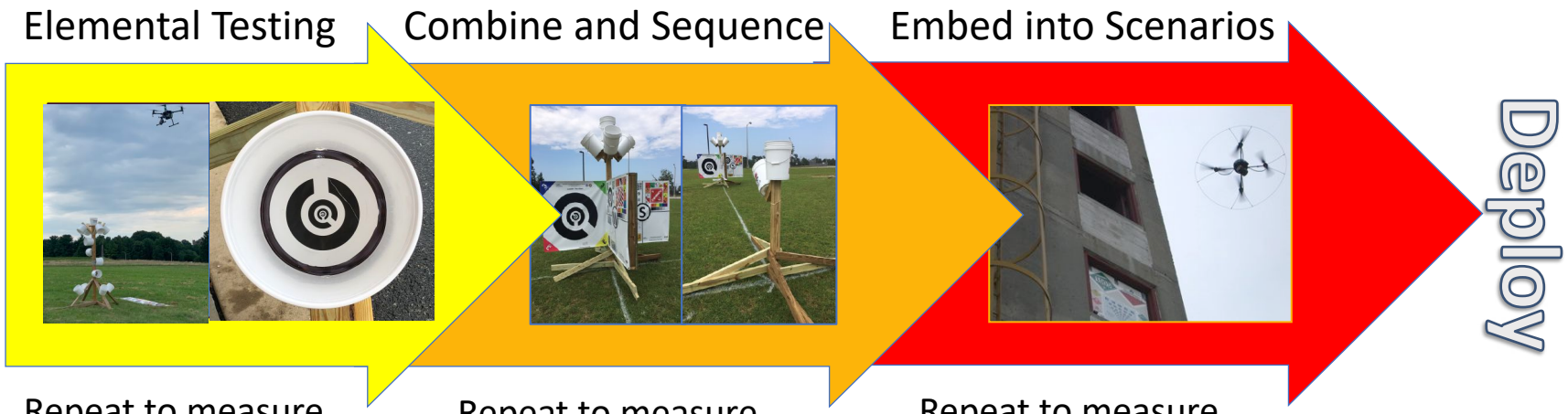
Sponsor:
Phil Mattson
Science and Technology Directorate
U.S. Department of Homeland Security

Internet
RobotTestMethods.nist.gov

Email
RobotTestMethods@nist.gov

Using Standard Test Methods

Safety | Capabilities | Proficiency



Repeat to measure ***individual capabilities.***

Identify and fix weaknesses.

Practice and evaluate task proficiency with quantitative scores in timed trials.

Repeat to measure ***system trade-offs.***

Increase complexity in stepwise ways.

Practice and evaluate mission proficiency with quantitative scores in timed trials.

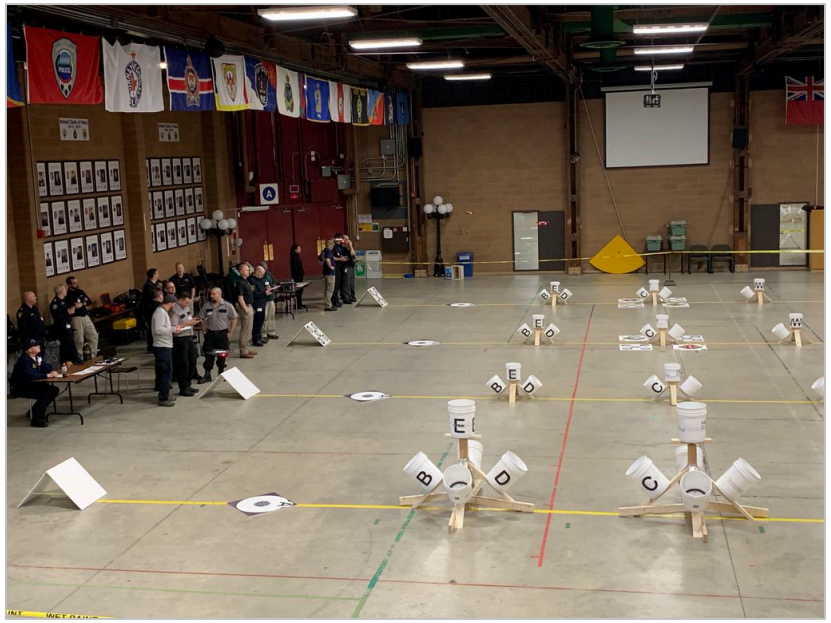
Repeat to measure ***degradation and tempo.***

Involve uncontrolled variables.

Practice and evaluate operational readiness with quantitative scores in timed trials.

Concurrent Test Lanes

Training and Evaluation



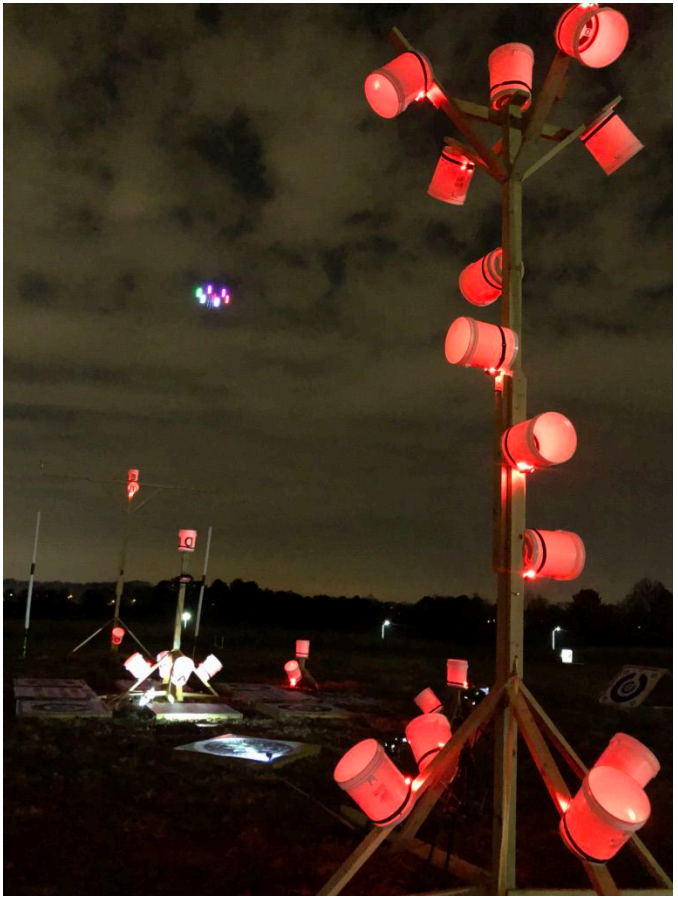
Ceiling height determines maximum safe hover altitude (2X)

Canadian Police College, London, Ontario, Canada

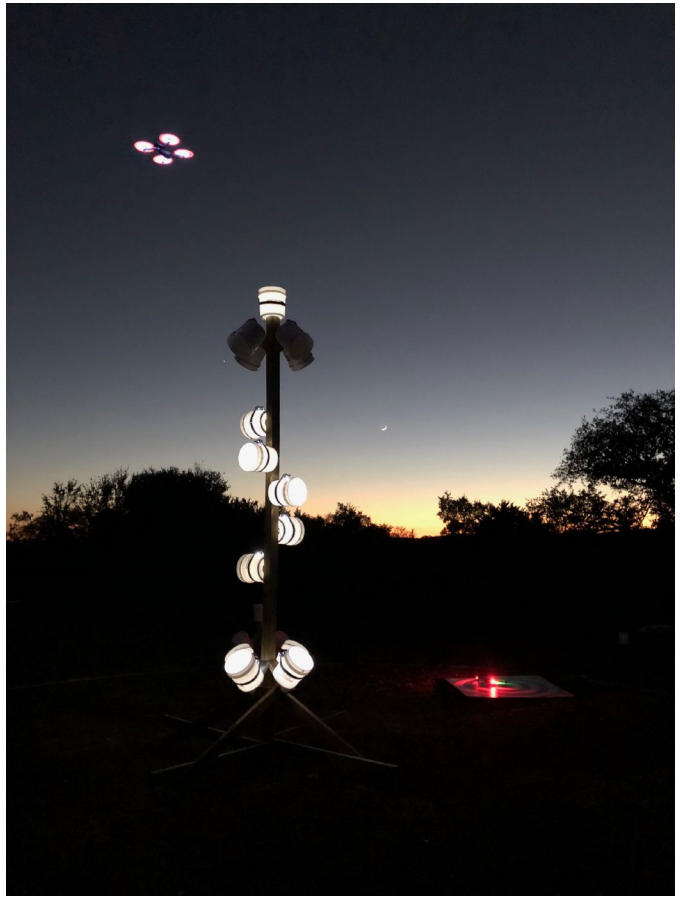
Night Operations

Training and Evaluation

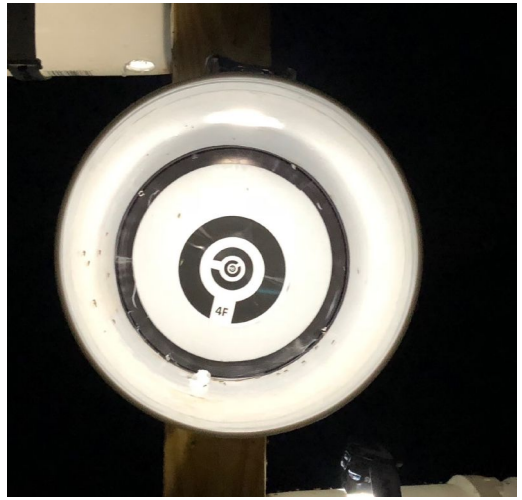
Headlamps wrapped around the buckets pointed inward!



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

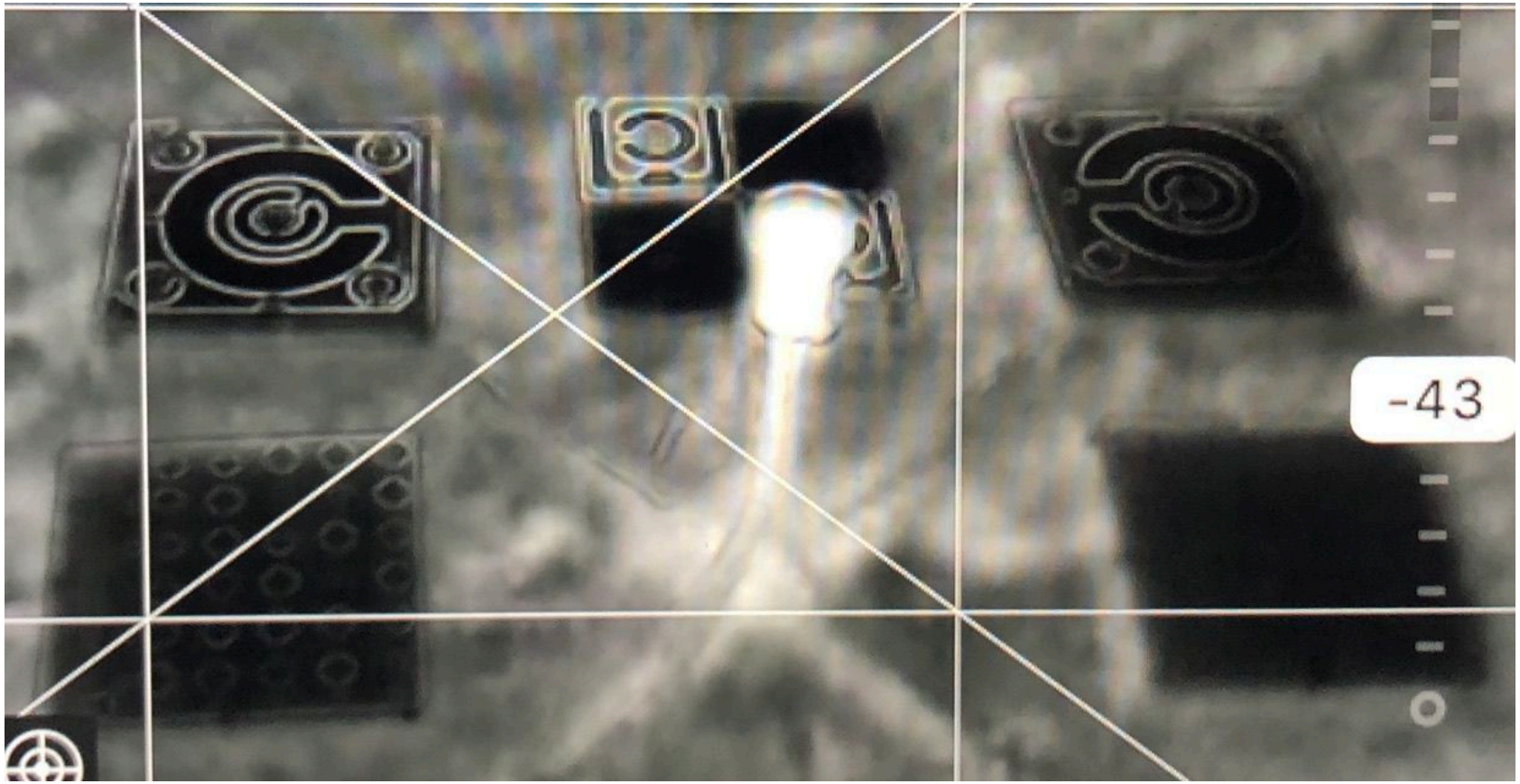
Thermal Targets

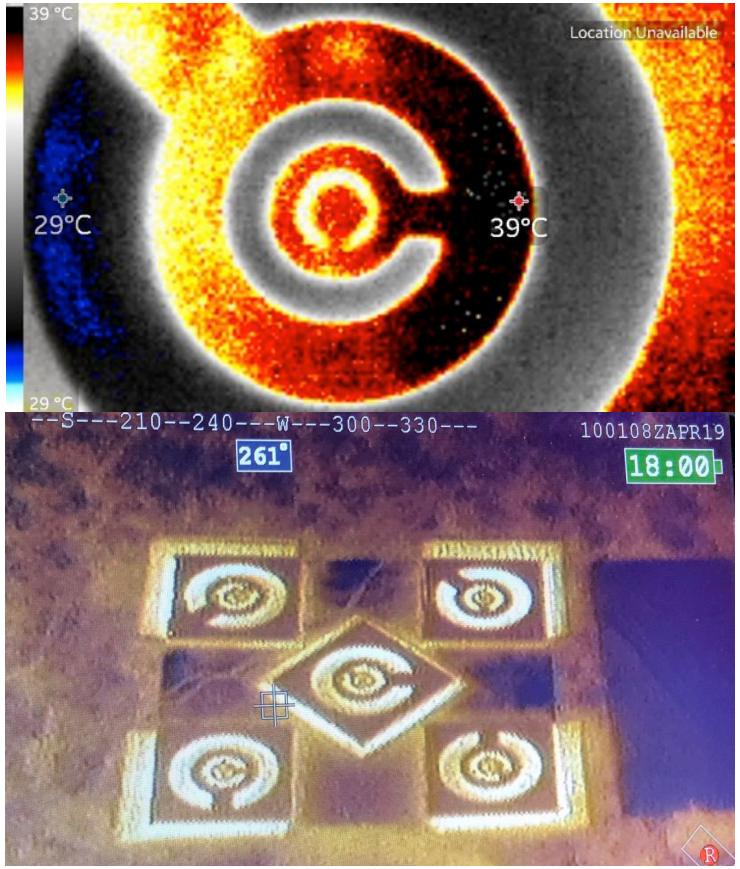
Measure additional sensor capabilities

NIST and Reveille Peak Ranch, Burnet, TX

Thermal Targets

Training and Evaluation





NIST and Reveille Peak Ranch, Burnet, TX

Embed 20 Targets into ANY Scenario

Training and Evaluation

DOWNLOAD THE 8IN ROUND STICKER FILE

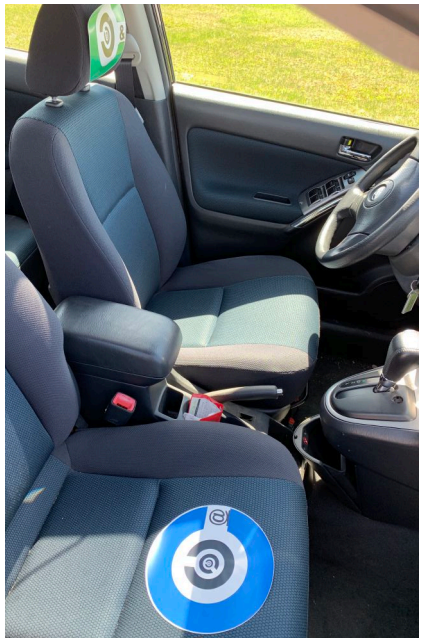
20 Visual/Color Acuity Targets x 5 Concentric Cs = 100 Points

https://drive.google.com/file/d/15G1NUarr1_vOdf_1gYgJellA8HuqJngT/view?usp=sharing

#	ROOF STAND – TOP BUCKET Any unique number to identify the scenario feature

A	ROOF STAND – ANGLED BUCKET Front of the vehicle
B	ROOF STAND – ANGLED BUCKET Driver side
C	ROOF STAND – ANGLED BUCKET Rear
D	ROOF STAND – ANGLED BUCKET Passenger side
E	FRONT License plate
F	FRONT Vehicle ID number
G	DRIVER SIDE Window profile of driver
H	DRIVER SIDE Other location of interest
I	DRIVER SIDE Other location of interest
J	DRIVER SIDE Other location of interest

K	REAR License plate
L	REAR Other location of interest
M	PASSENGER SIDE Other location of interest
N	PASSENGER SIDE Other location of interest
O	PASSENGER SIDE Other location of interest
P	PASSENGER SIDE Window profile of passenger
Q	CAB NTERIOR Passenger headrest face view
R	CAB INTERIOR Passenger seat with object
S	CAB INTERIOR Driver seat with object
T	CAB INTERIOR Driver headrest face view



Sedan Inspection

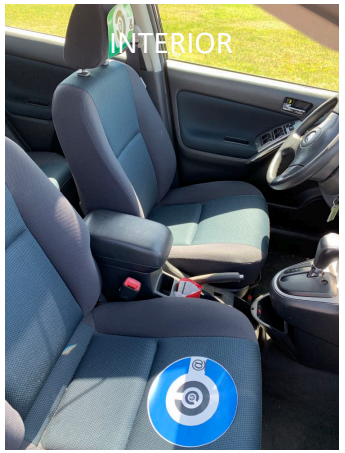
Training and Evaluation

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



Canadian Police College, London, Ontario, Canada

Box Truck Inspection

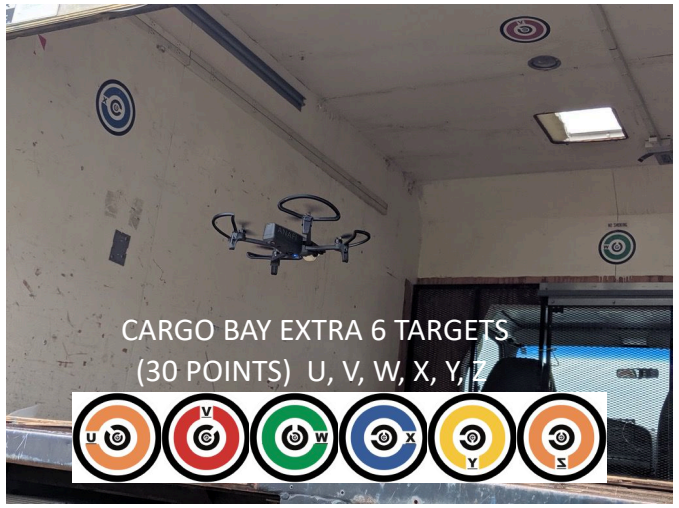
Training and Evaluation

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

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

Spiral inspect all sides and interior.

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



NIST, Gaithersburg, MD

Fuel Truck / Rail Car Inspection

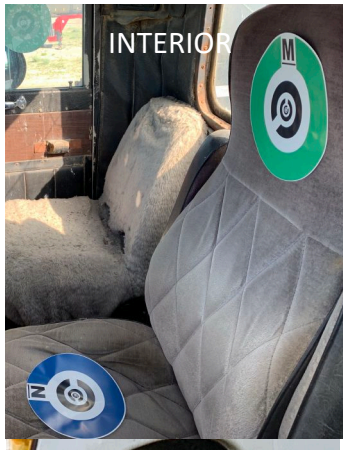
Training and Evaluation

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

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

Spiral inspect all sides and interior.

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



Safety and Emergency Response Training Center, Pueblo, CO

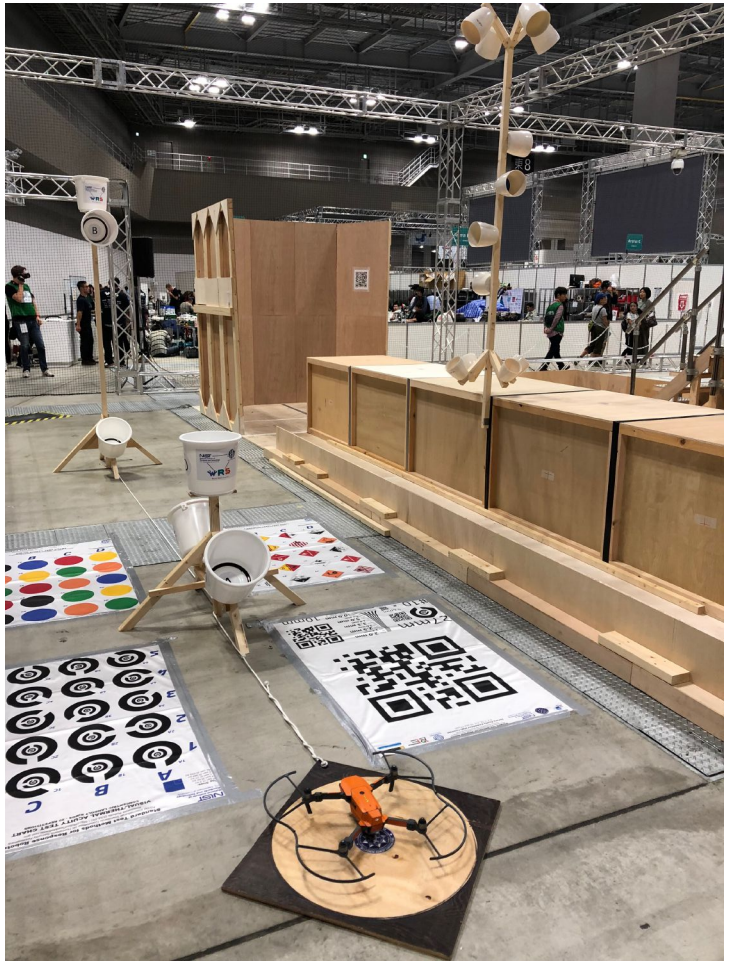
Wide Area Search

Training and Evaluation

NIST, Gaithersburg, MD

Indoor Search

Training and Evaluation



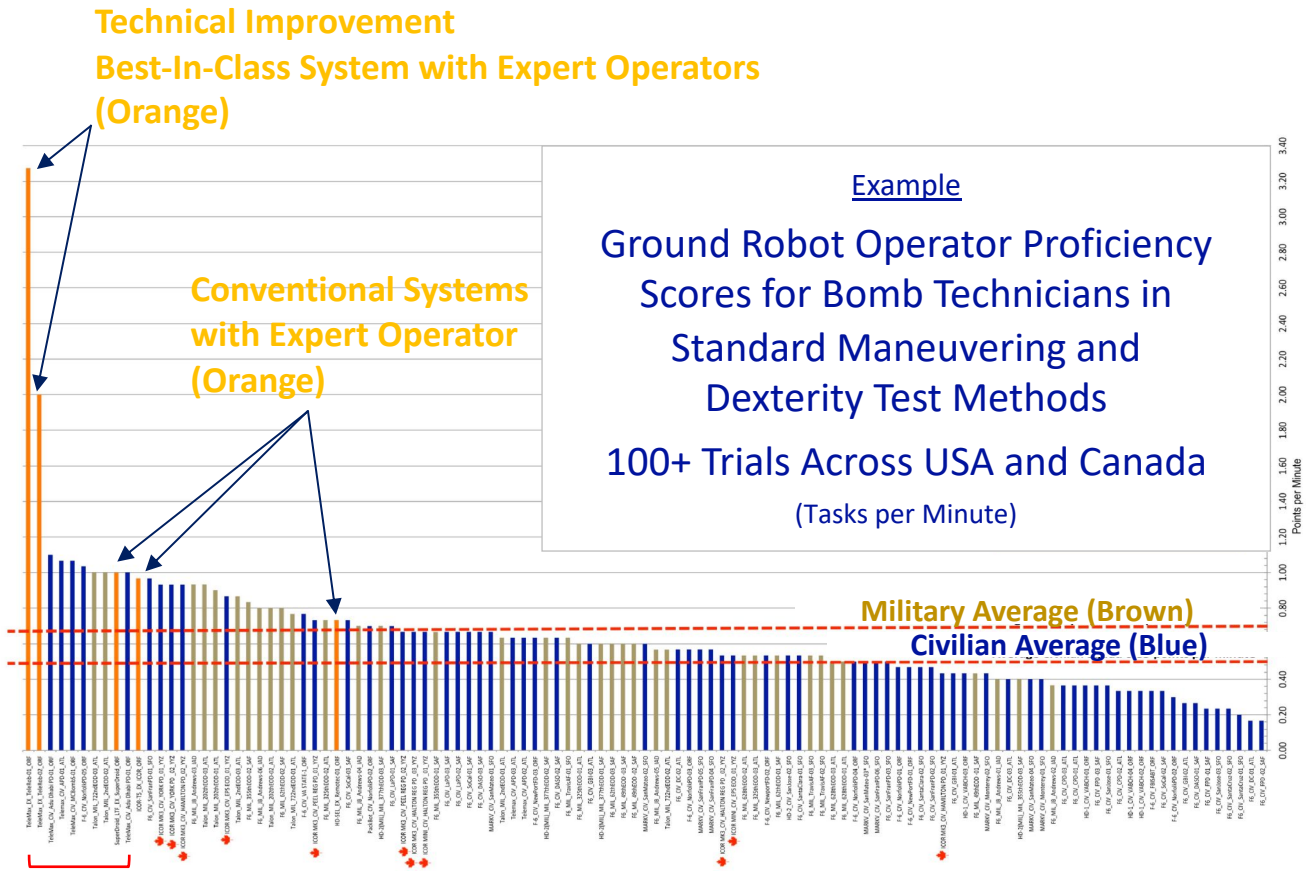
Standard Disaster Response Robot Challenge and Plant Disaster Prevention Challenge, World Robot Summit, Japan

Measure and Track Performance, Then Set Thresholds

Training and Evaluation

Roles for Standards Organizations and Others

NFPA, ANSI, AUVSI	Select standard tests that define readiness for mission tasks. Set thresholds or adopt averages
ASTM INTERNATIONAL	Develop standard test methods and collect robot capability and reliability data with "expert" operators



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:	Quantitative Thresholds (Examples, You May Set Your Own)	Benefits
4) PROFICIENT Can do the complete task quickly and accurately. Can tell or show others how to do the task.	80-100% ◆	Scores captured in standard tests.
3) COMPETENT Can do all parts of the task. Needs only a spot check of completed work.	60-79% ■	Relative to the "expert" provided by the manufacturer (or best score of all).
2) PARTIALLY PROFICIENT Can do most parts of the task. Needs only help on hardest parts.	40-59% ●	Same description applies, but thresholds can be chosen based on measured data.
1) LIMITED Can do simple parts of task. Needs to be told or shown how to do most of task.	20-39% ○	Provides clear thresholds for self-evaluation.

Thank You To All Our Collaborators and Hosts

Test Method Validation Exercises

2018.02 ASTM E54.09 Standards Meeting, NIST, Gaithersburg, MD (3 days)
2018.03 Virginia UAS Summit on Public Safety, Crozet, VA (3 days)
2018.04 Canadian Police College Training, London Ontario, Canada (5 days)
2018.05 AUVSI Expo booth and Public Safety Presentation (1 day)
2018.05 NIST Aerial Payload Challenge, Fredericksburg, VA (3 days)
2018.06 RoboCupRescue World Championship, Montreal, Canada (4 days)

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2018.11 DHS/FBI/Federal meeting and demonstration, Manassas, VA (1 day)
2018.12 Yuneec UAS capabilities evaluation, NIST (3 days)
2019.01 IAFF Training Conference (1 day remote)
2019.01 Los Angeles Fire Dept. Training (3 days remote)

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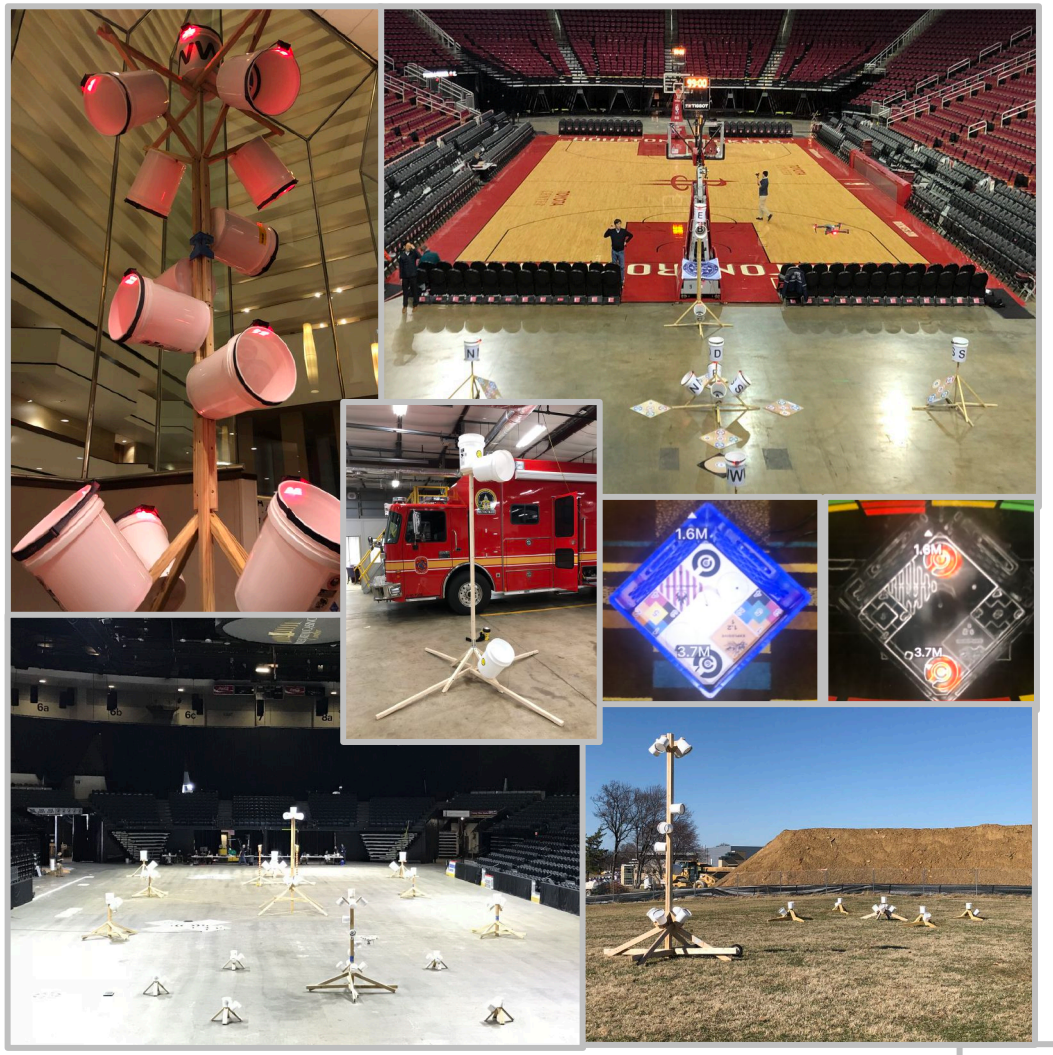

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APPARATUS

FABRICATION

Short Bucket Leveling Stand Fabrication

Optional Hinges for Stowing/Transportation

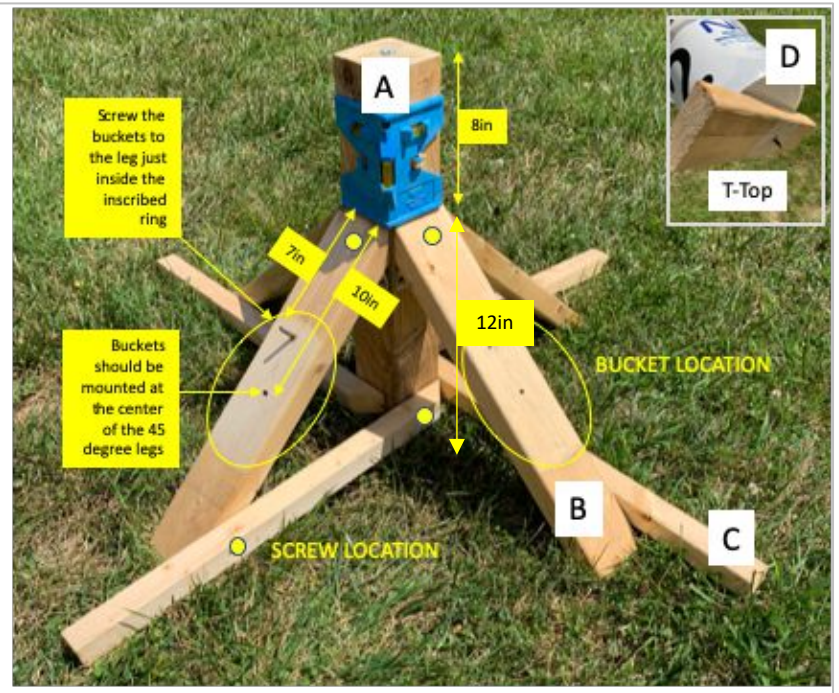
Short Bucket Leveling Stand

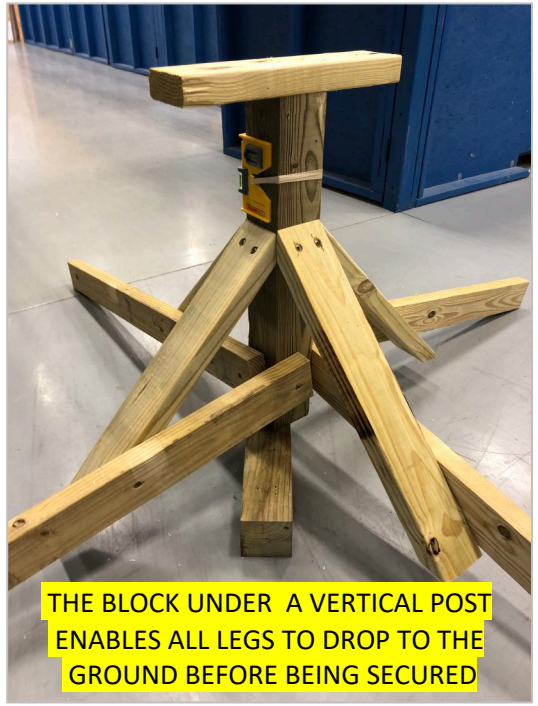
Cut list:

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.



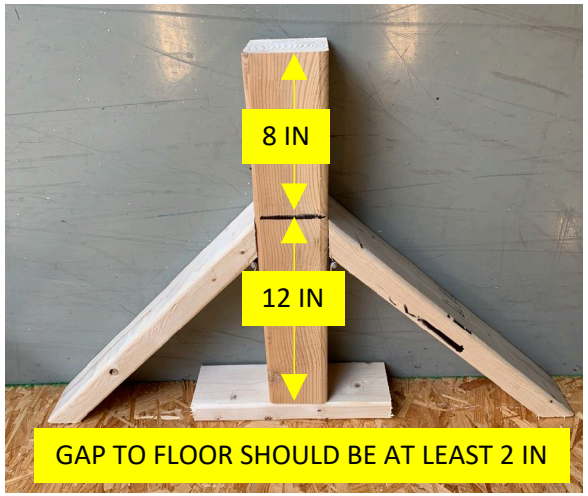

THE BLOCK UNDER A VERTICAL POST ENABLES ALL LEGS TO DROP TO THE GROUND BEFORE BEING SECURED

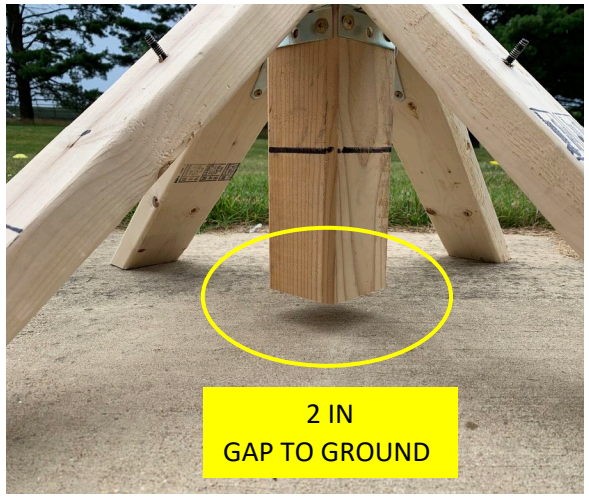

THE BLOCK CAN BE REMOVED ONCE THE STAND IS SECURED VERTICAL

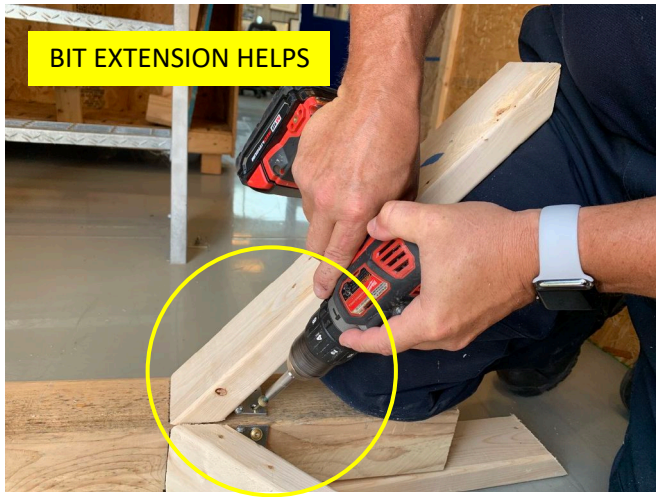
The advantage of this bucket leveling stand design is that they can be used WITHOUT THE OUTRIGGERS (shown here as either 2x2s or 2x4s) on flat surfaces indoors and in parking lots. The outriggers in this design allow leveling in grass or elsewhere. This is best done by resting the center post on a block 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. 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

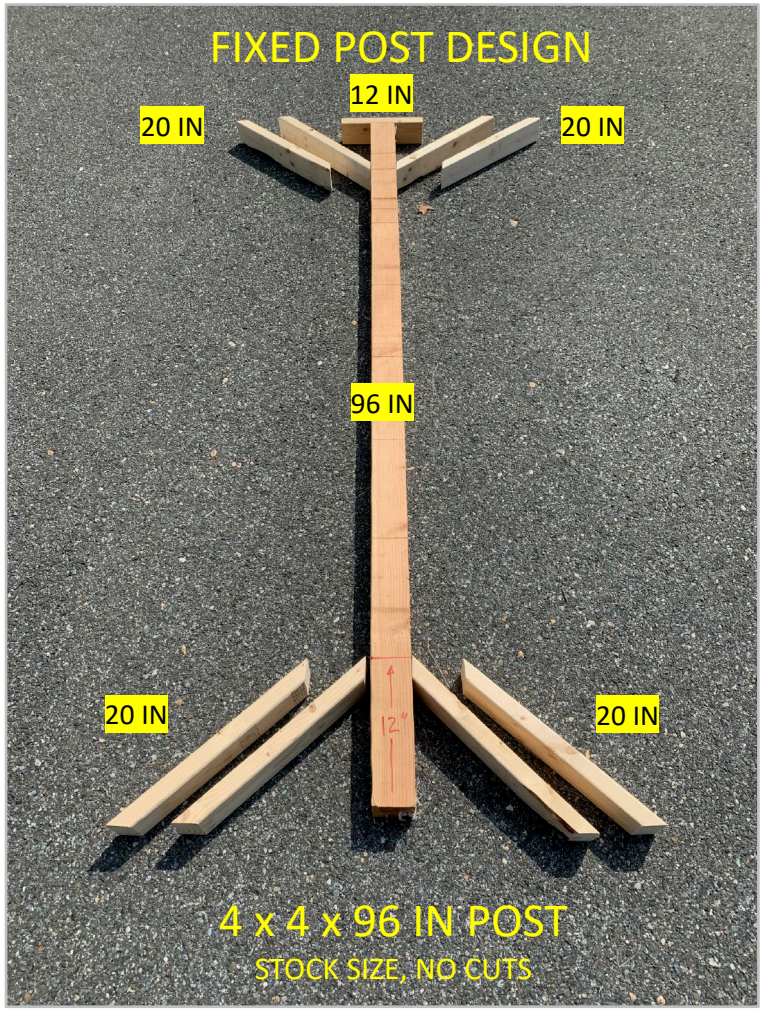


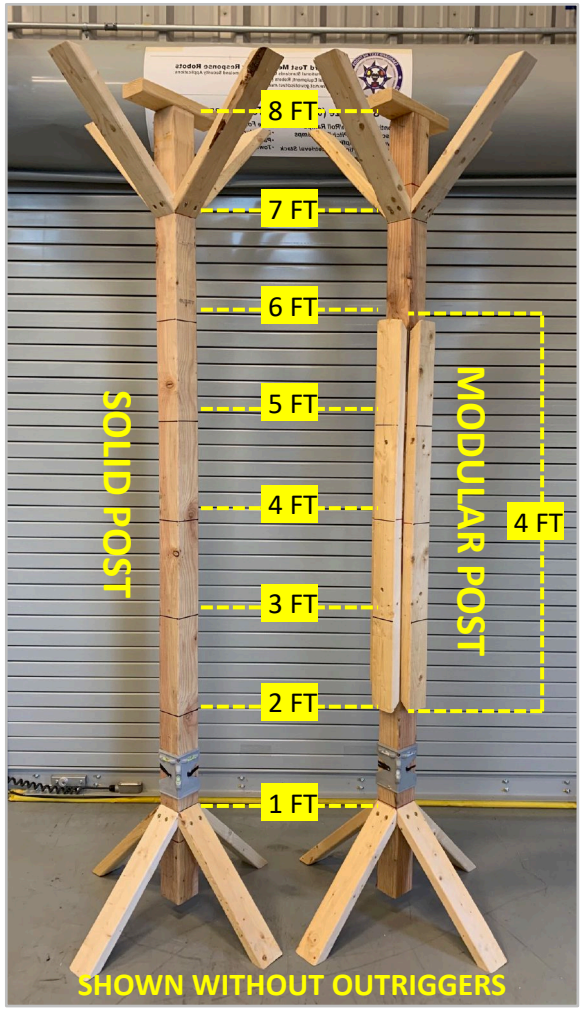


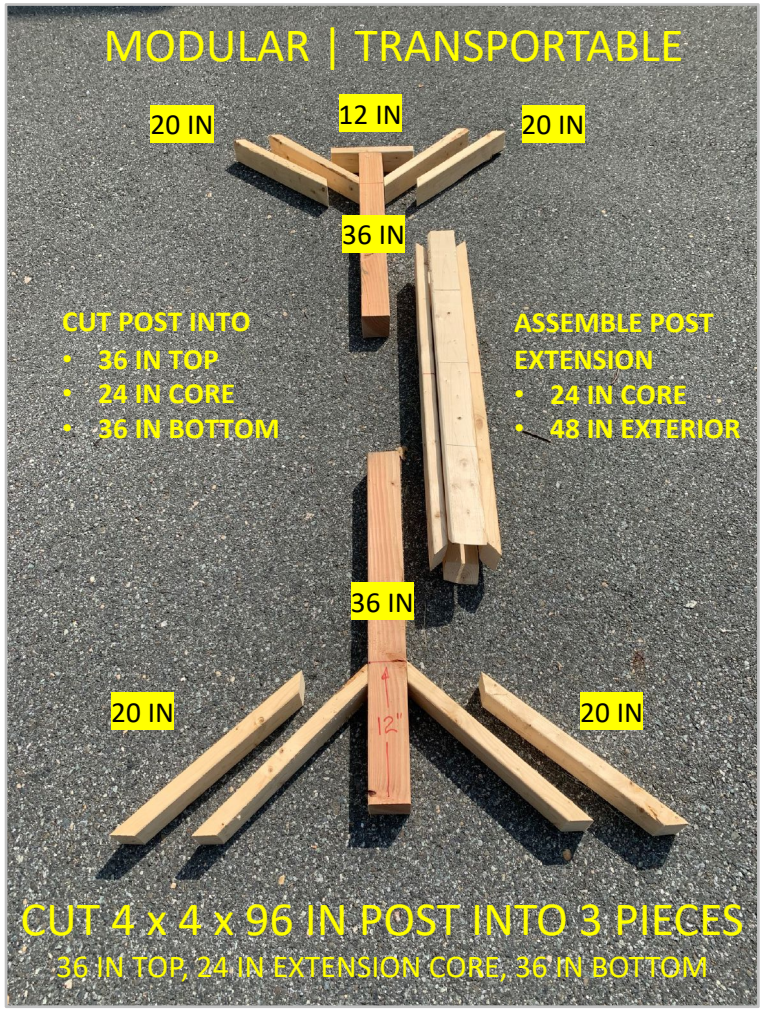


Tall Bucket Leveling Post Fabrication

Fixed Post Design or Modular/Transportable Design

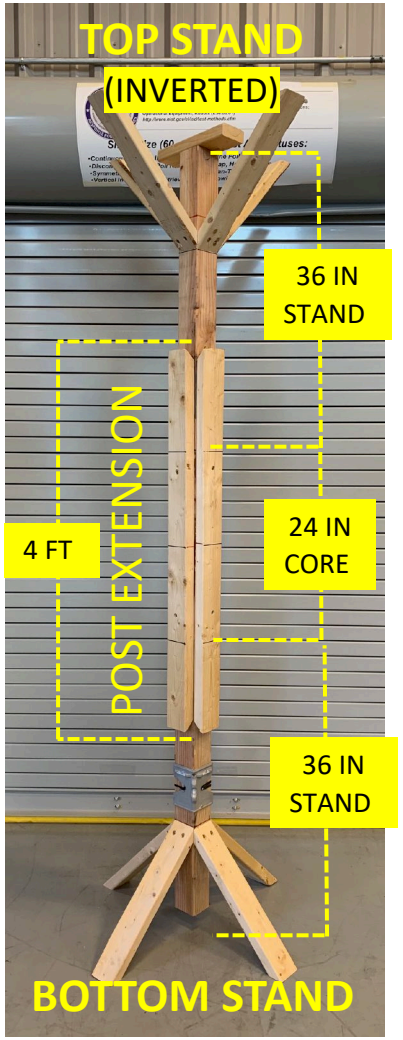


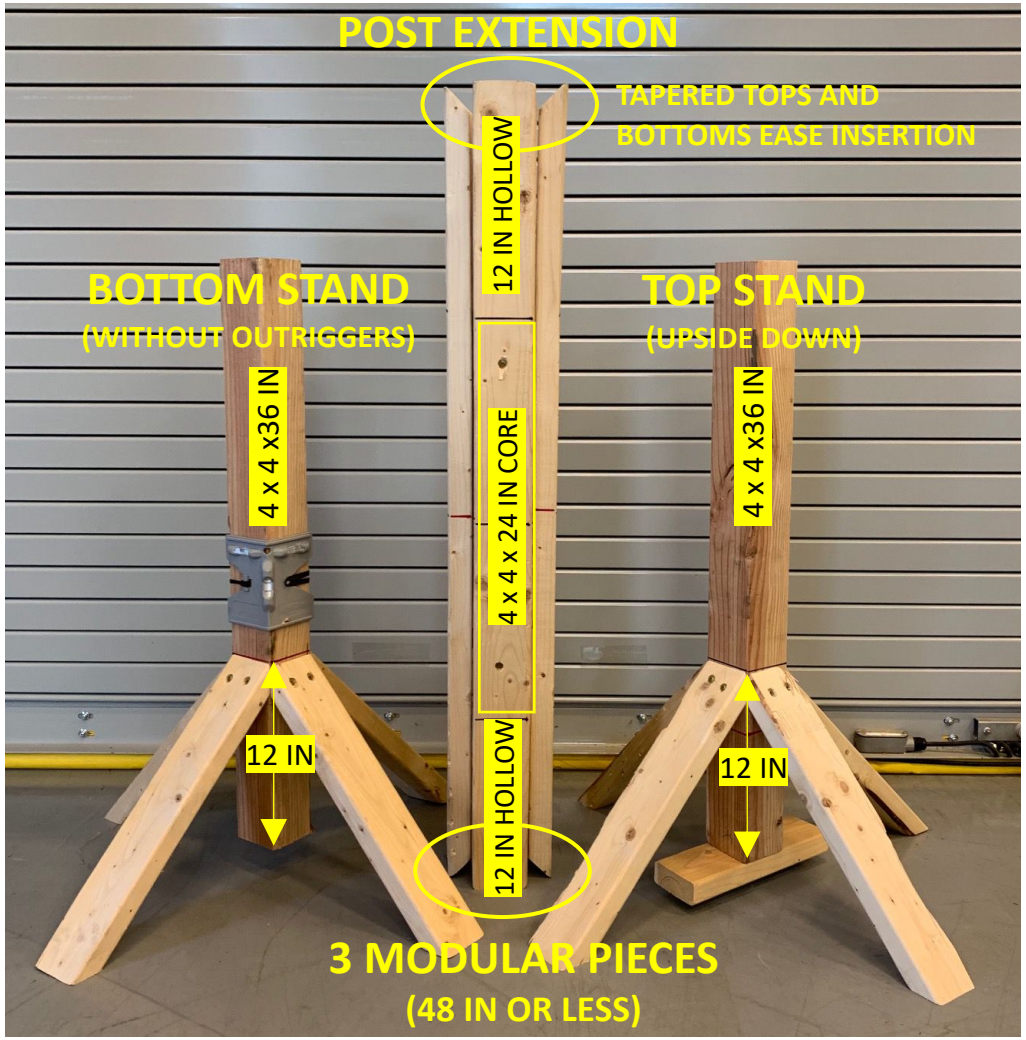


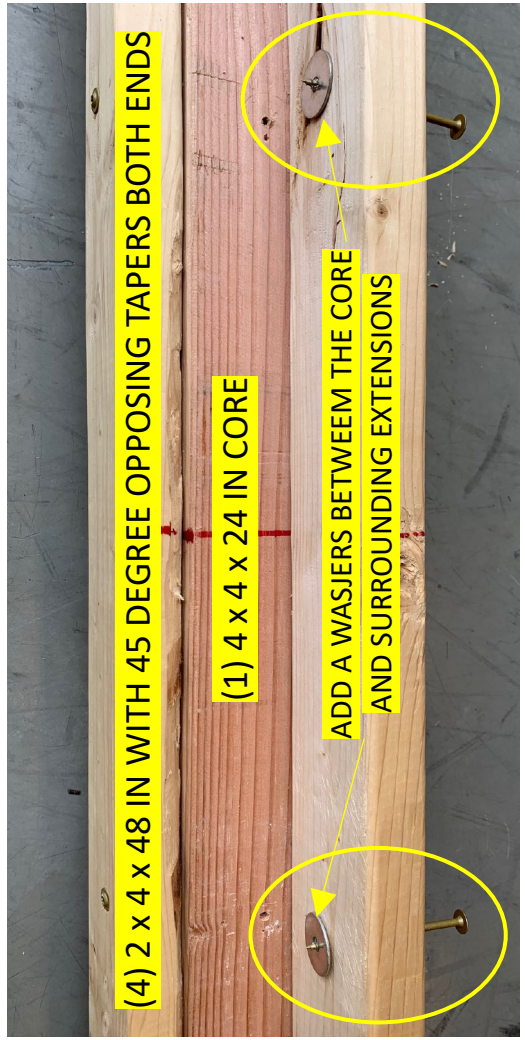


Tall Bucket Leveling Post Fabrication

Modular Design Details for Stowing/Transportation

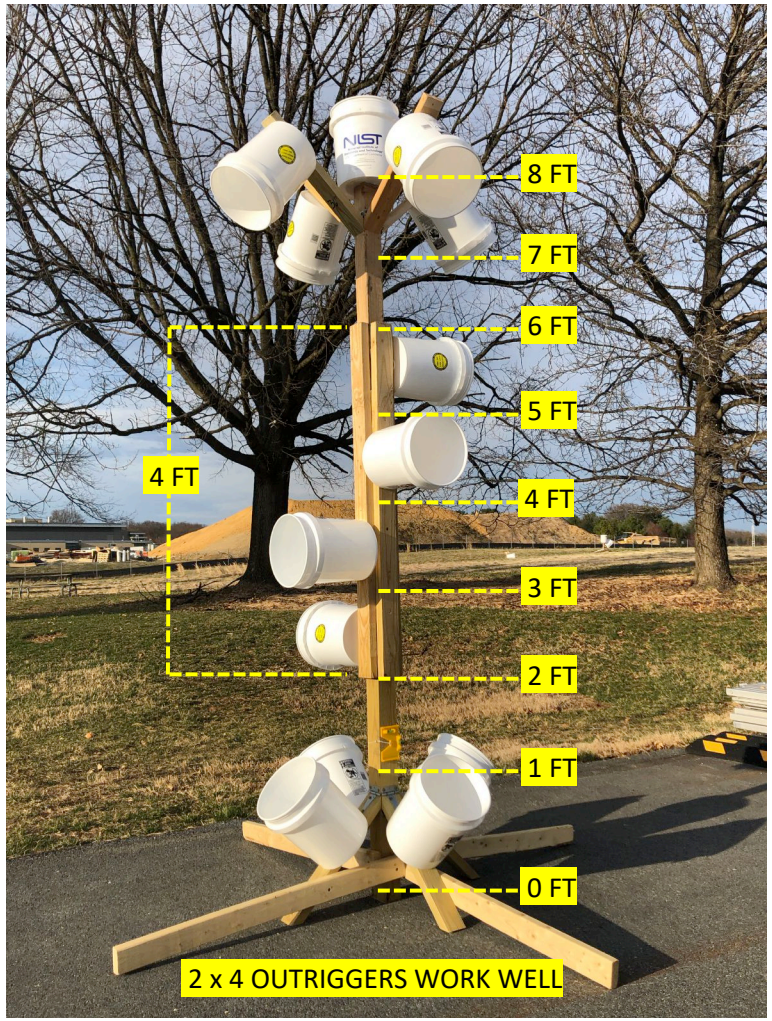






Tall Bucket Leveling Post Fabrication

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

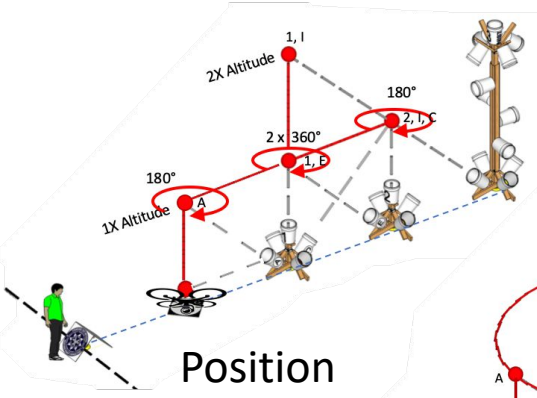
NIST-ASTM-NFPA 2400 Test Methods for sUAS: Stowing a 2ft Bucket Leveling Stand for Flat Terrain.
https://vimeo.com/325052953

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

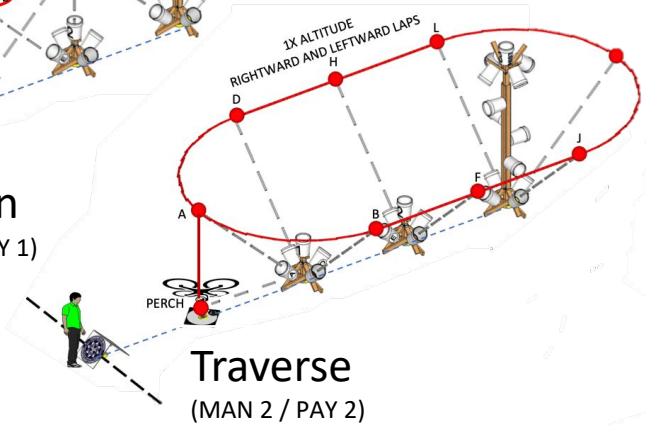
NIST-ASTM-NFPA 2400 Test Methods for sUAS: Deploying a 10ft Spiral Inspect Post (stowable/transportable in three pieces).
https://vimeo.com/327968250

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

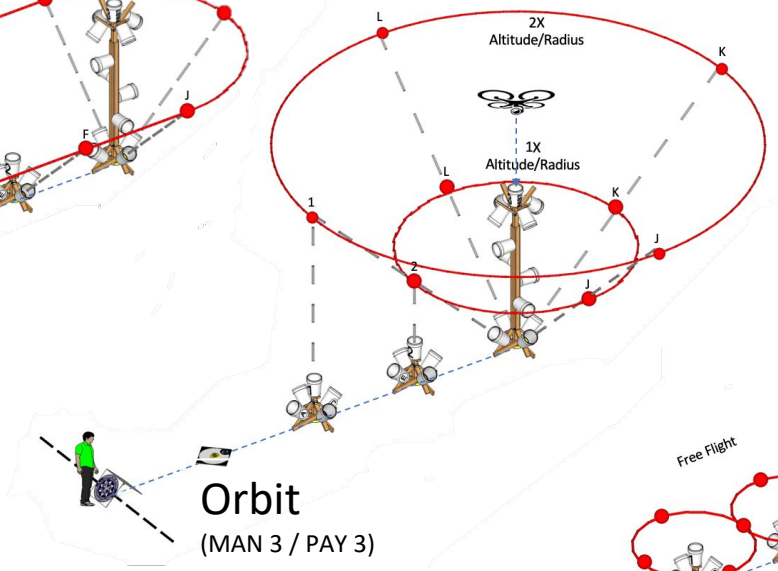
Comprehensive Flight Paths in a Single Lane



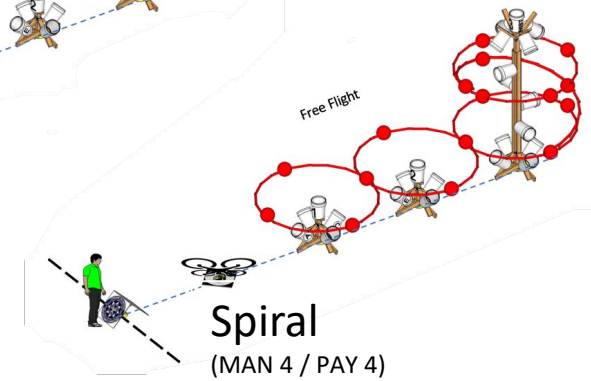
Position
(MAN 1 / PAY 1)



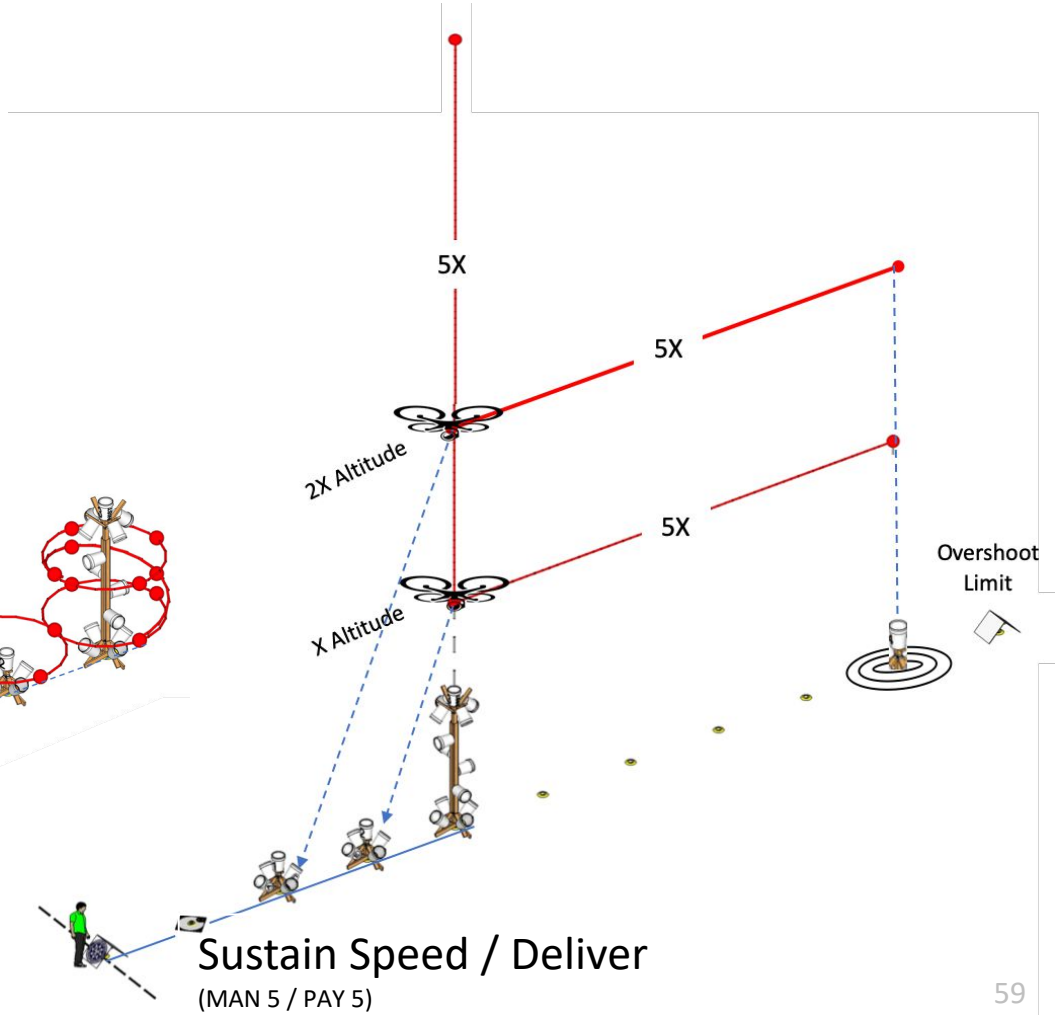
Traverse
(MAN 2 / PAY 2)



Orbit
(MAN 3 / PAY 3)



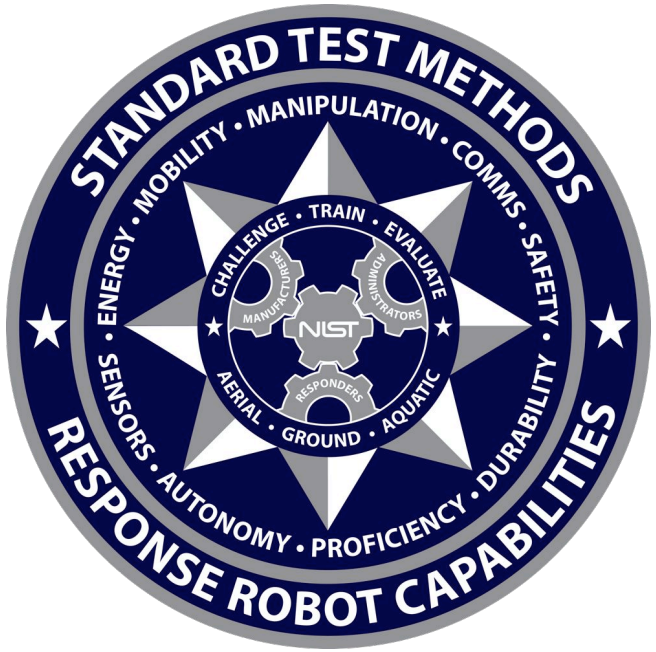
Spiral
(MAN 4 / PAY 4)



Sustain Speed / Deliver
(MAN 5 / PAY 5)

Test Method Procedures and Flight Paths

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



WATCH THE VIDEO VERSION WITH FLY THROUGH ANIMATIONS

DOWNLOAD FORMS AND STICKER FILES

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

FLIGHT PATHS

POSITION

MAN 1-5 LETTER IDENTIFIERS

ALIGNED

See the entire inscribed ring inside the buckets to evaluate successful alignments. The letters are bucket identifiers.

PAY 1-5 VISUAL ACUITY TARGETS

NOT ALIGNED

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

Position

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

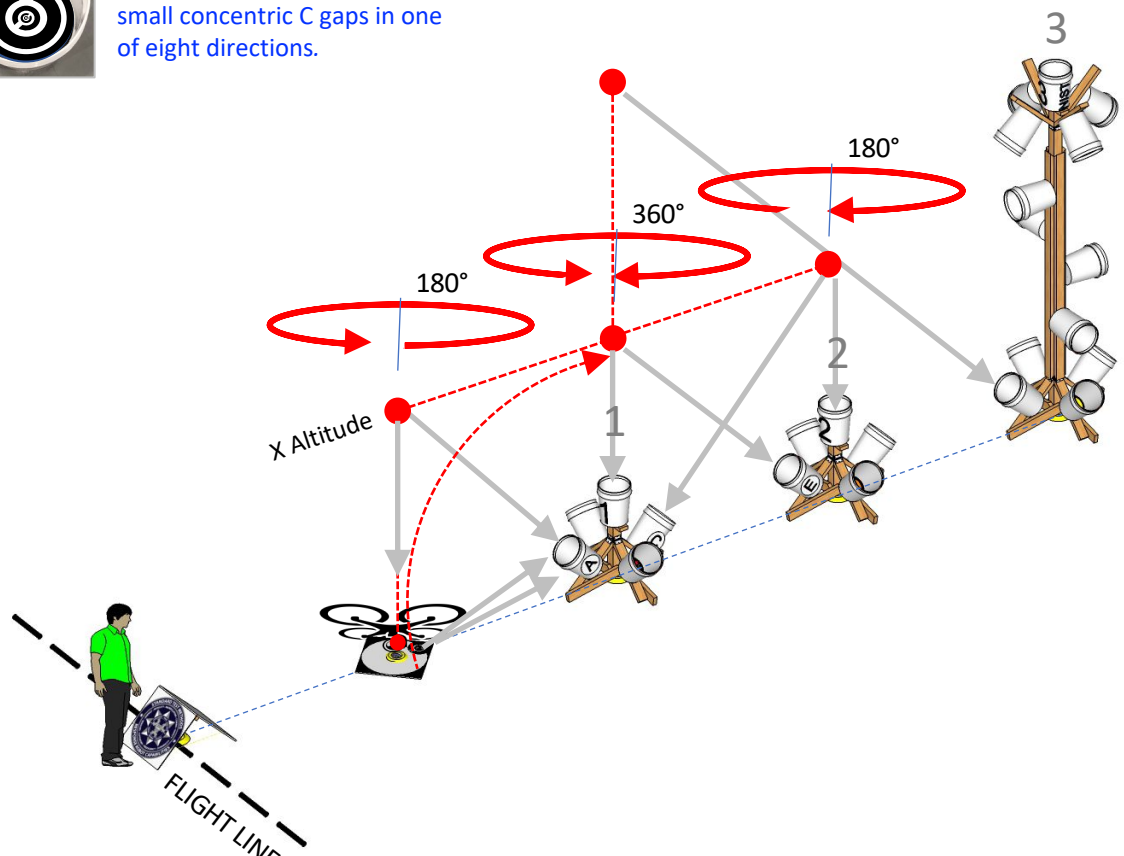
MAN 1-5 LETTER IDENTIFIERS

See the entire inscribed ring inside the buckets to evaluate successful alignments. 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.



SCORING

MAN PAY

FLIGHT PATH

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 RIGHT 180° over 2	Bucket C	Bucket 2
9.	FORWARD/ROTATE LEFT 180° over Land	Bucket A	Landing
10.	LAND CENTERED facing stands	Centered	Perch 1
		Centered	Perch 2

MAN: 20 points = 10 Positions, 18 Alignments and 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

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

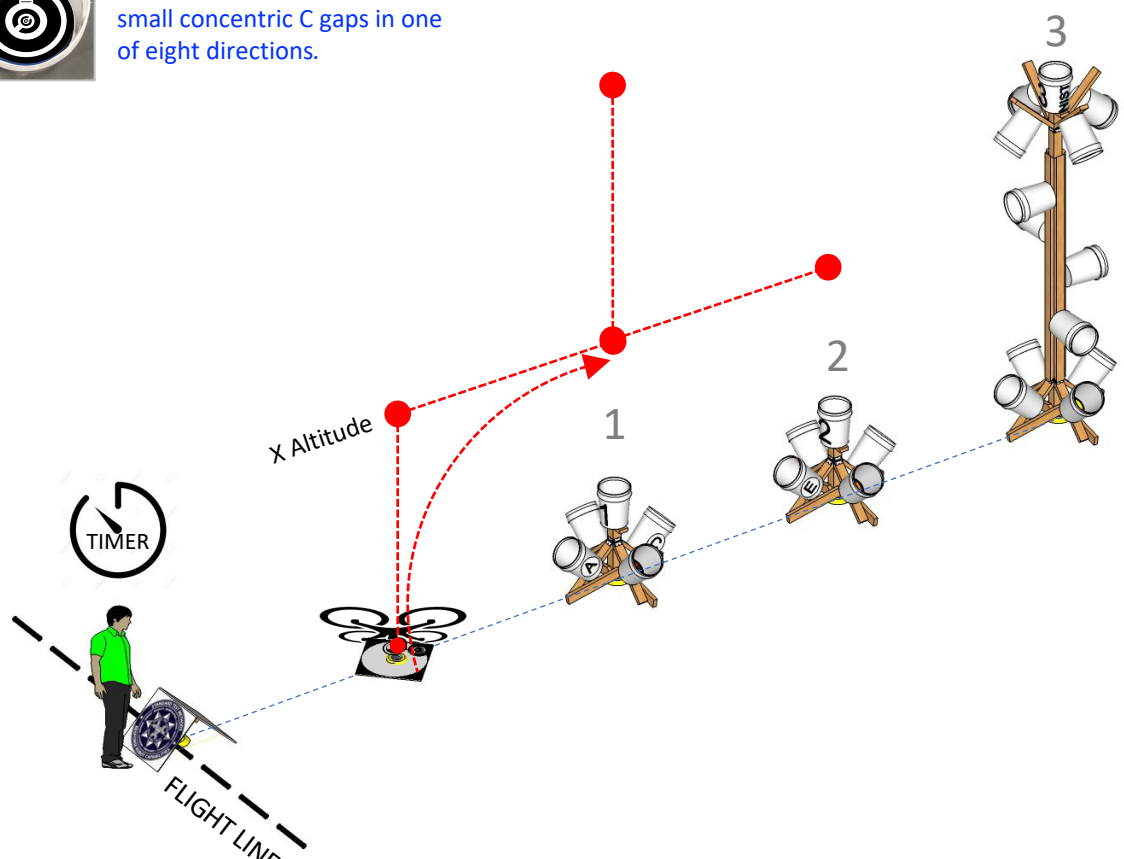
MAN 1-5 LETTER IDENTIFIERS

See the entire inscribed ring inside the buckets to evaluate successful alignments. 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.



SCORING

MAN PAY

FLIGHT PATH

START THE TIMER when the drone launches from the platform

1.	HOVER at to 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 RIGHT 180° over 2 -	Bucket C	Bucket 2
9.	FORWARD/ROTATE LEFT 180° over Land	Bucket A	Landing
10.	LAND CENTERED facing stands ----------	Centered	Perch 1
		Centered	Perch 2

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Position

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

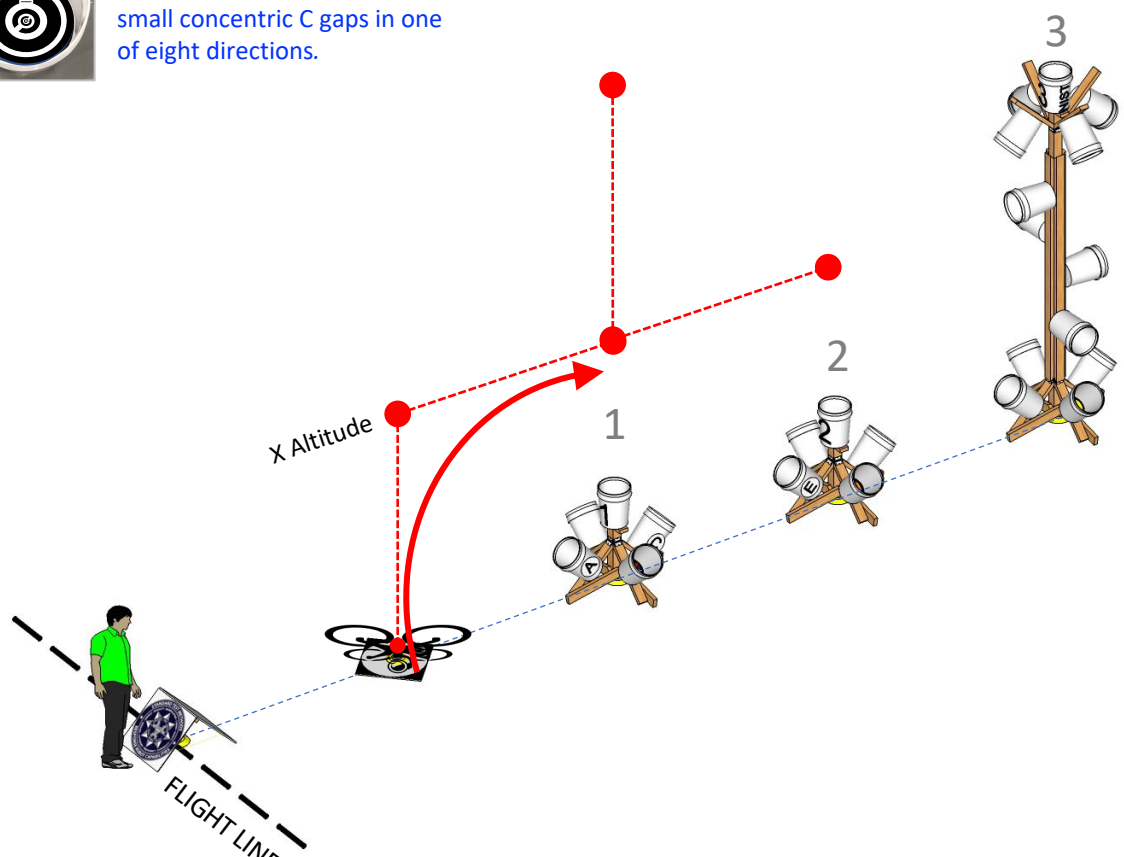
MAN 1-5 LETTER IDENTIFIERS

See the entire inscribed ring inside the buckets to evaluate successful alignments. 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.



SCORING

MAN PAY

FLIGHT PATH

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 RIGHT 180° over 2	Bucket C	Bucket 2
9.	FORWARD/ROTATE LEFT 180° over Land	Bucket A	Landing
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Position

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

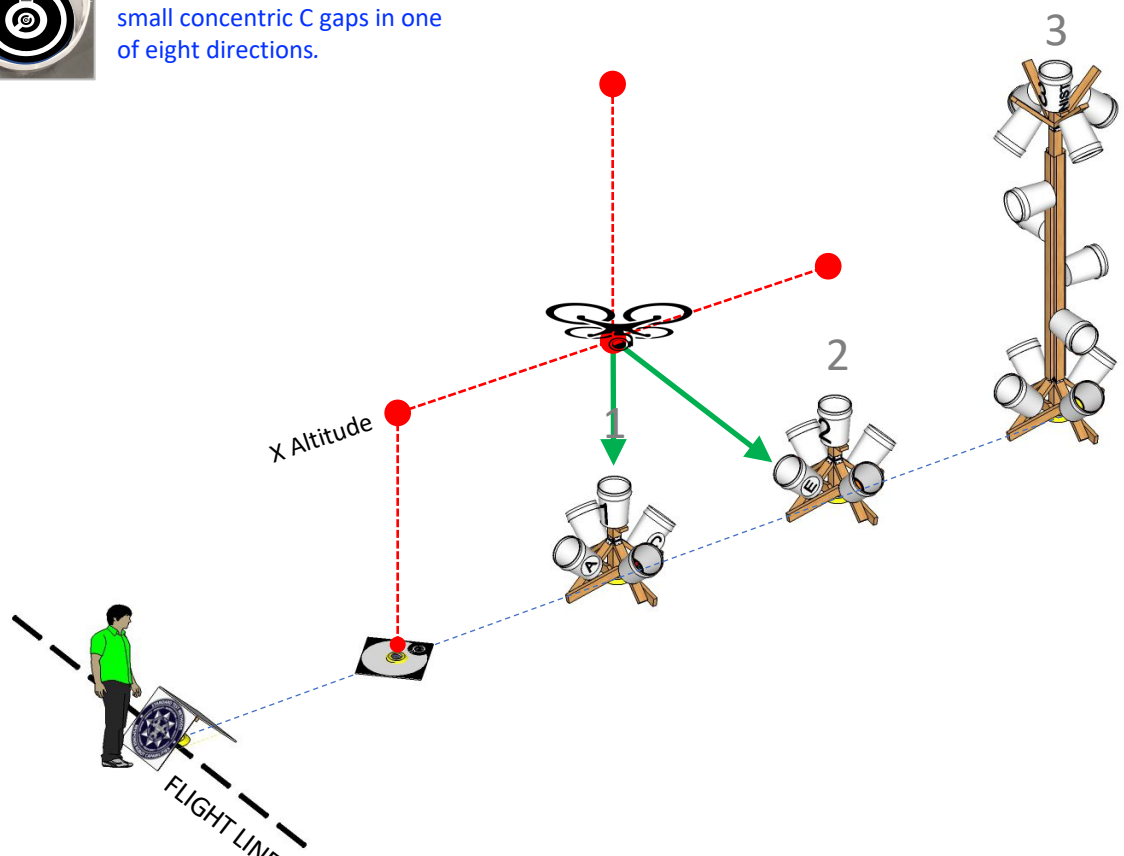
MAN 1-5 LETTER IDENTIFIERS

See the entire inscribed ring inside the buckets to evaluate successful alignments. 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.



SCORING

FLIGHT PATH

	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 RIGHT 180° over 2 -	Bucket C	Bucket 2
9. FORWARD/ROTATE LEFT 180° over Land	Bucket A	Landing
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	Centered	Perch 2

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Position

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

MAN 1-5 LETTER IDENTIFIERS

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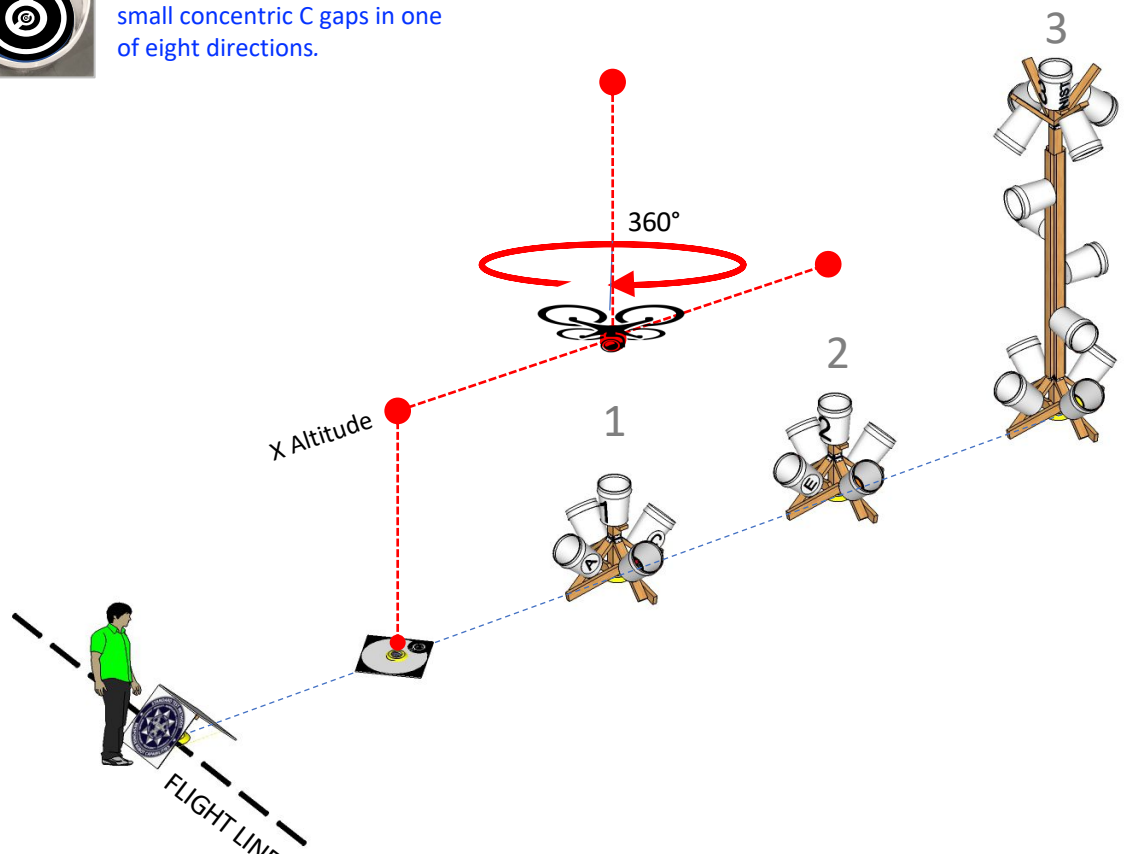
PAY 1-5 VISUAL ACUITY TARGETS

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



SCORING

MAN PAY

FLIGHT PATH

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
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Position

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

MAN 1-5 LETTER IDENTIFIERS

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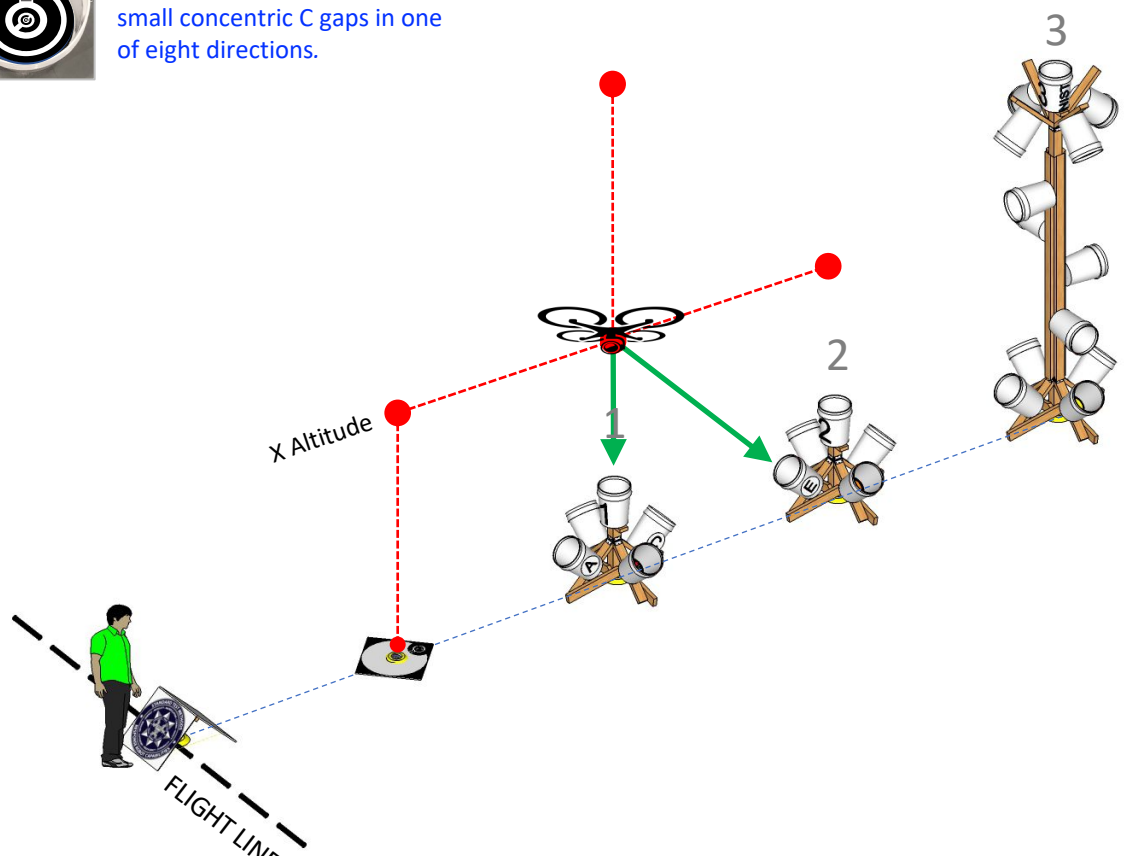
NOT QUITE ALIGNED

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
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Position

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

MAN 1-5 LETTER IDENTIFIERS

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NOT QUITE ALIGNED

PAY 1-5 VISUAL ACUITY TARGETS

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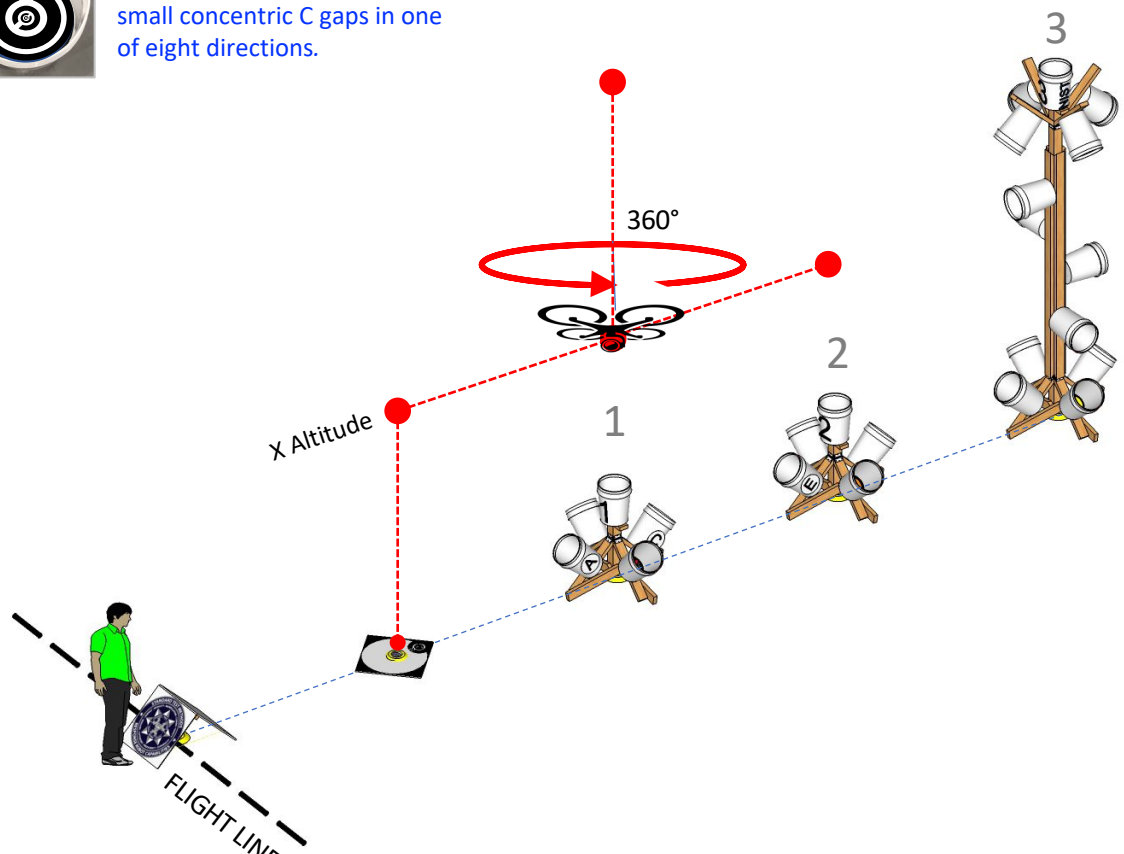

FLIGHT PATH

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
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Position

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

MAN 1-5 LETTER IDENTIFIERS

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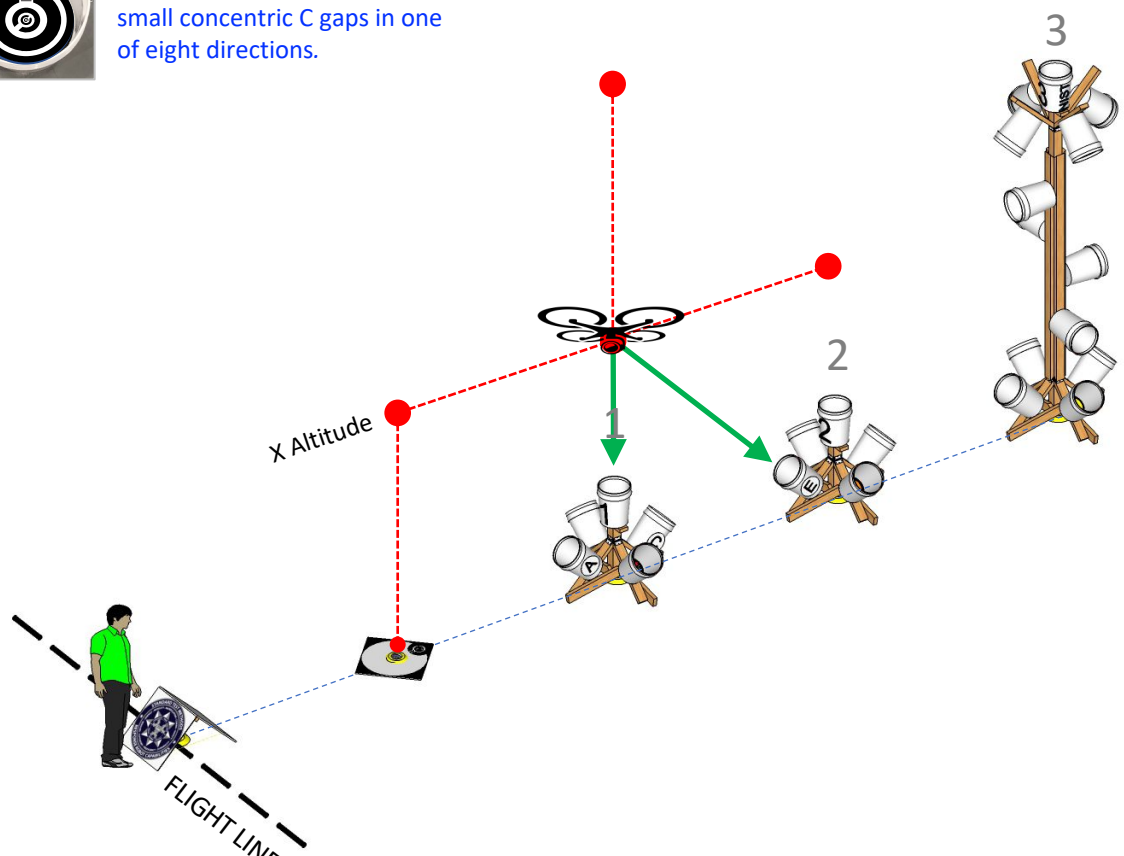
PAY 1-5 VISUAL ACUITY TARGETS

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
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Position

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

MAN 1-5 LETTER IDENTIFIERS

See the entire inscribed ring inside the buckets to evaluate successful alignments. The letters are bucket identifiers.

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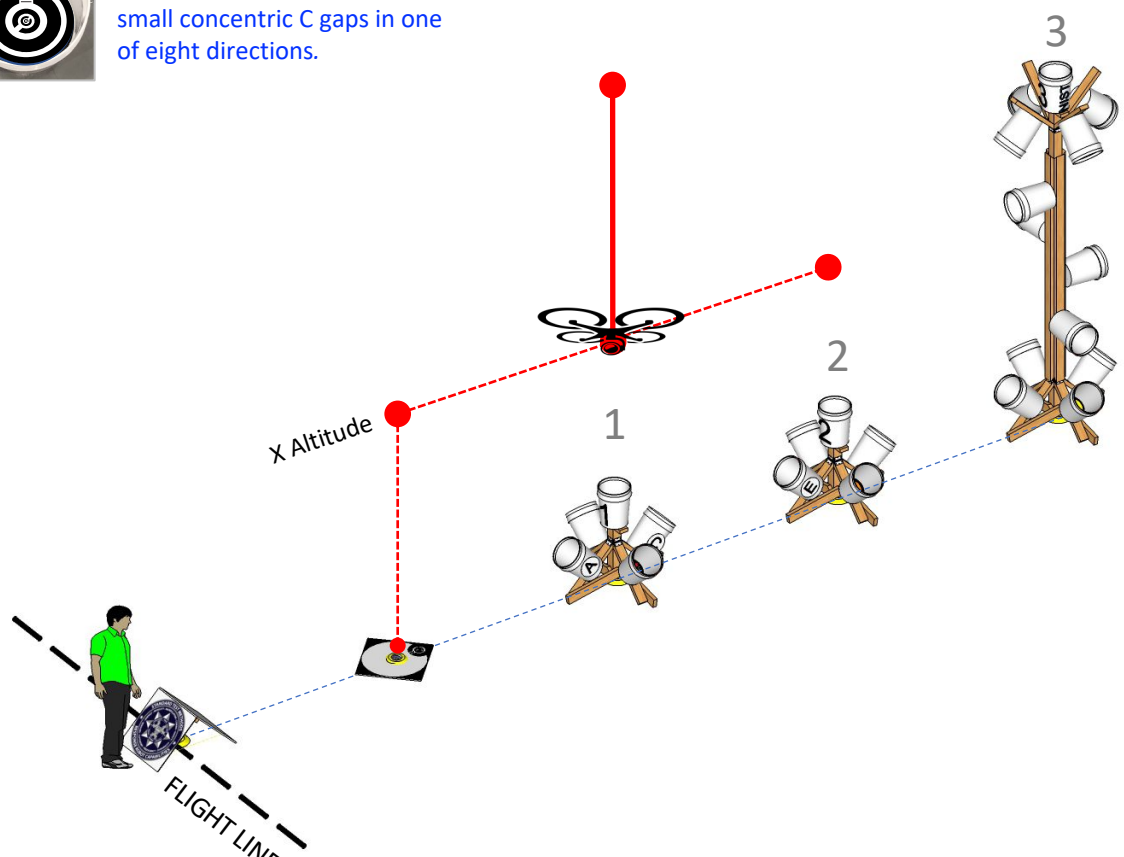
PAY 1-5 VISUAL ACUITY TARGETS

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



SCORING

MAN PAY

FLIGHT PATH

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
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Position

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

MAN 1-5 LETTER IDENTIFIERS

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NOT QUITE ALIGNED

PAY 1-5 VISUAL ACUITY TARGETS

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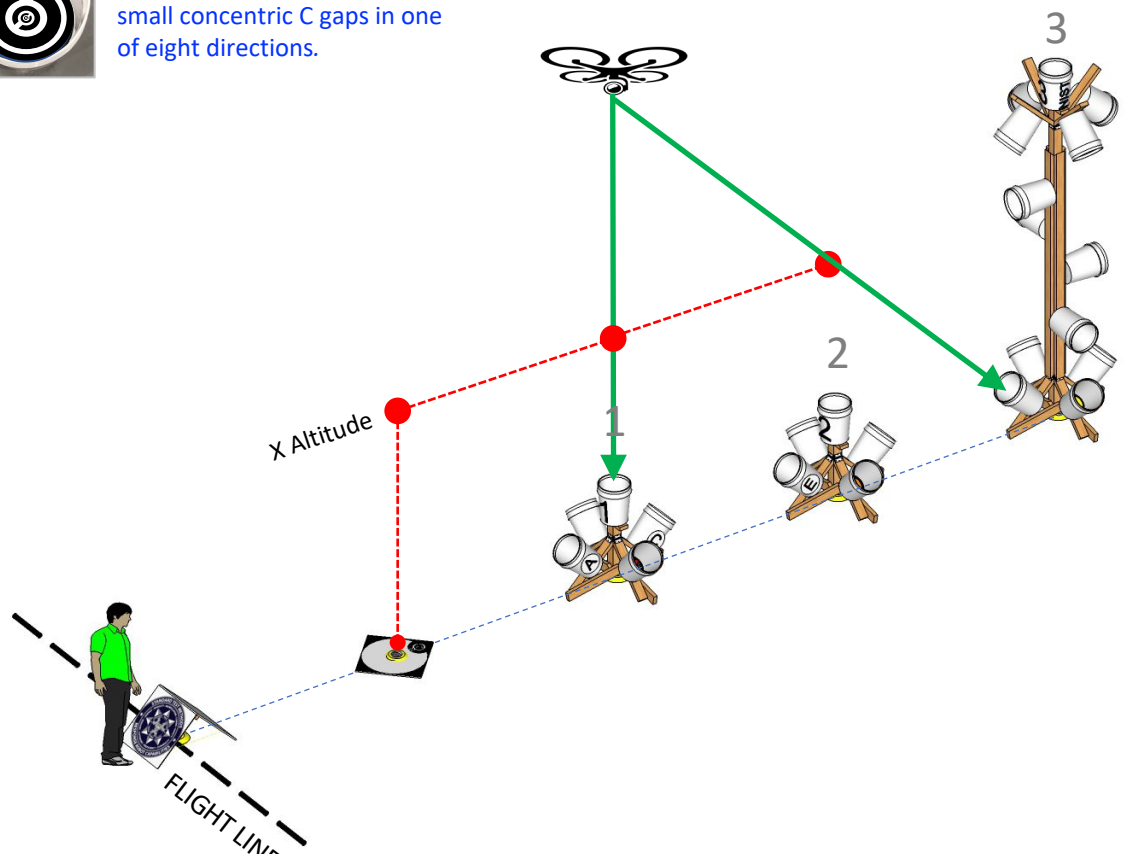

FLIGHT PATH

SCORING

MAN	PAY

START THE TIMER when the drone launches from the platform

		MAN	PAY
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 RIGHT 180° over 2 -	Bucket C	Bucket 2
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Maneuvering (MAN 1) and Payload Functionality (PAY 1)

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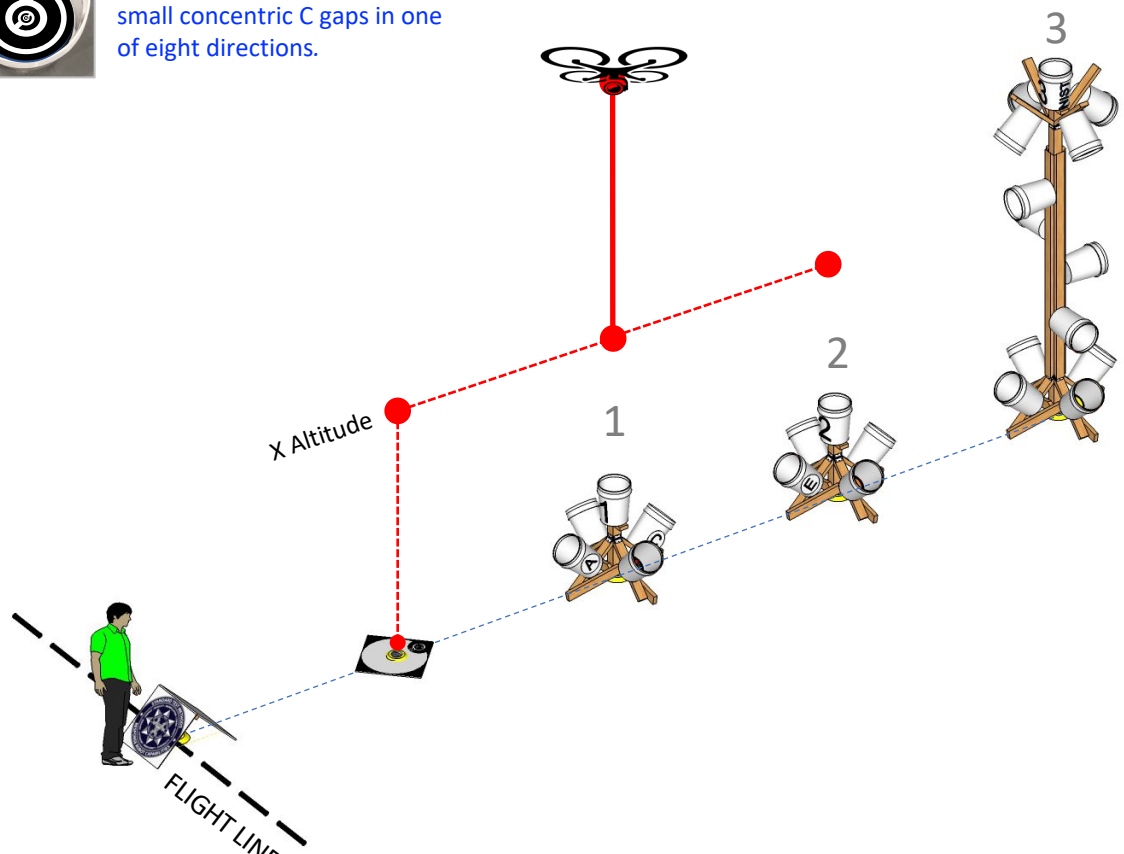
Align and identify the visual acuity targets with increasingly small concentric C gaps in one of eight directions.



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
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Position

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

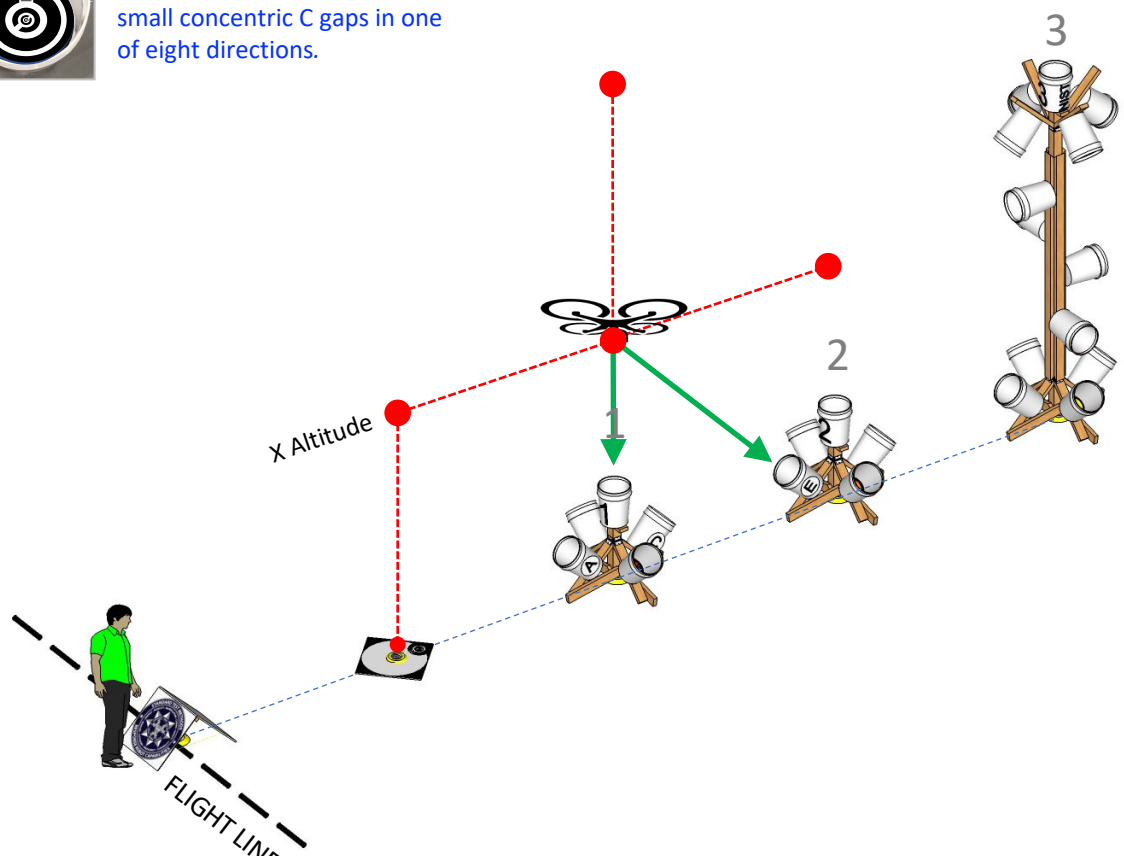
MAN 1-5 LETTER IDENTIFIERS

See the entire inscribed ring inside the buckets to evaluate successful alignments. 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
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10.	LAND CENTERED facing stands	Centered	Perch 1
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MAN: 20 points = 10 Positions, 18 Alignments and Landing (2pts)
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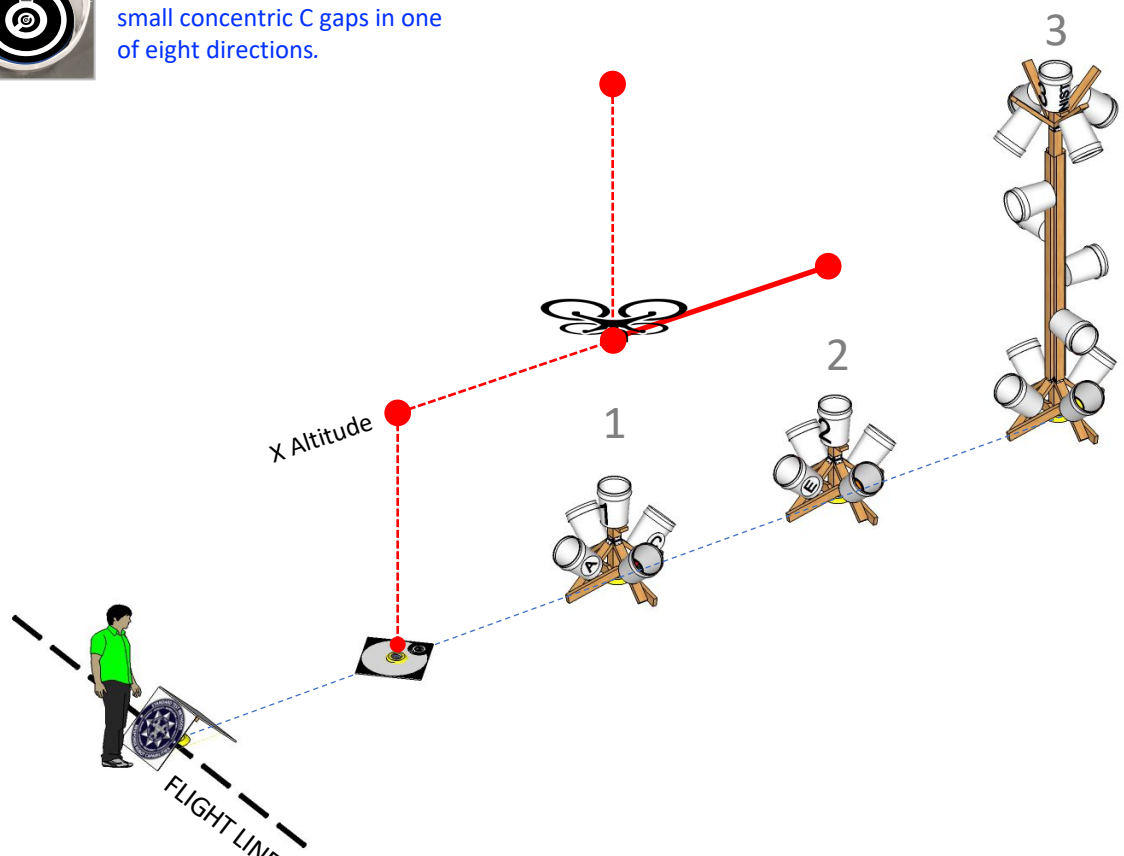

SCORING

MAN PAY

FLIGHT PATH

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1.	HOVER at X over Bucket 1	Bucket E	Bucket 1
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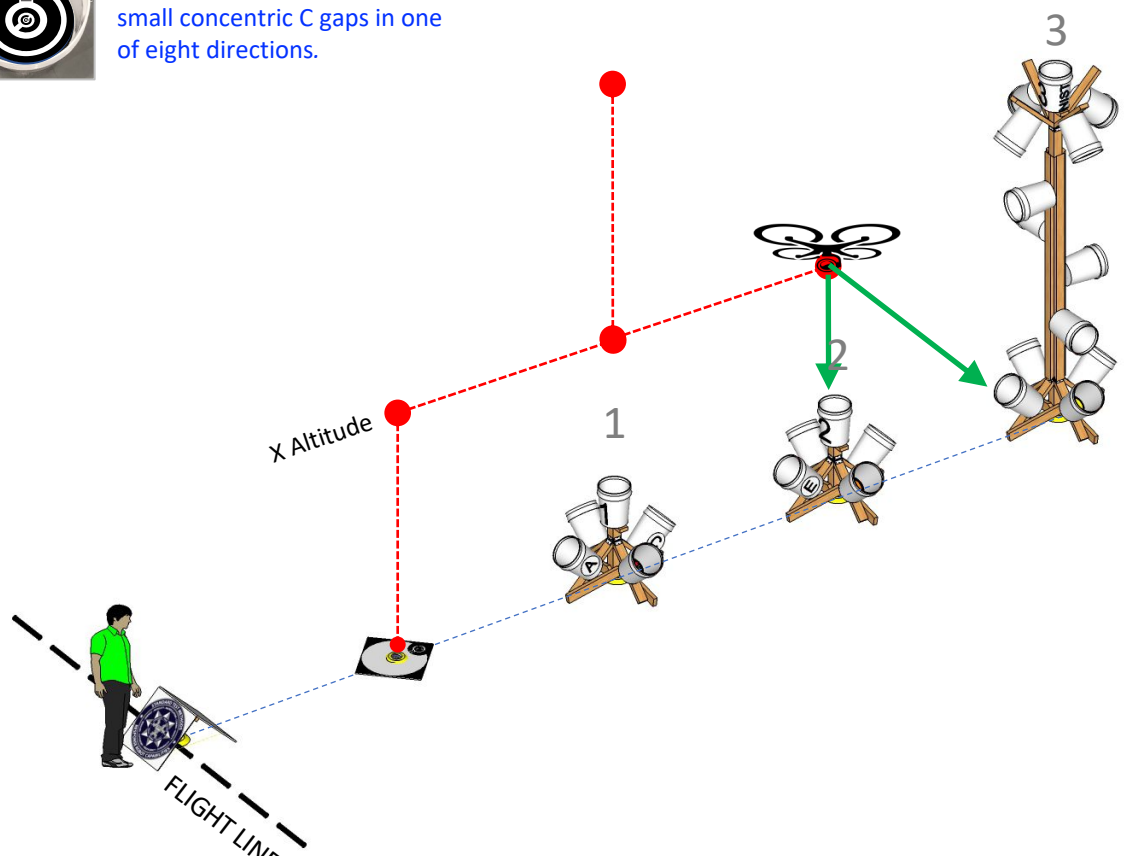

FLIGHT PATH

SCORING

	MAN	PAY

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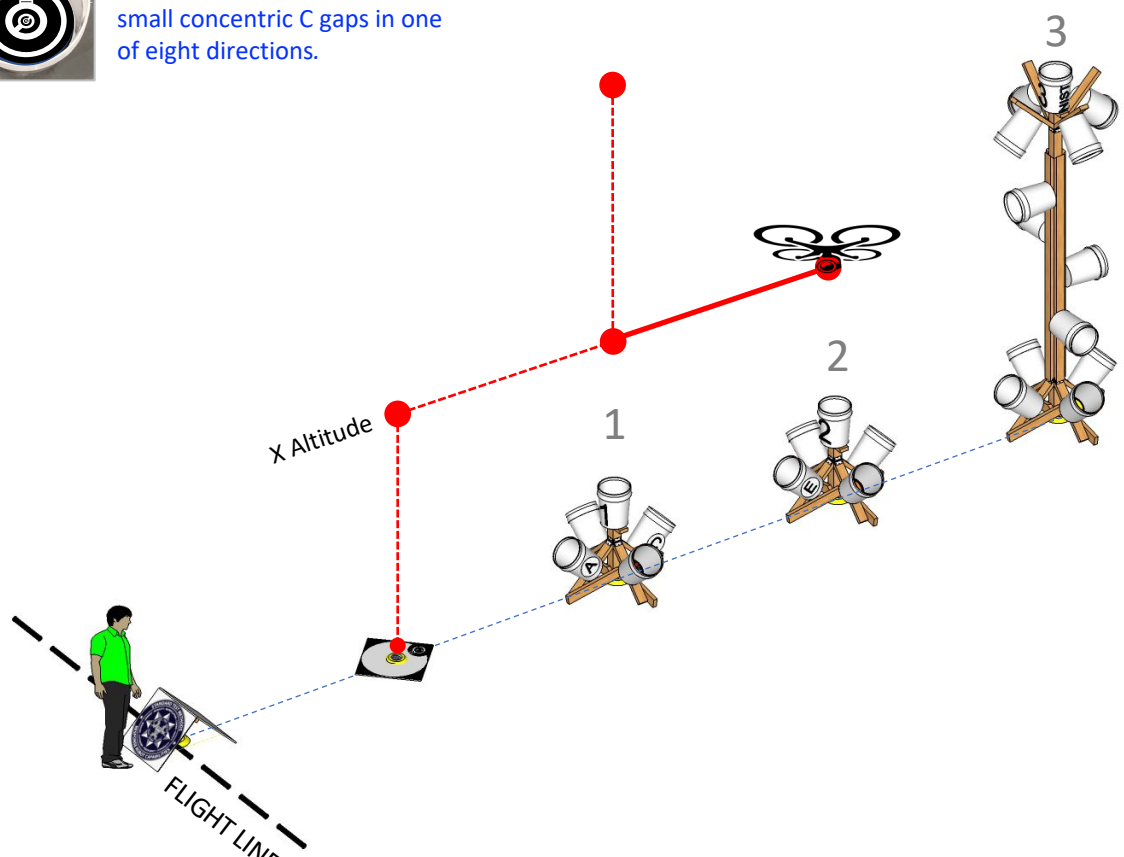

FLIGHT PATH

SCORING

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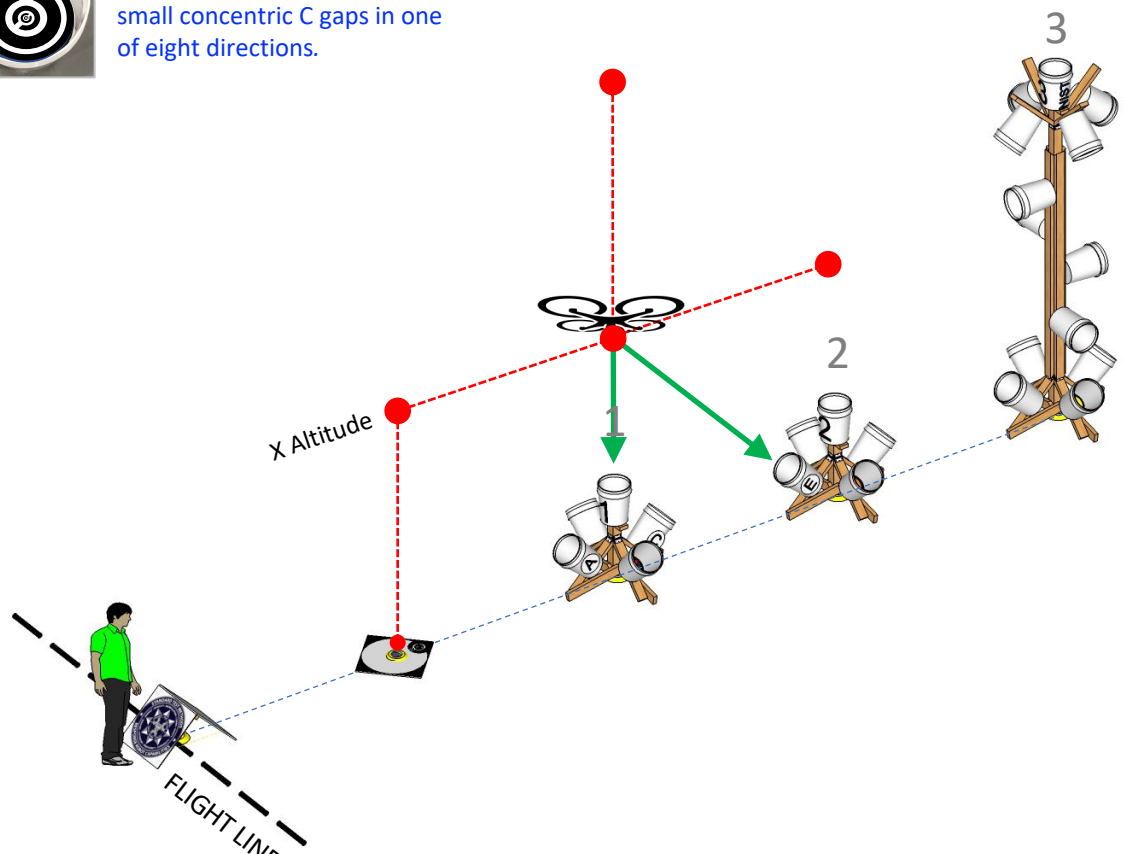

SCORING

FLIGHT PATH

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1.	HOVER at X over Bucket 1	Bucket E	Bucket 1
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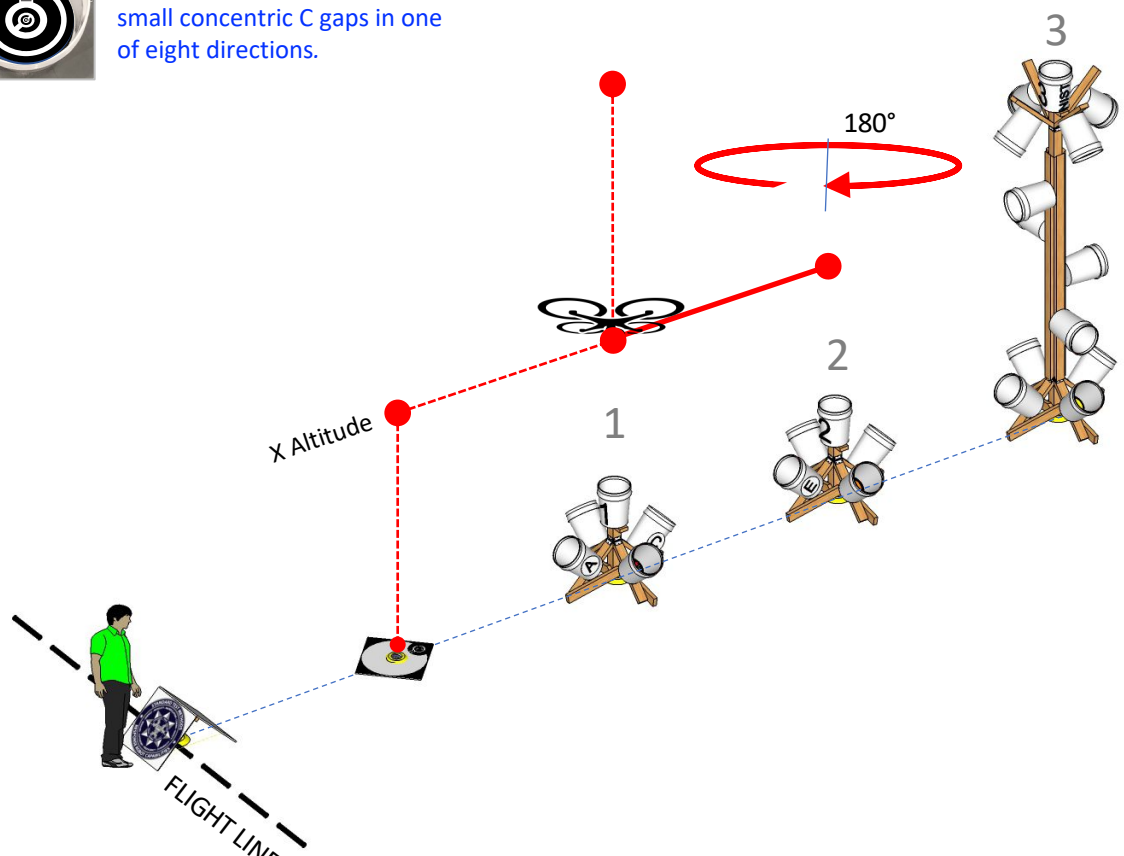

SCORING

MAN PAY

FLIGHT PATH

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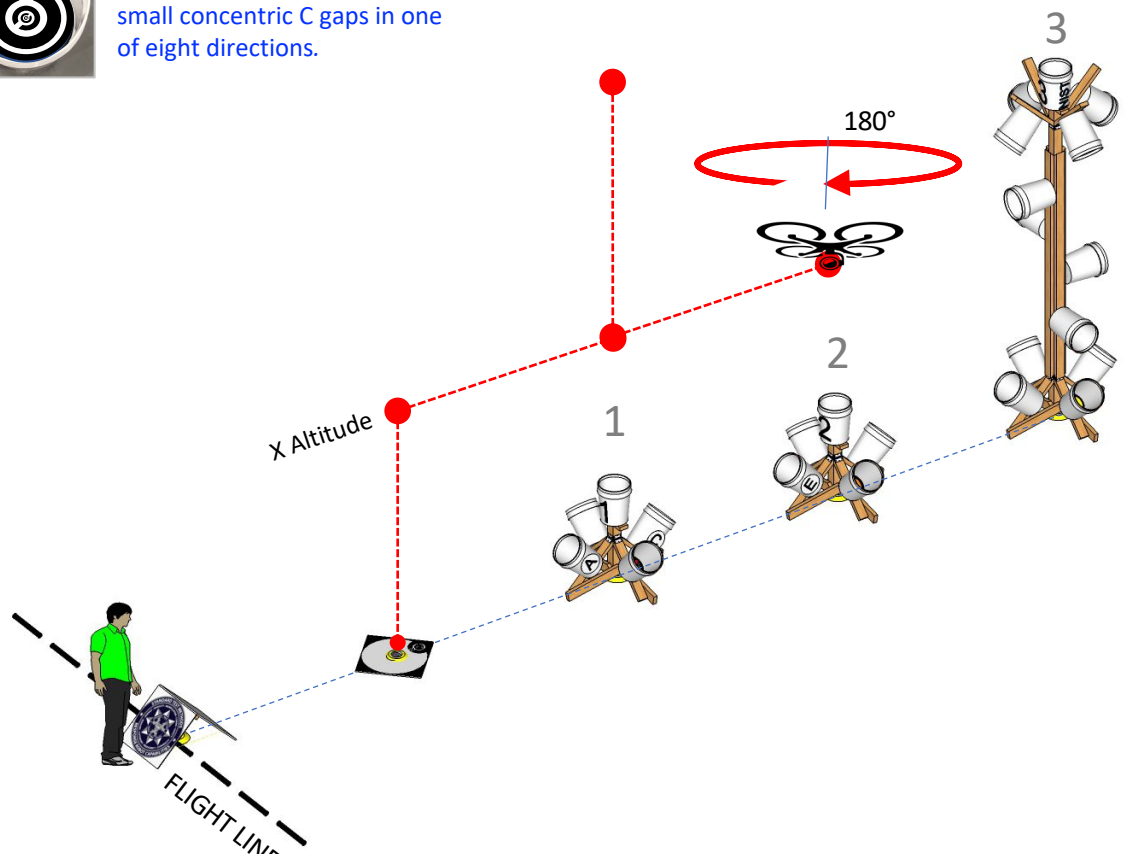

FLIGHT PATH

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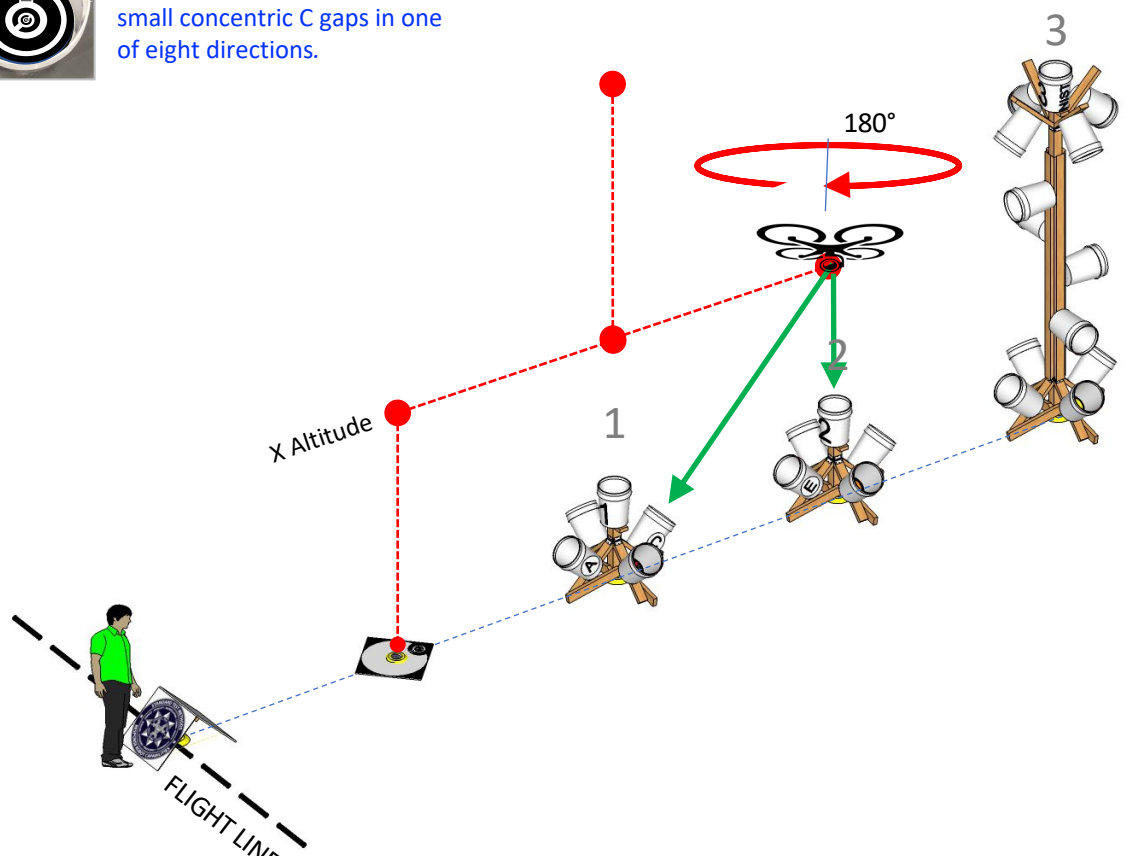

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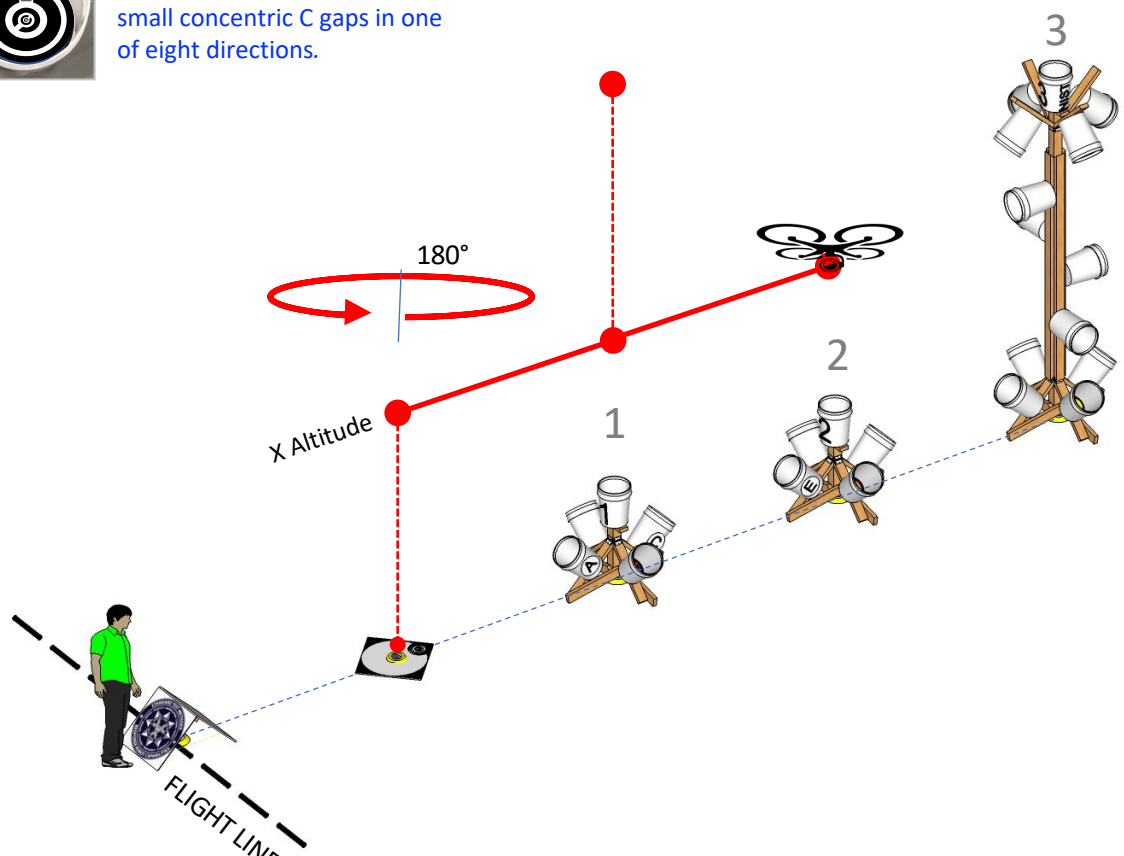

FLIGHT PATH

SCORING

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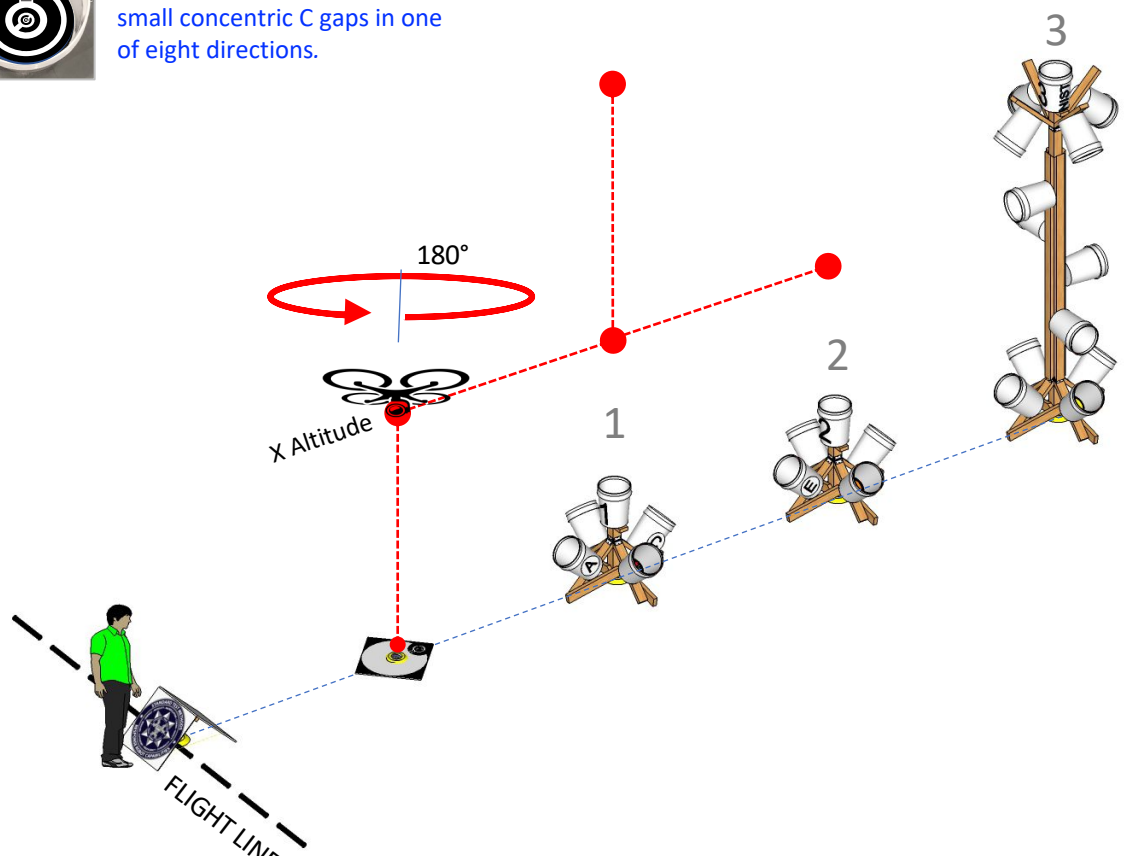

SCORING

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FLIGHT PATH

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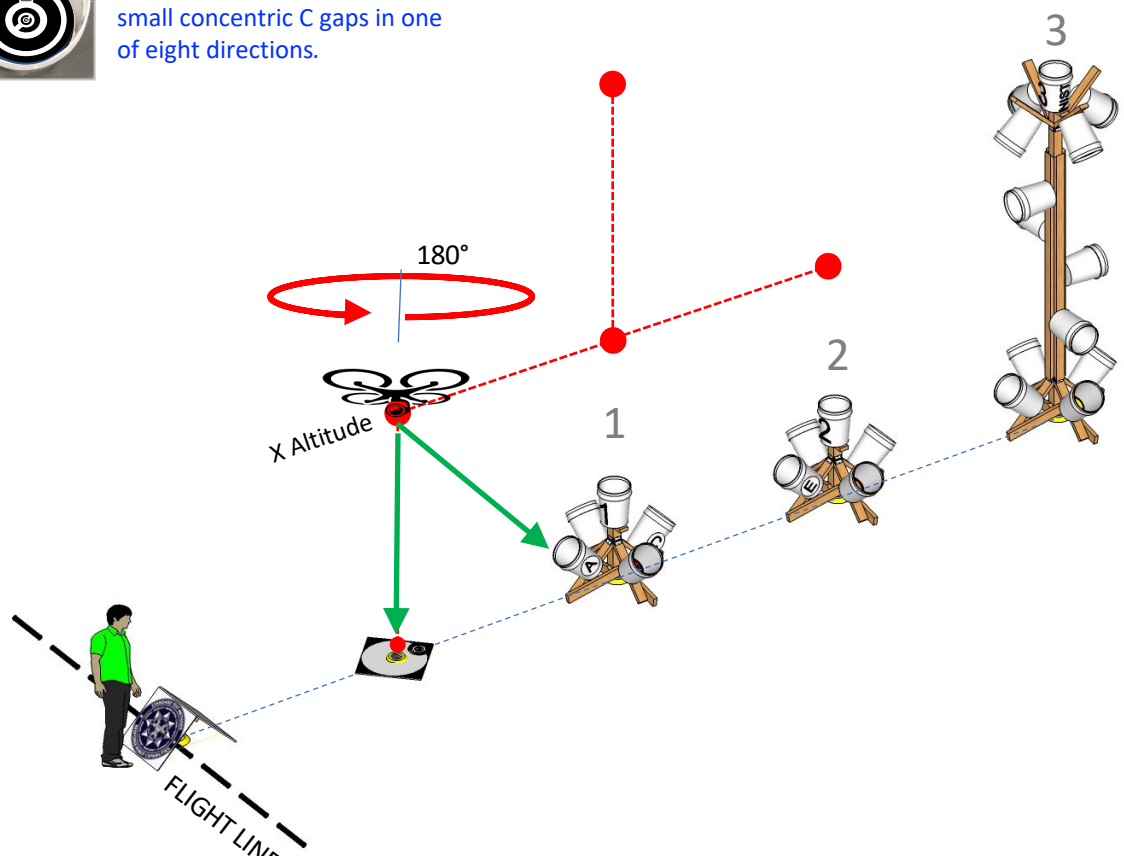

FLIGHT PATH

SCORING

MAN | PAY

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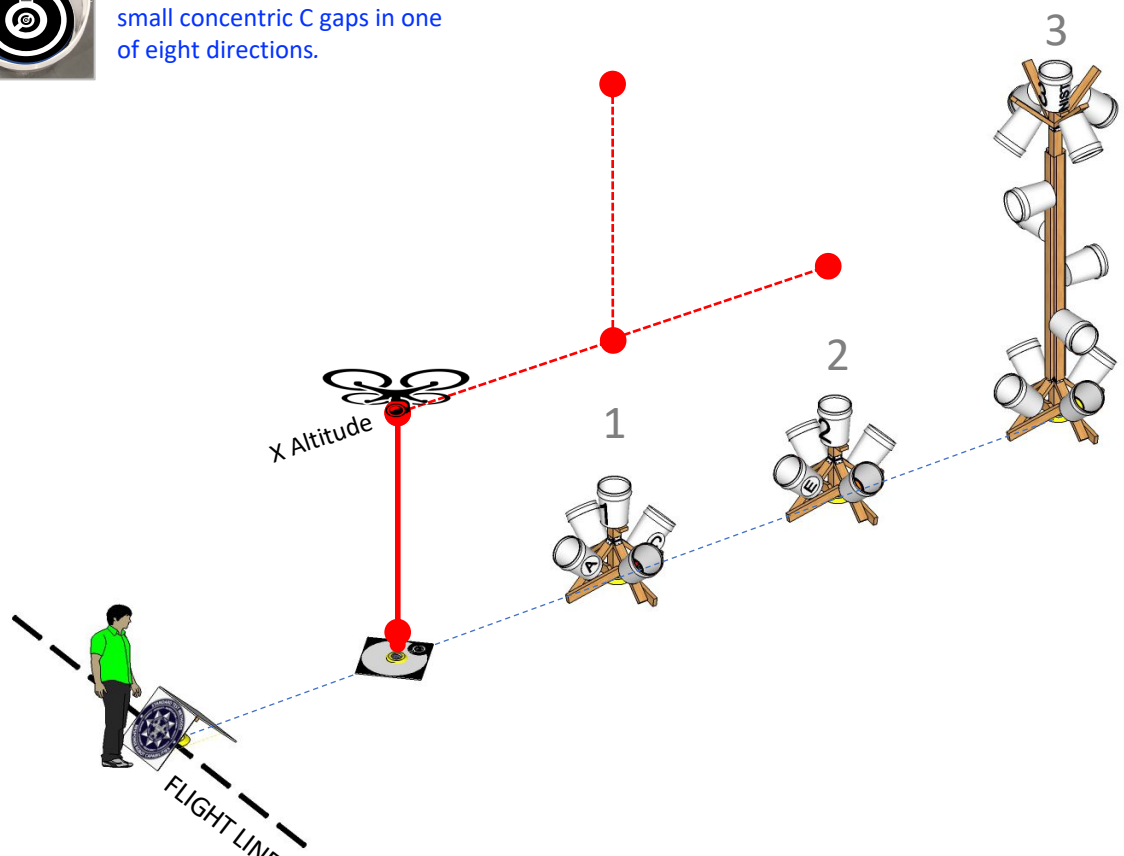

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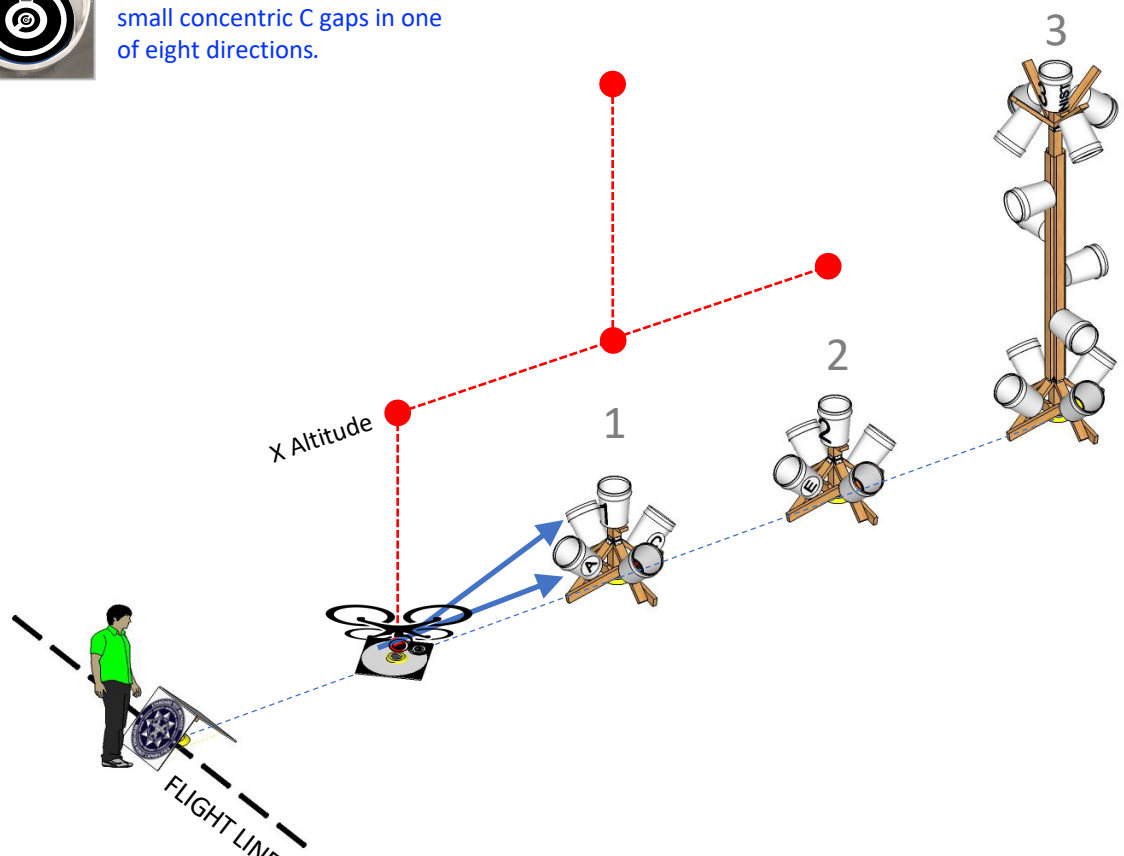

FLIGHT PATH

SCORING

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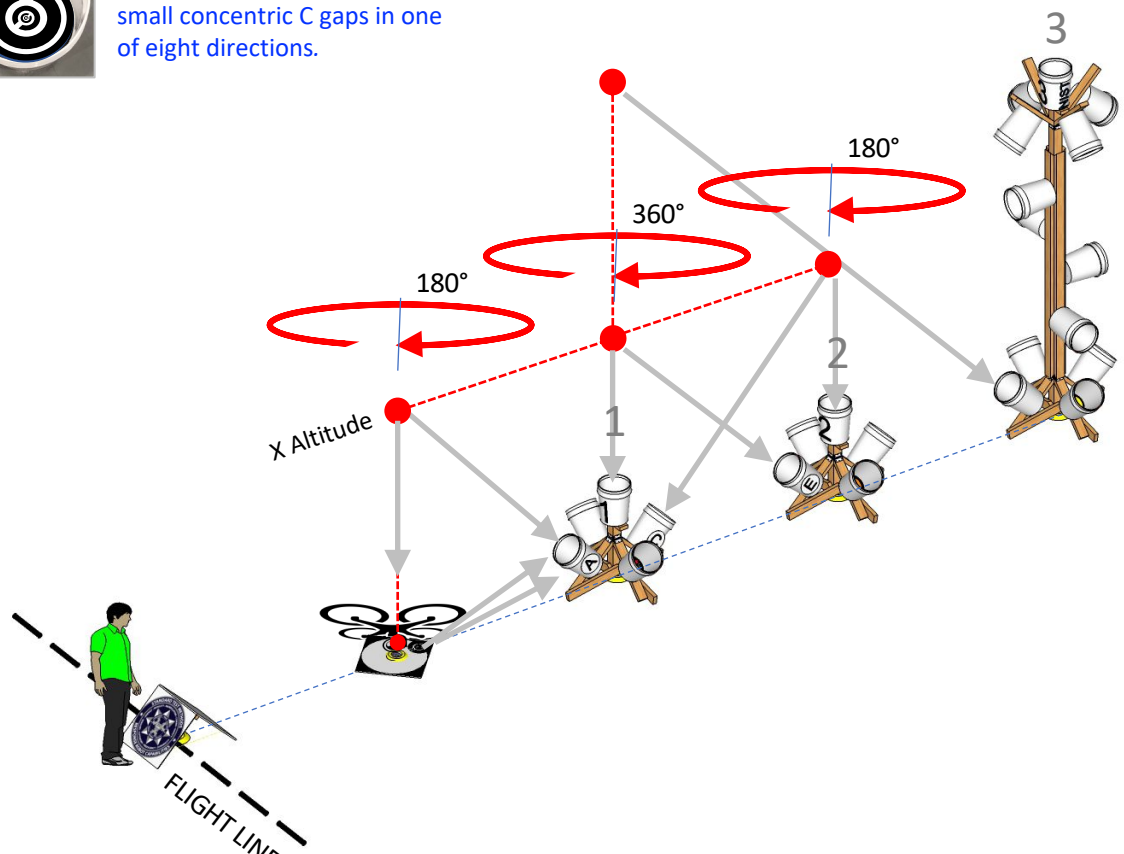

SCORING

MAN PAY .

FLIGHT PATH

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1.	HOVER at X over Bucket 1 ----------	Bucket E	Bucket 1
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FLIGHT PATHS

TRAVERSE

MAN 1-5 LETTER IDENTIFIERS

ALIGNED

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PAY 1-5 VISUAL ACUITY TARGETS

NOT ALIGNED

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Traverse

Maneuvering (MAN 2) and Payload Functionality (PAY 2)

MAN 1-5 LETTER IDENTIFIERS

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NOT QUITE ALIGNED

PAY 1-5 VISUAL ACUITY TARGETS

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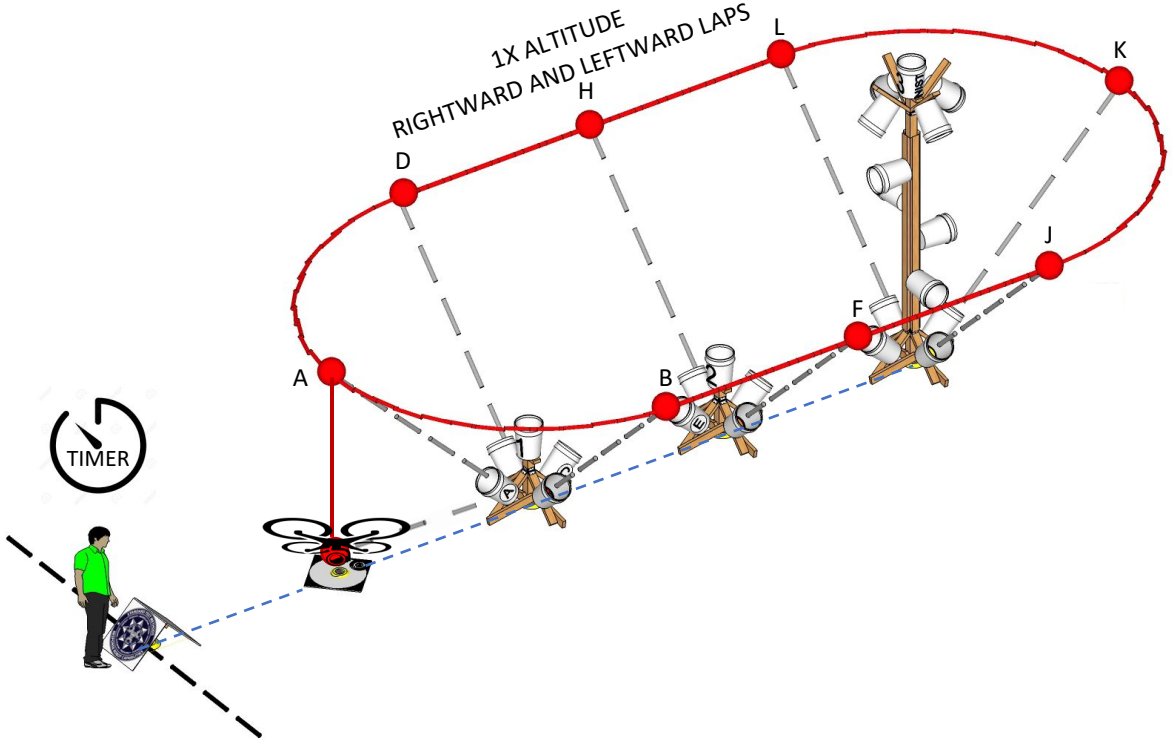

FLIGHT PATH

MAN PAY

START THE TIMER when the drone launches from the platform

1. HOVER at X over the Launch Platform
2. TRAVERSE RIGHTWARD ---------- Buckets A B F J K L H D A
3. LAND ON CENTER facing stands --------- Center or Perch 1

REVERSE DIRECTION

4. HOVER at X over the Launch Platform
5. TRAVERSE LEFTWARD ---------- Buckets A D H L K J F B A
6. LAND ON CENTER facing stands --------- Center or Perch 2

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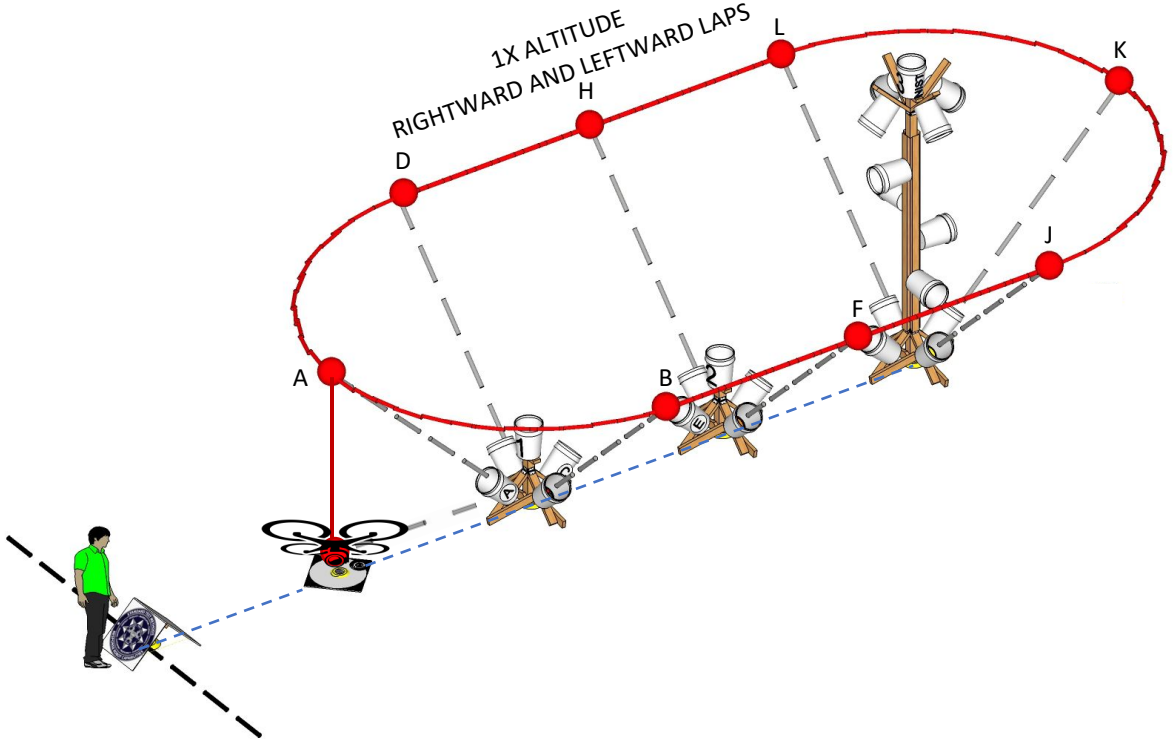

FLIGHT PATH

SCORING

MAN PAY

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Maneuvering (MAN 2) and Payload Functionality (PAY 2)

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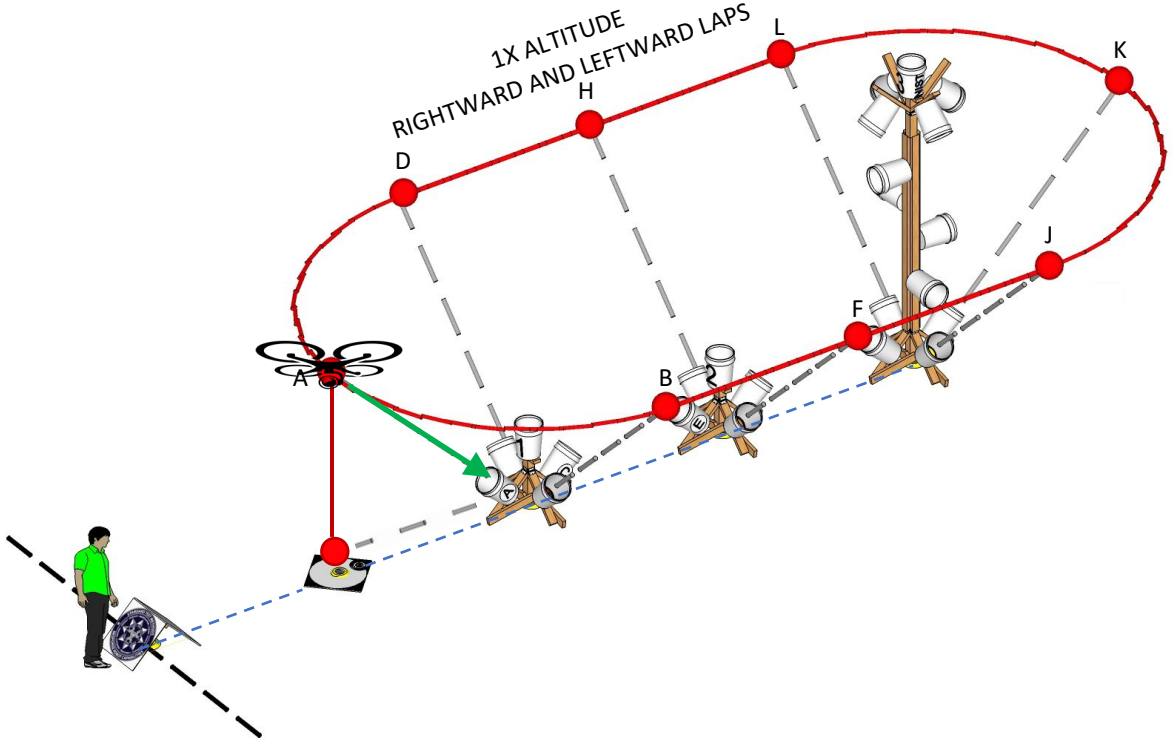

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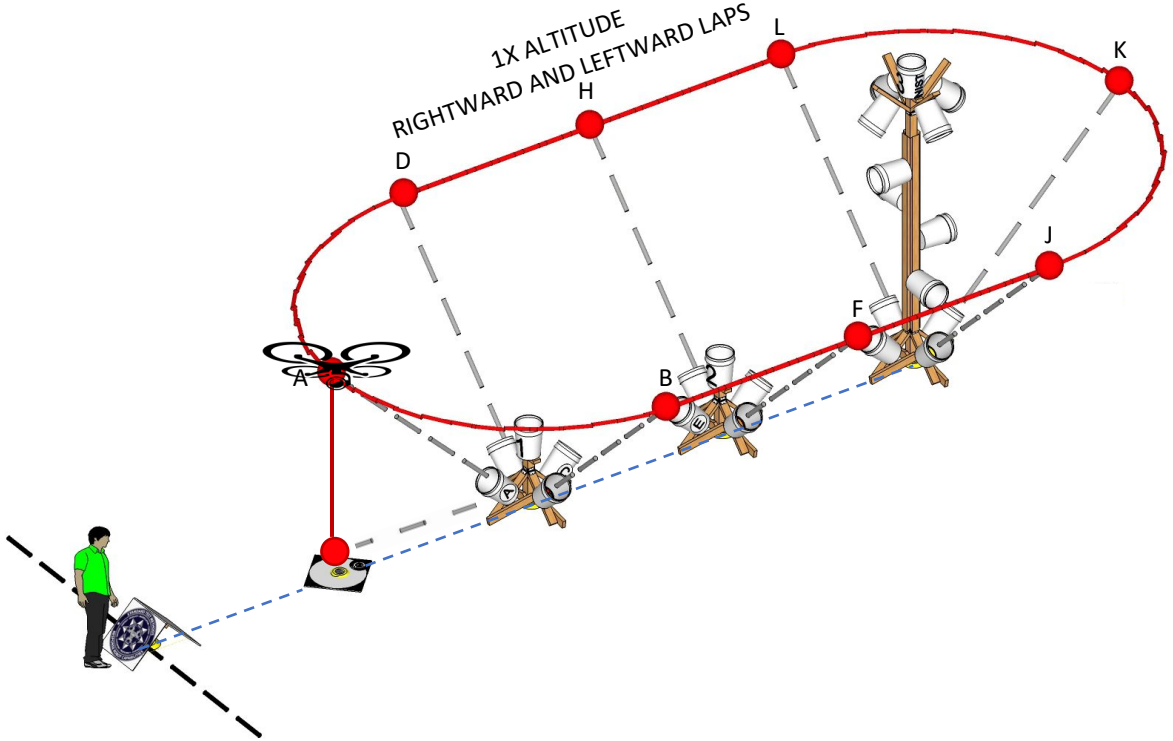

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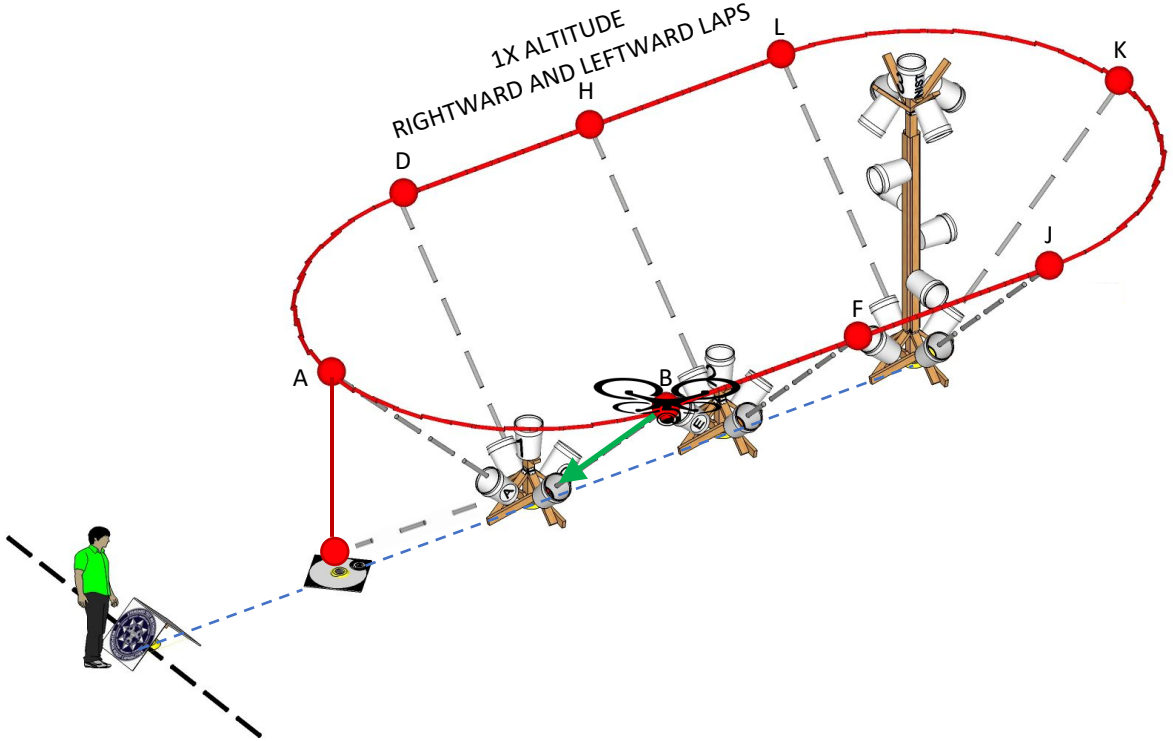

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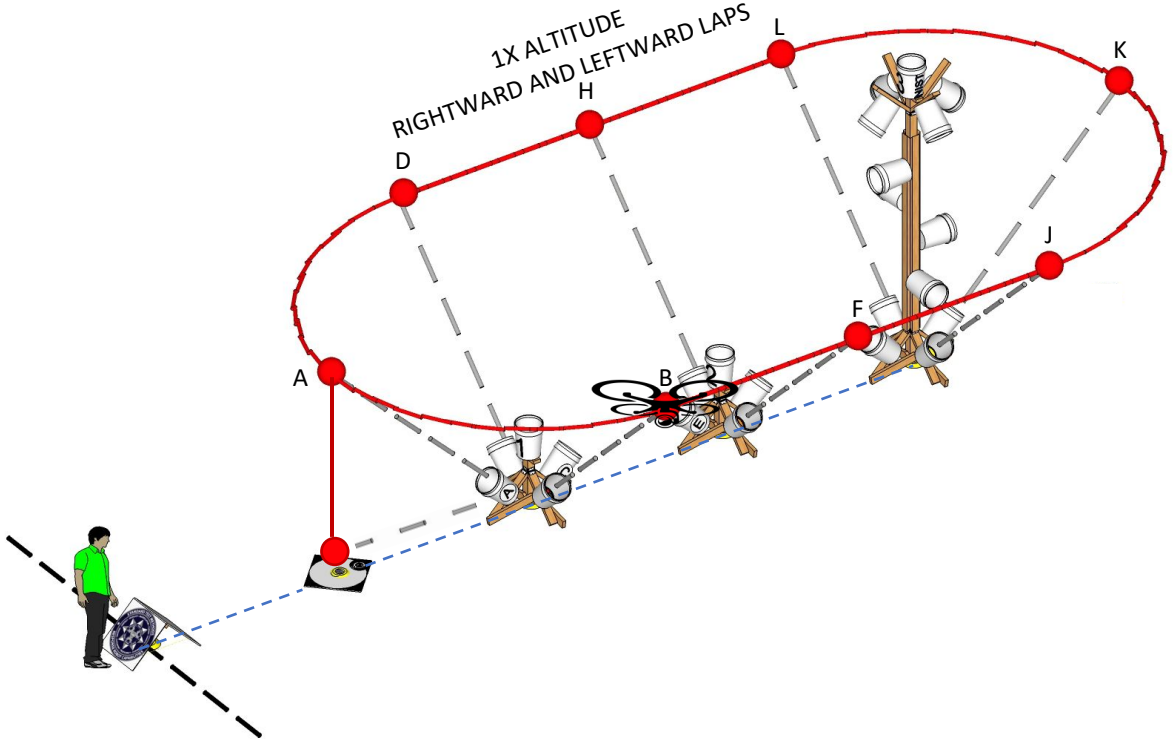

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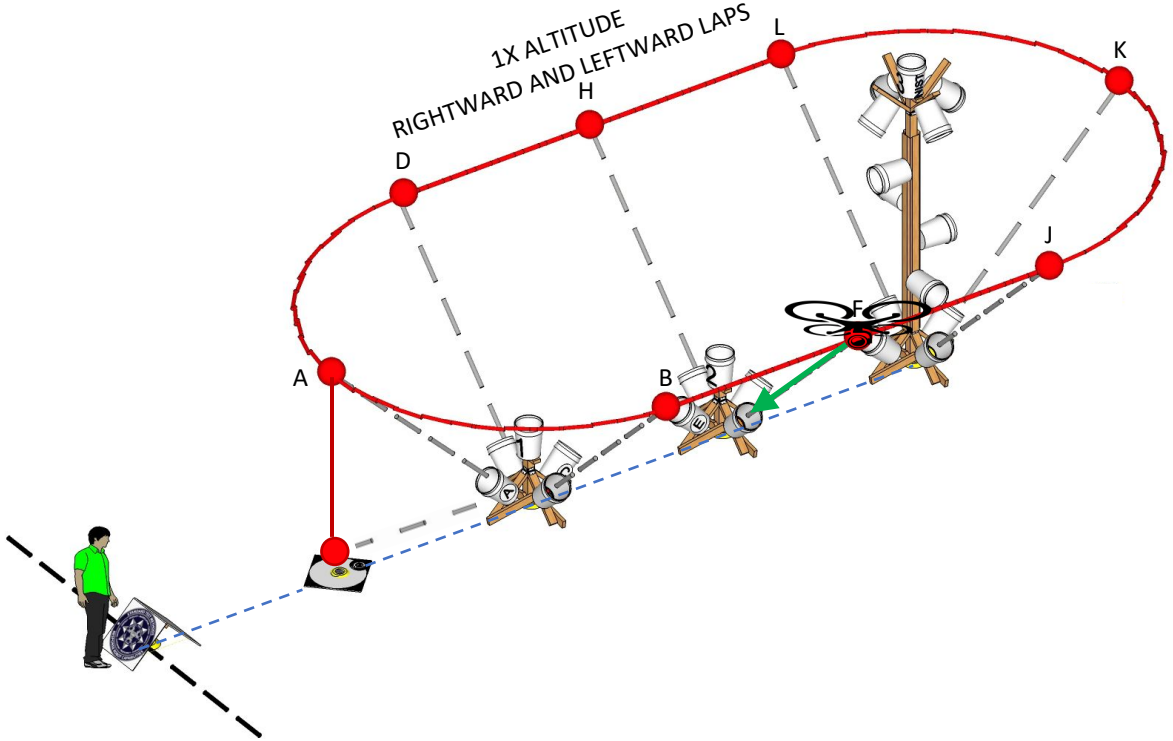

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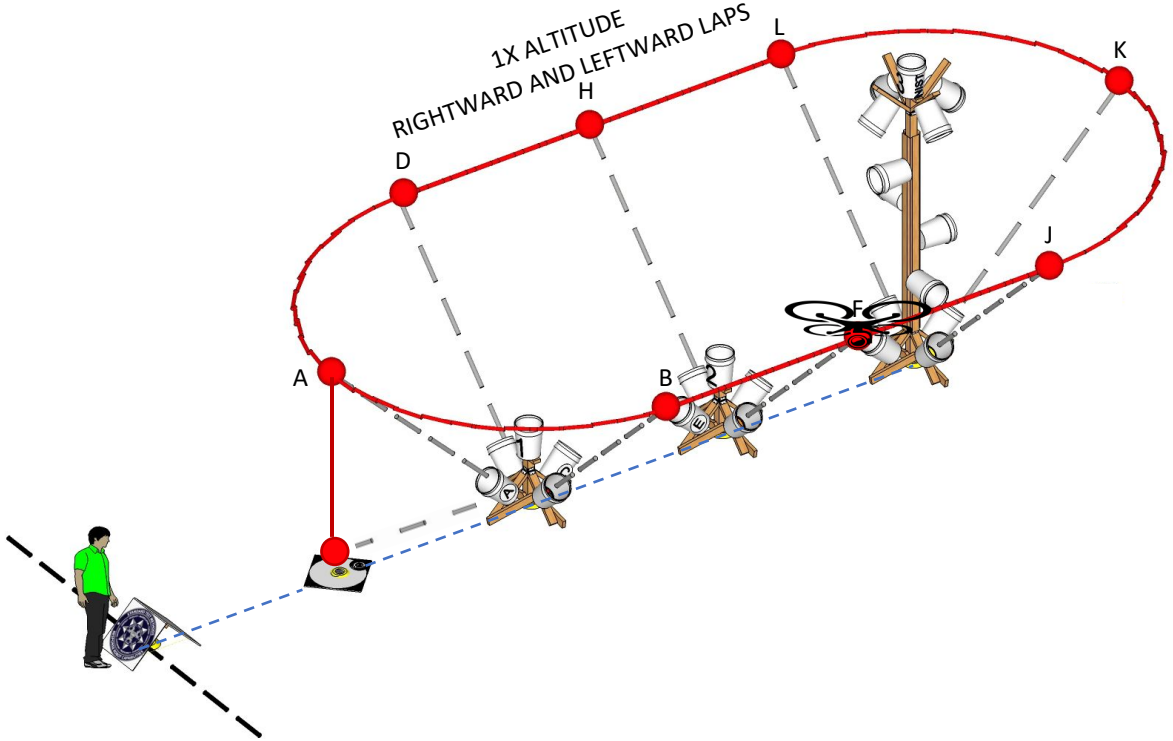

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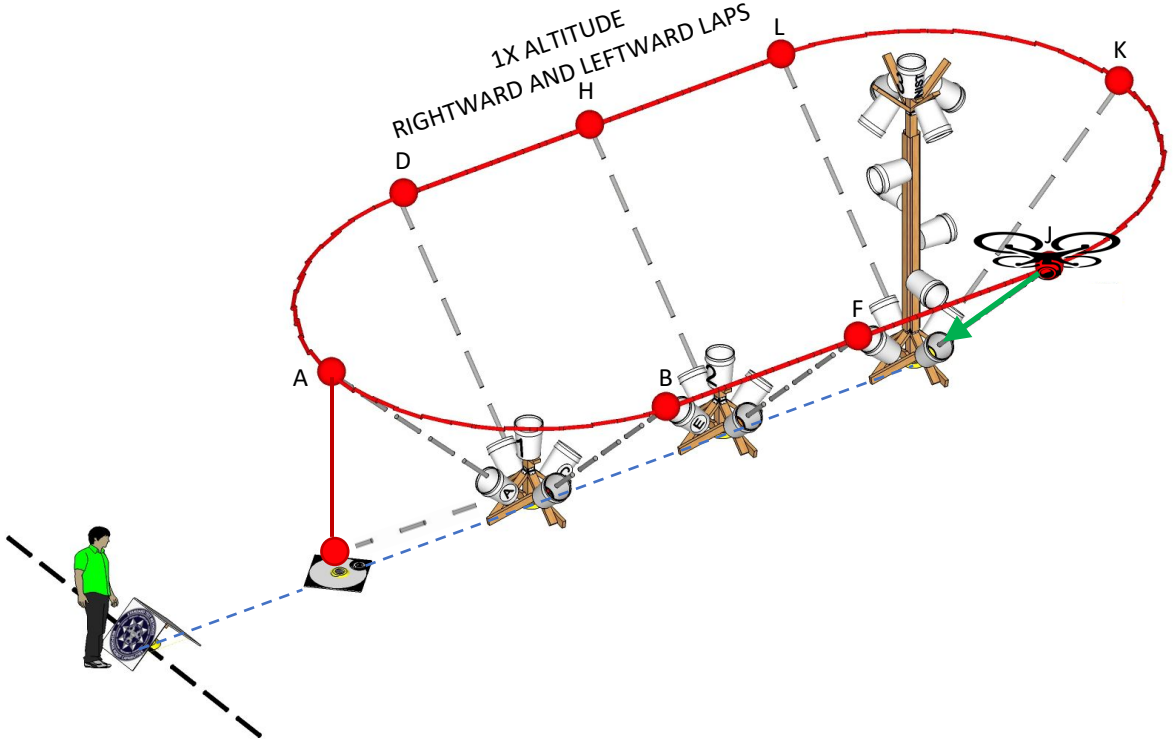

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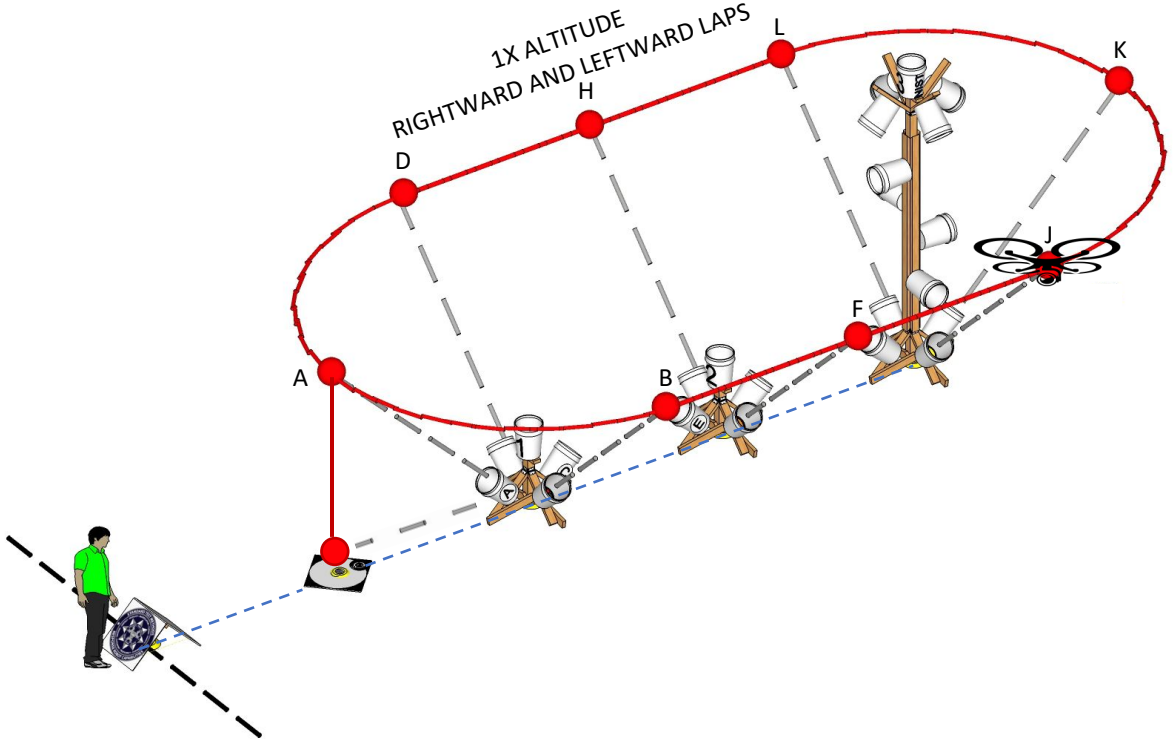

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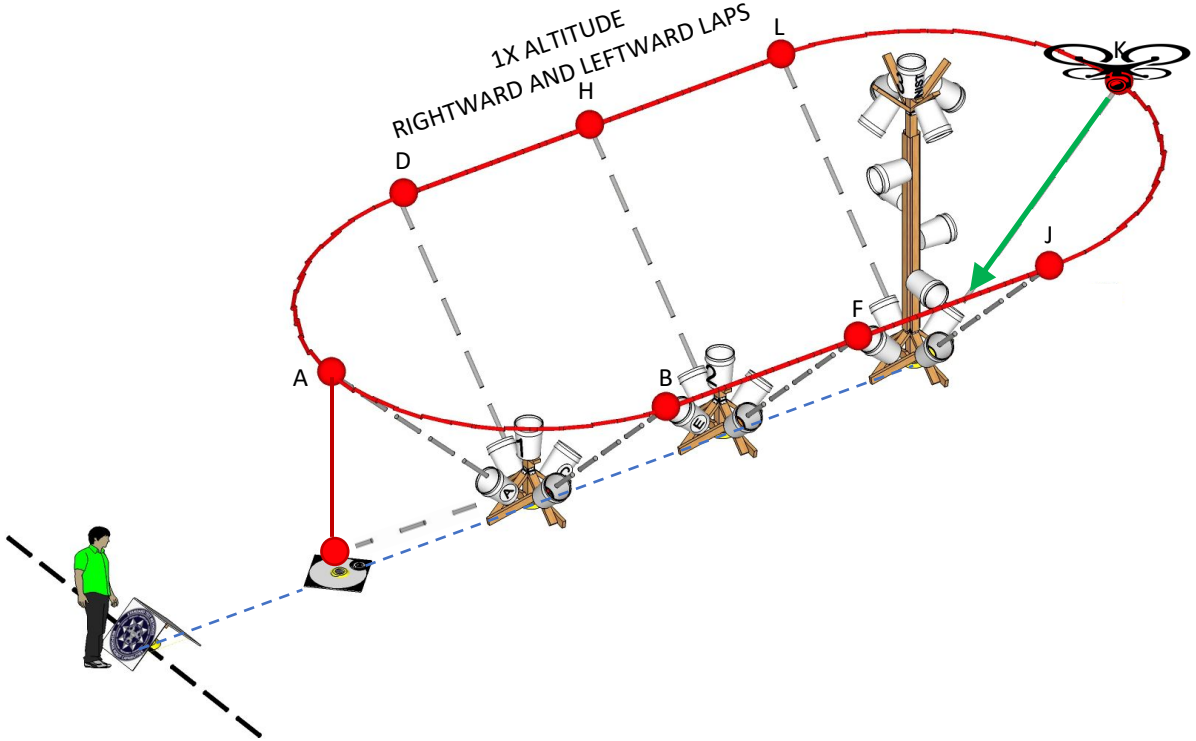

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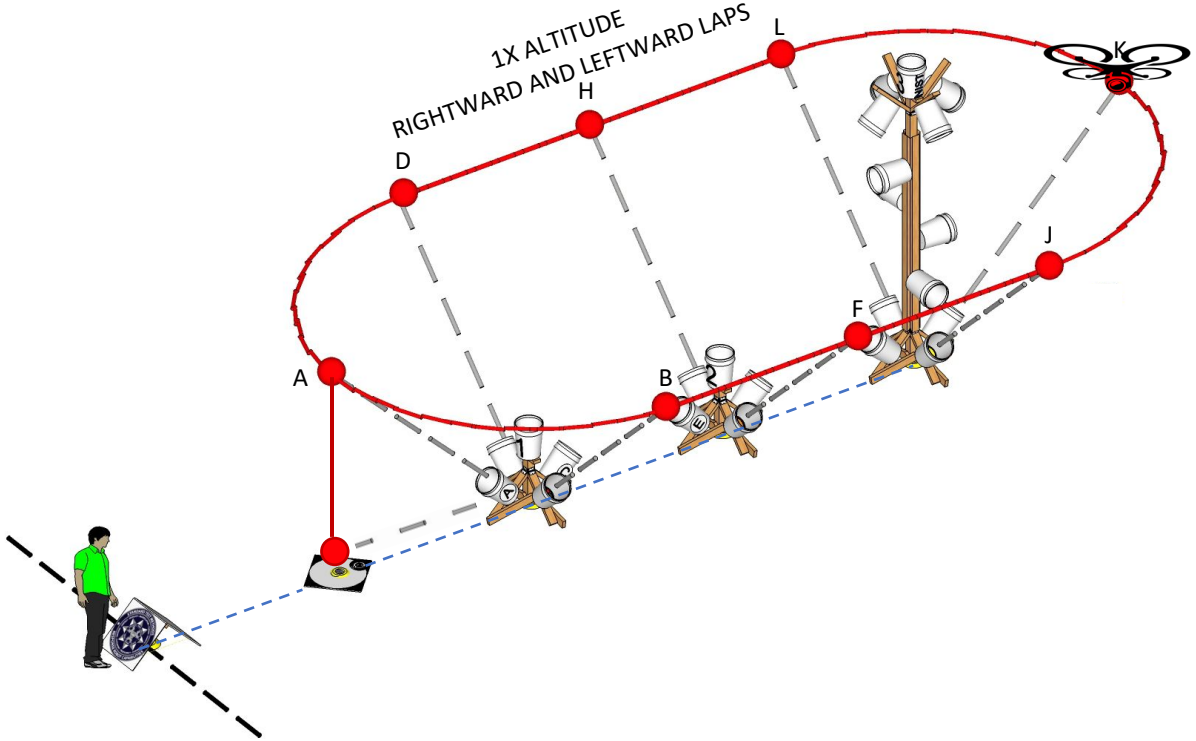

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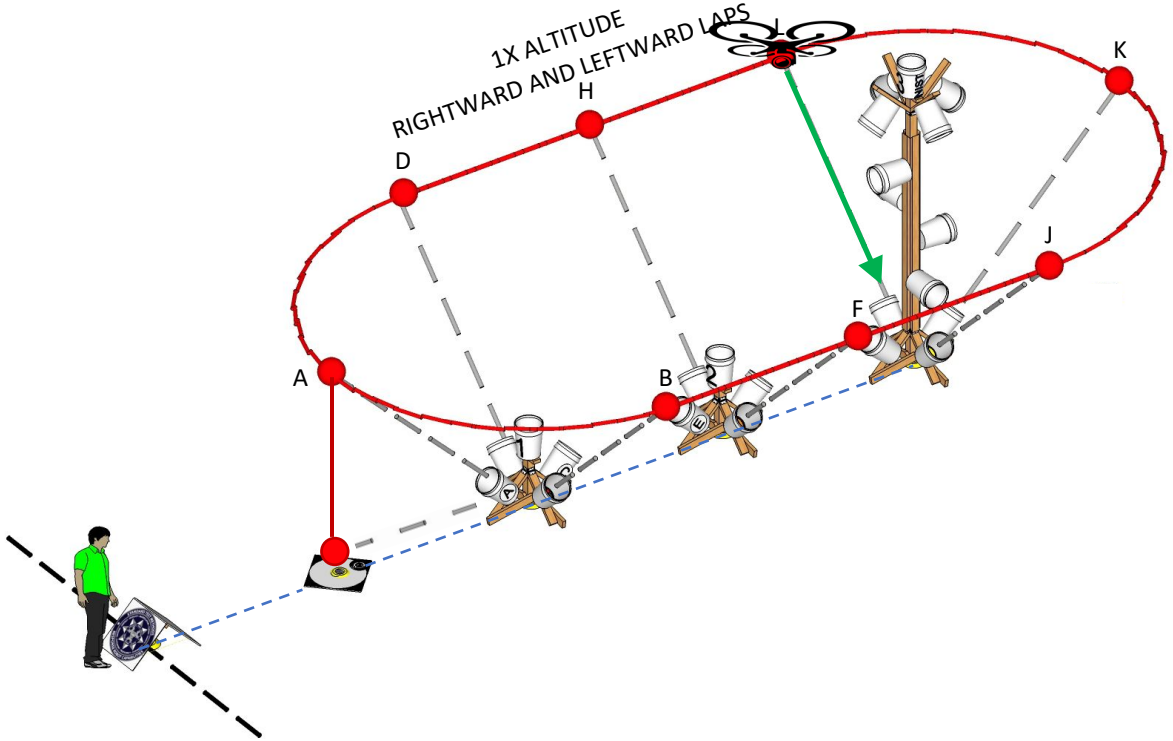

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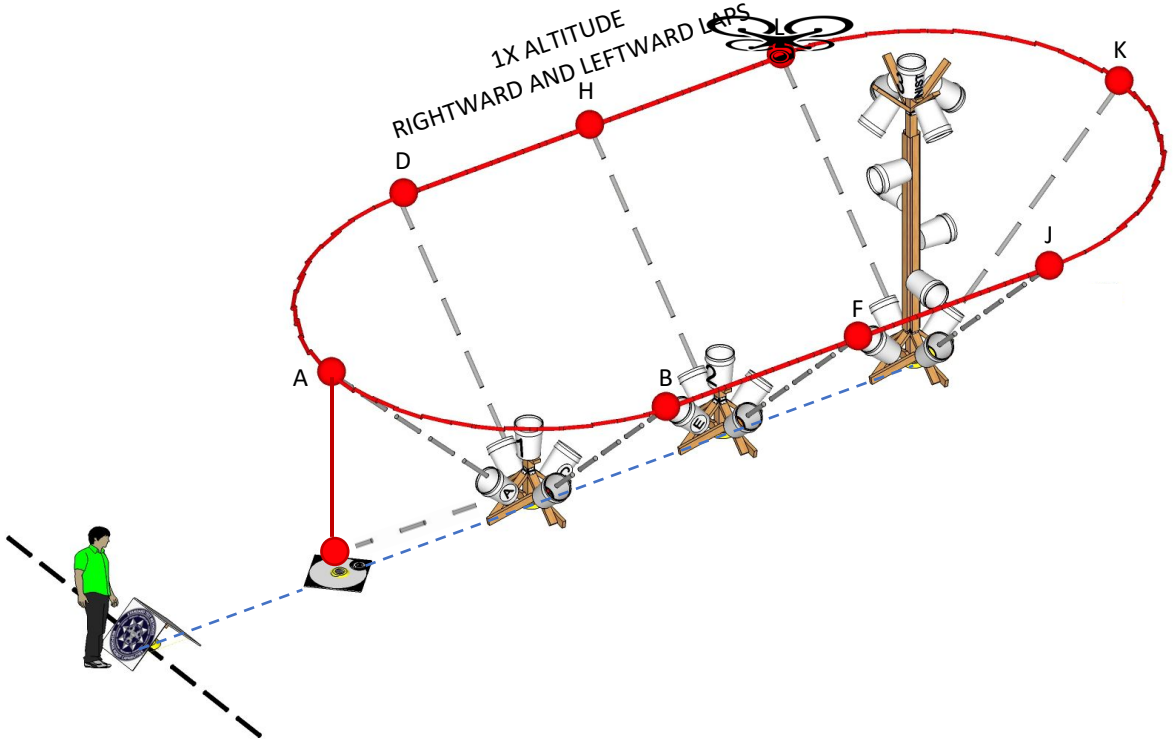

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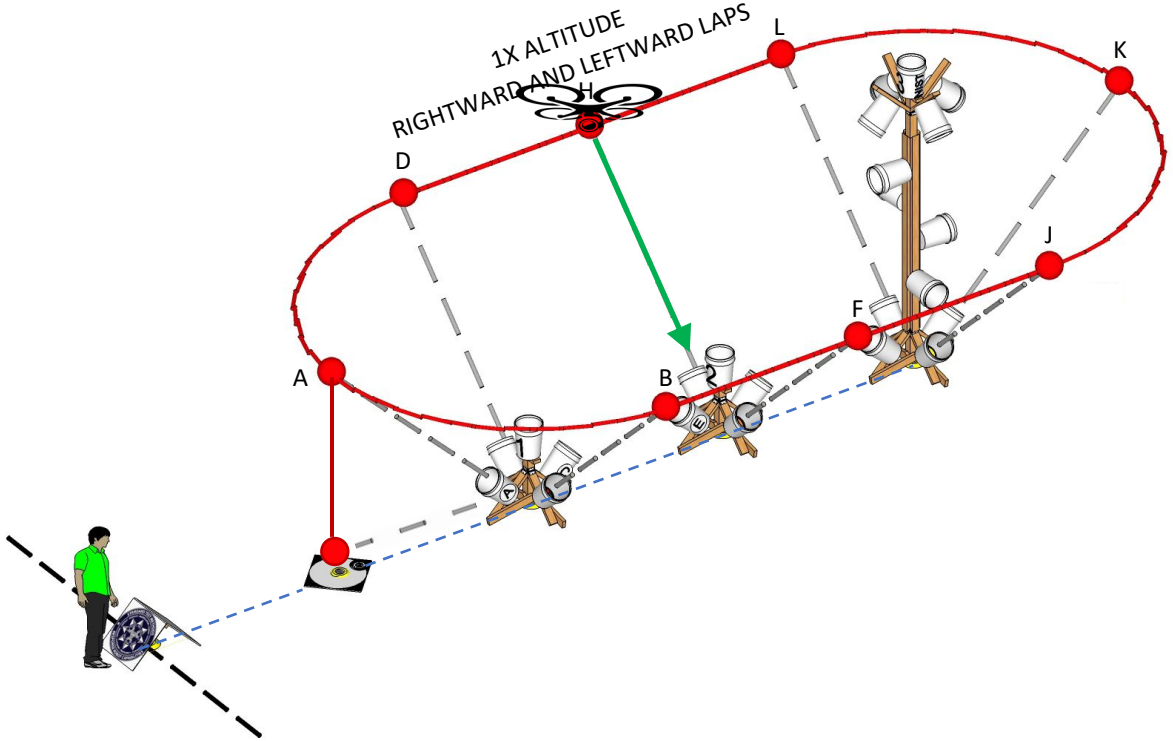

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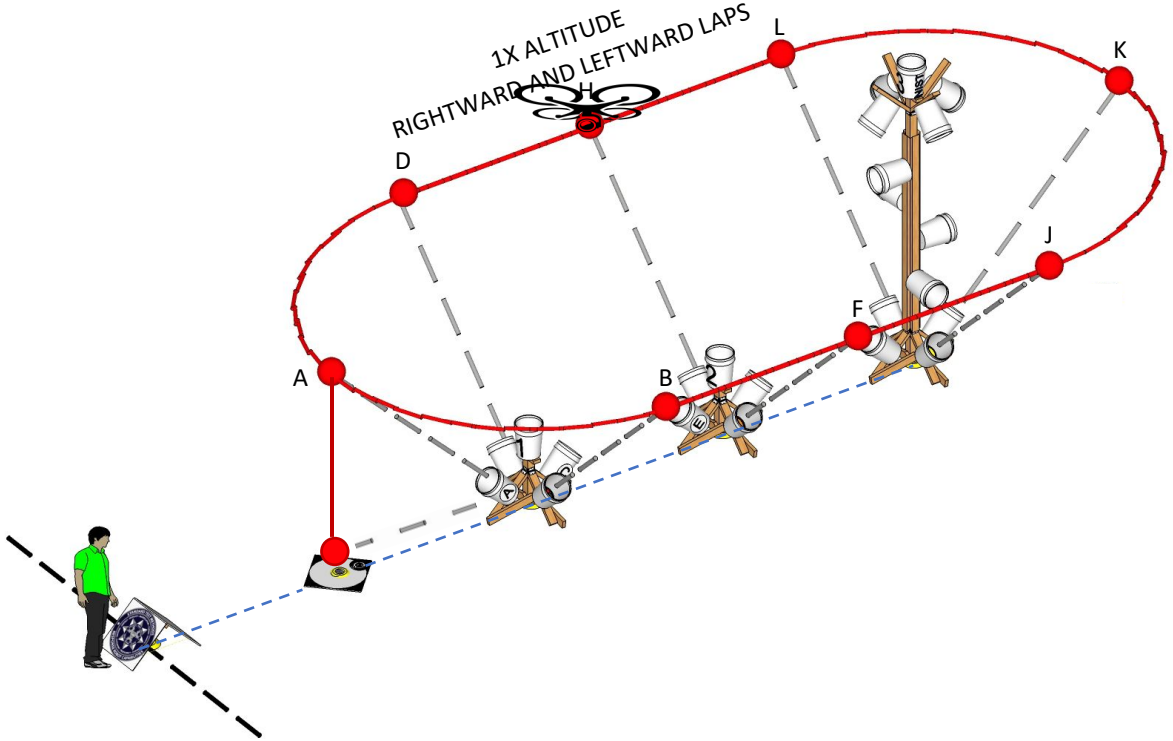

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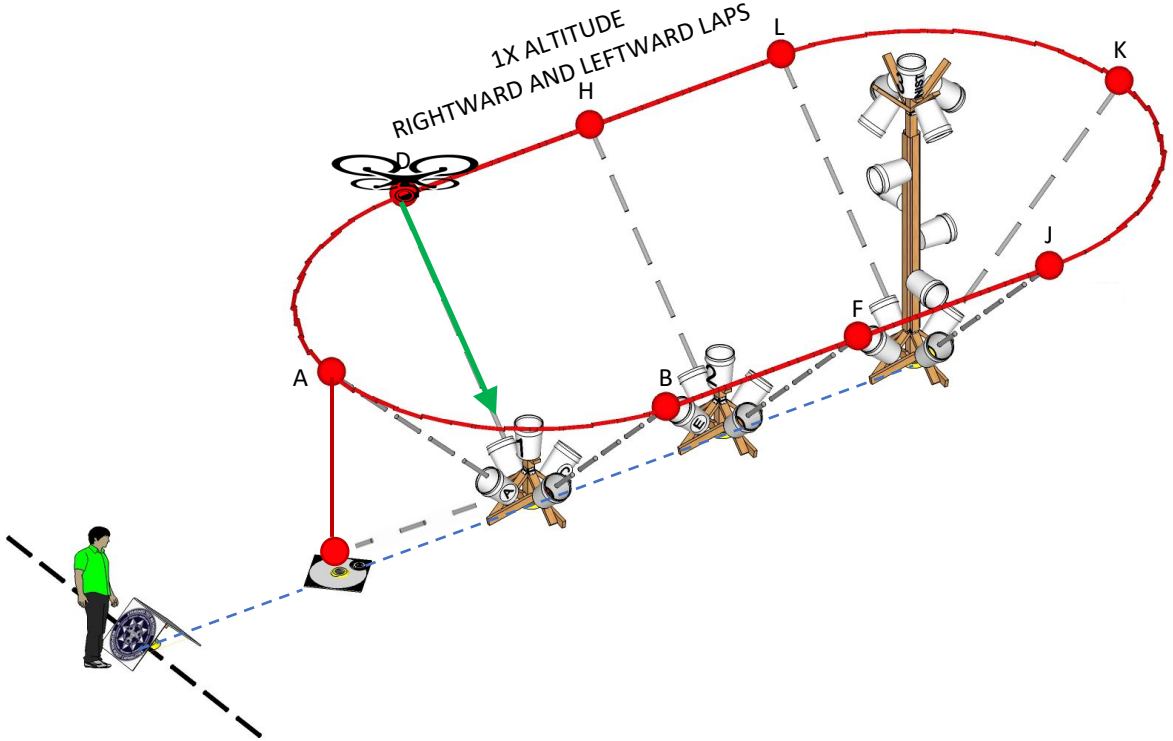

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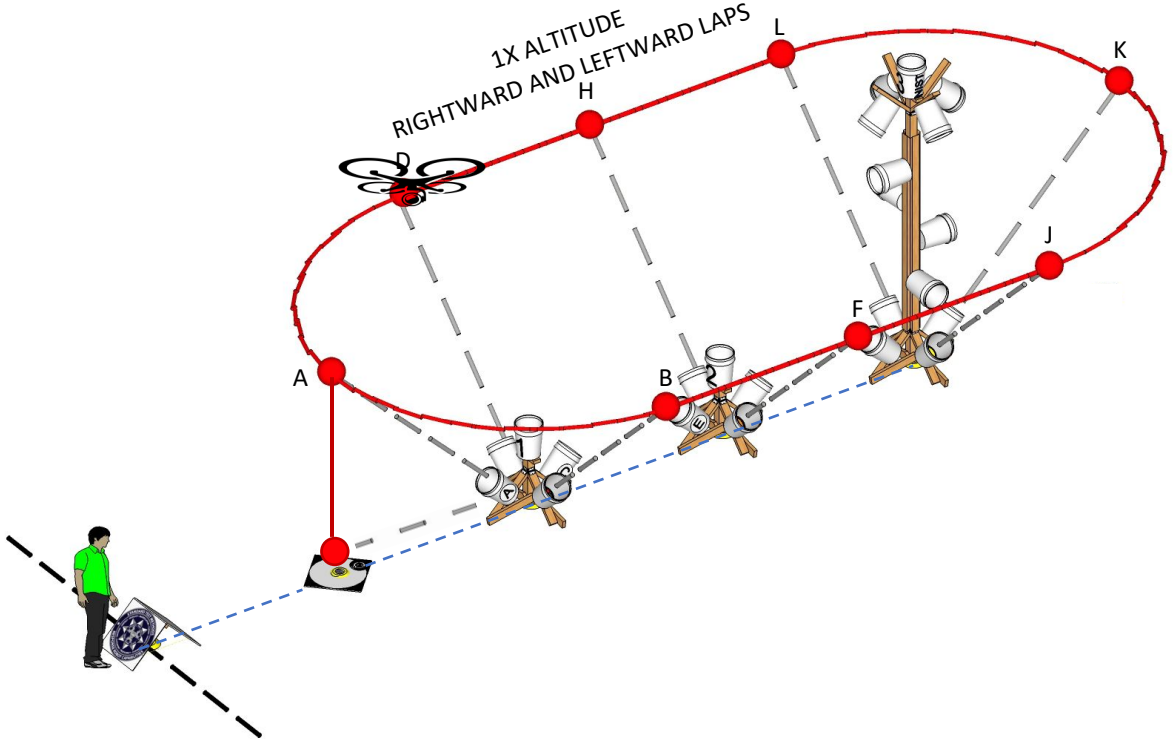

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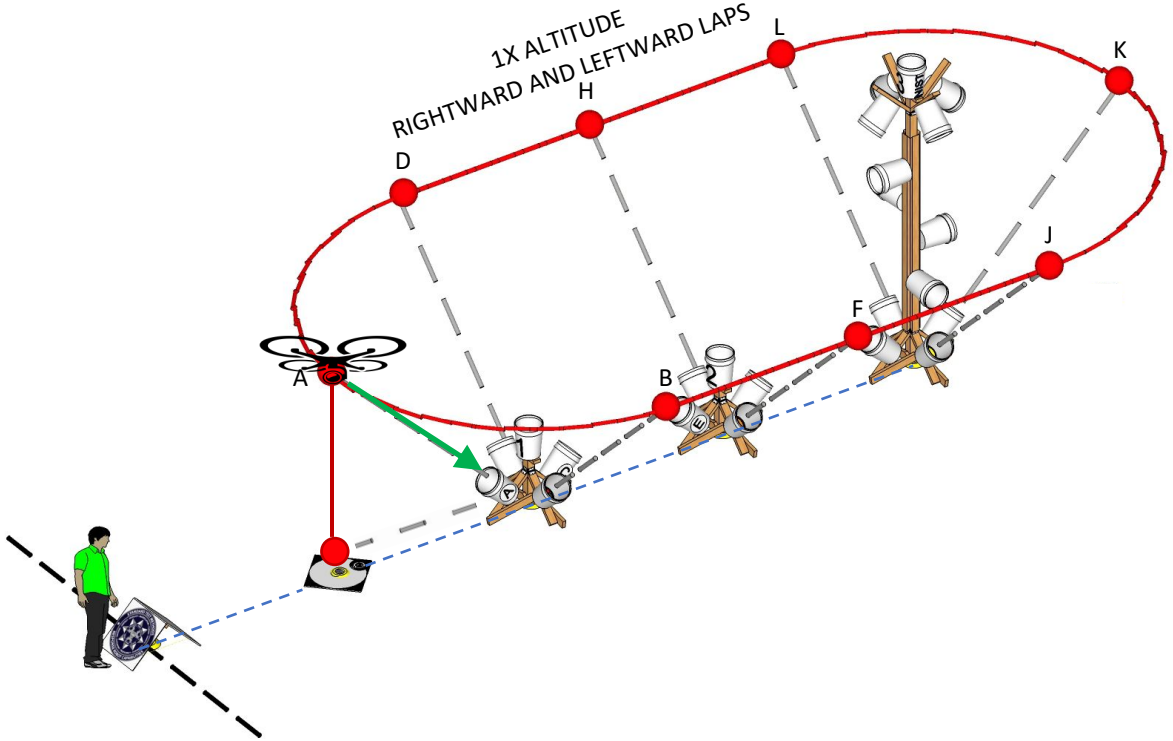

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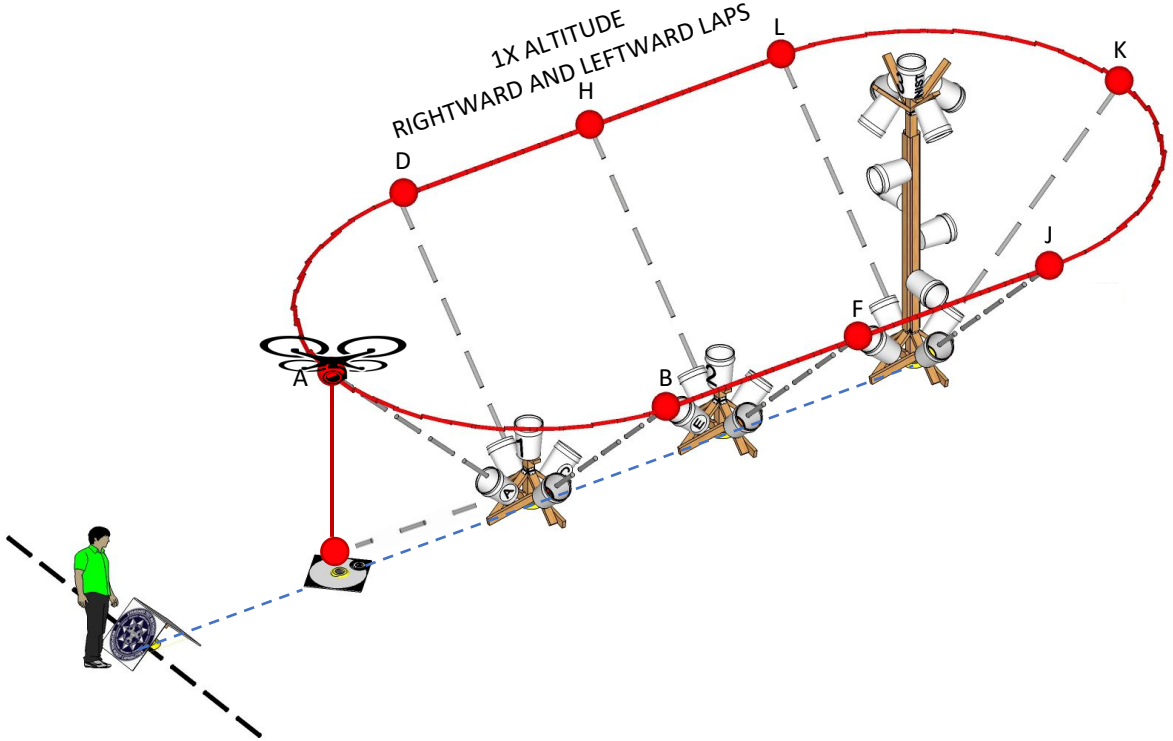

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MAN PAY

START THE TIMER when the drone launches from the platform

1. HOVER at X over the Launch Platform
2. TRAVERSE RIGHTWARD ---------- Buckets A B F J K L H D A
3. LAND ON CENTER facing stands --------- Center or Perch 1

REVERSE DIRECTION

4. HOVER at X over the Launch Platform
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6. LAND ON CENTER facing stands --------- Center or Perch 2

MAN: 20 points = 20 Positions, 18 Alignments and 2 Landings
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Traverse

Maneuvering (MAN 2) and Payload Functionality (PAY 2)

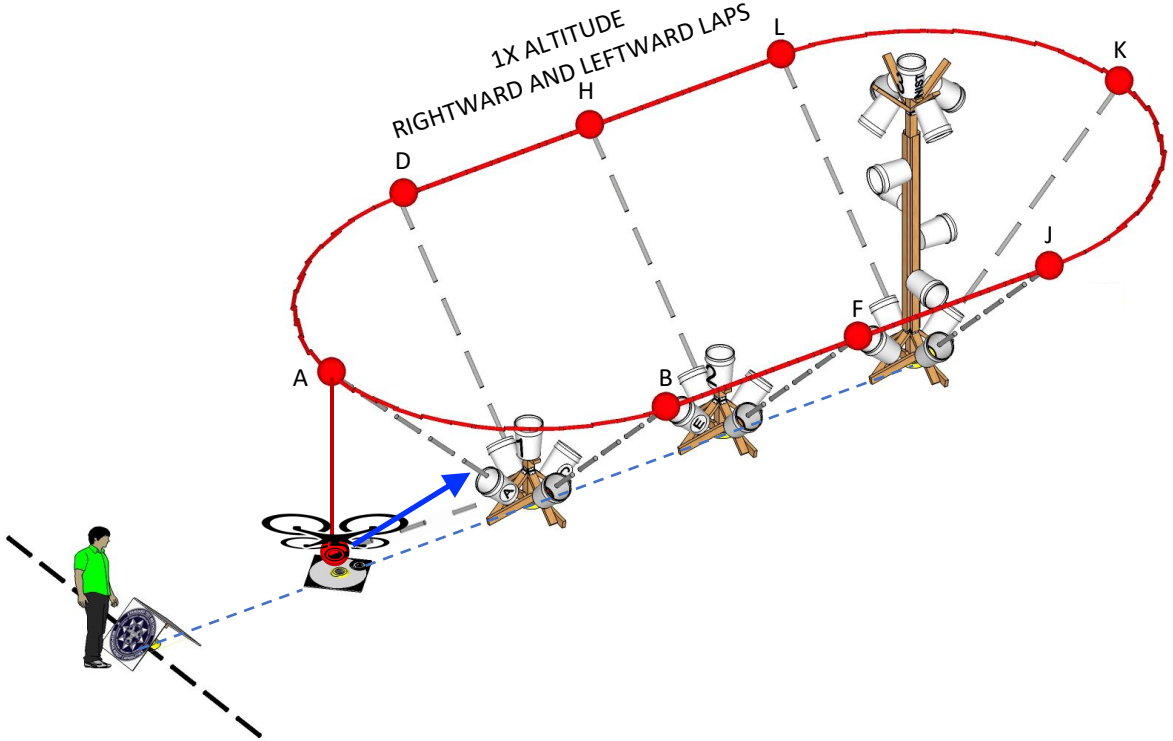
MAN 1-5 LETTER IDENTIFIERS

See the entire inscribed ring inside the buckets to evaluate successful alignments. 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.



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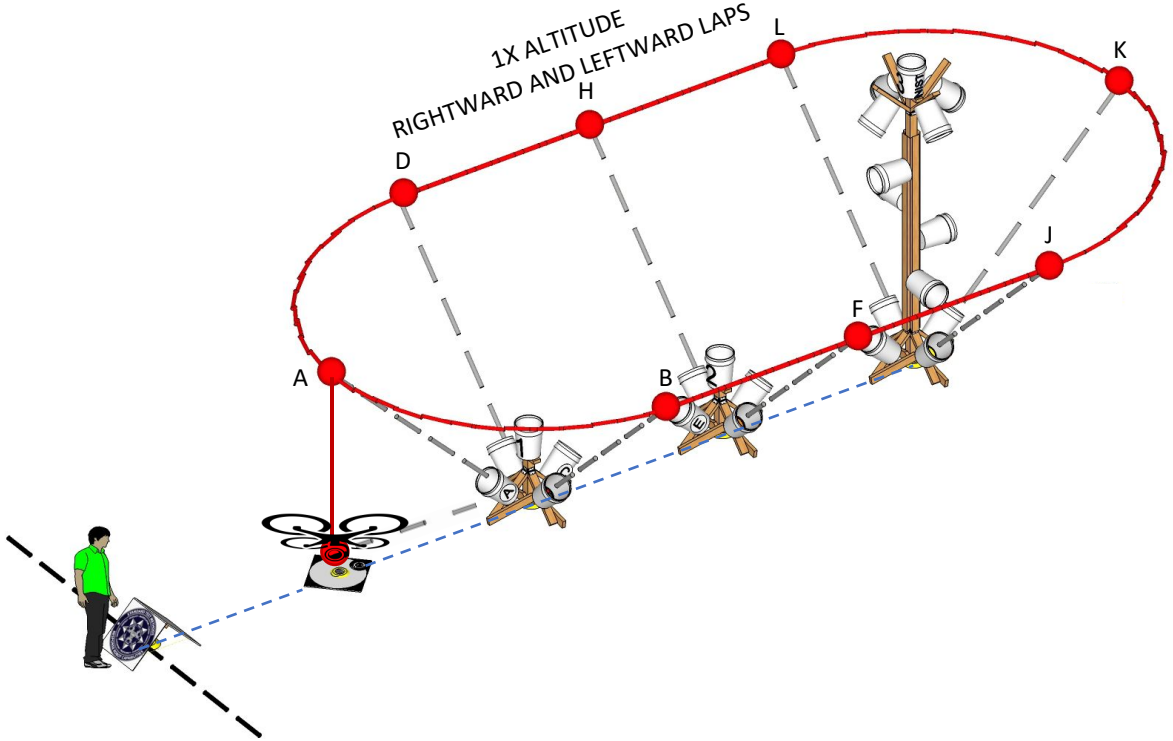

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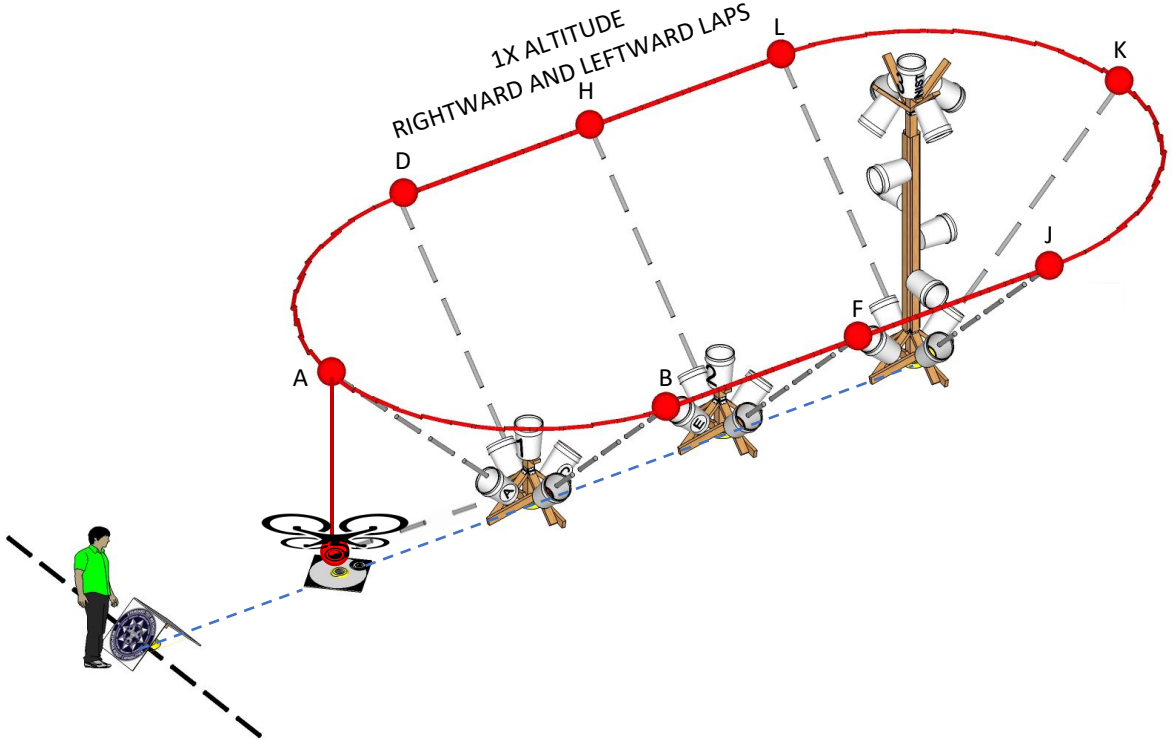

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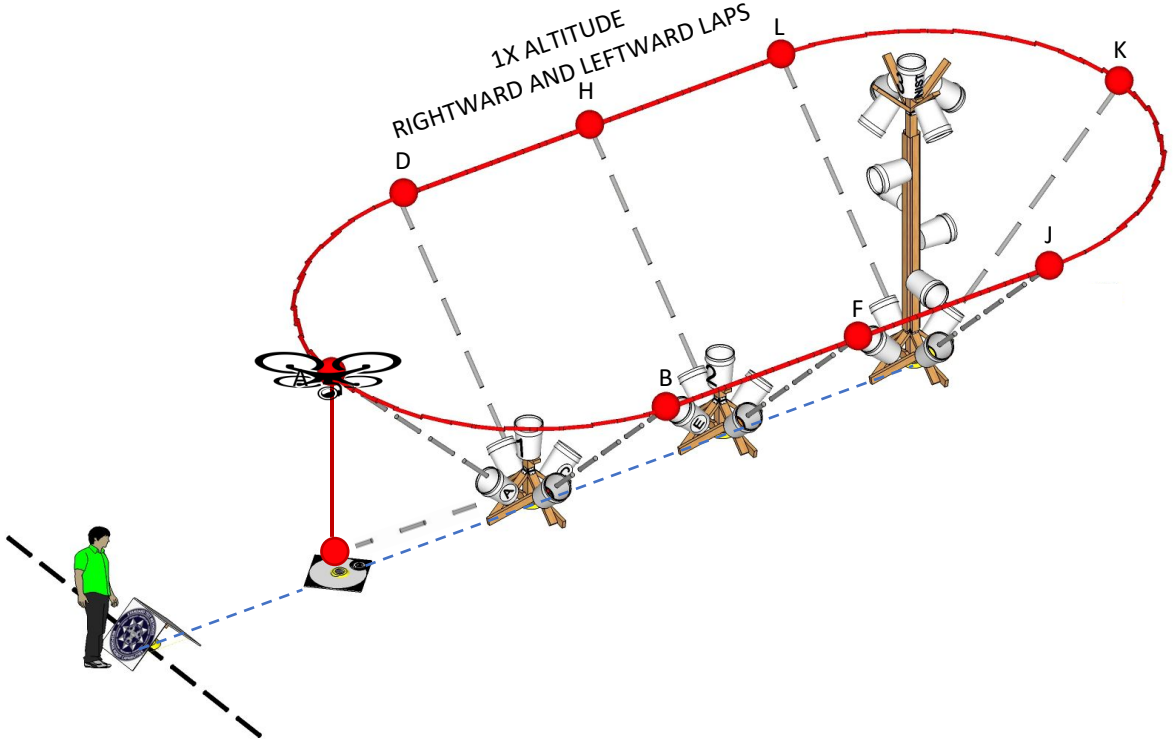

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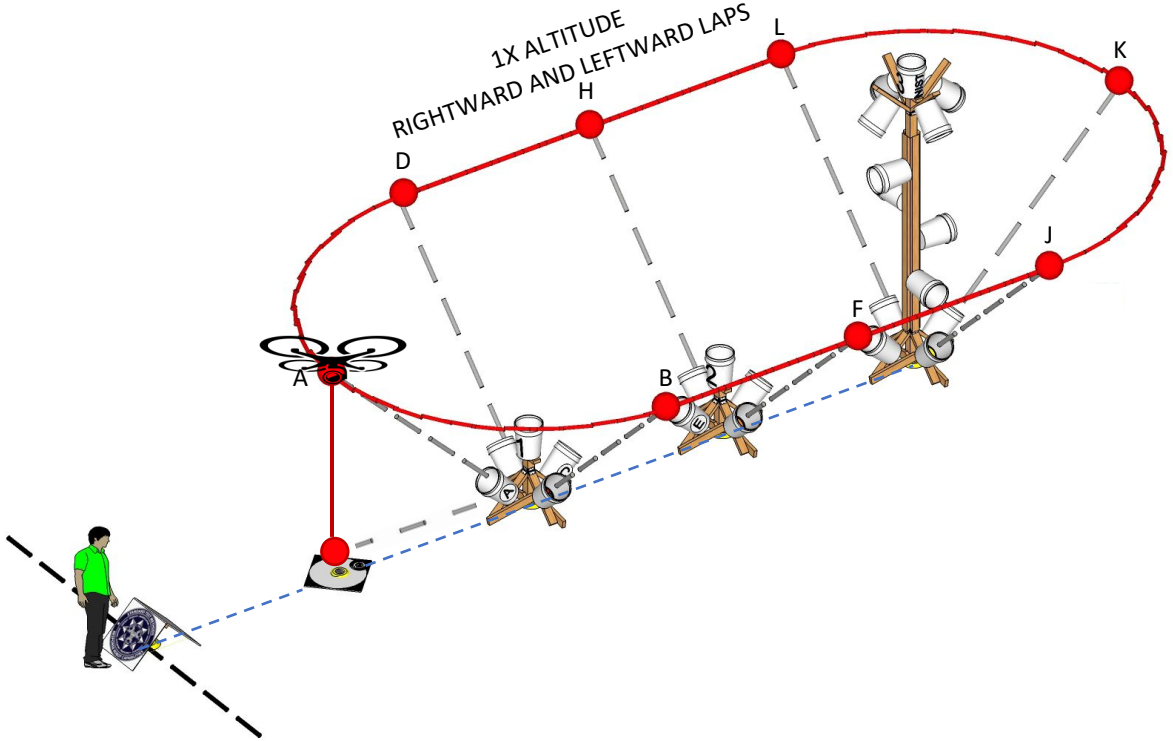

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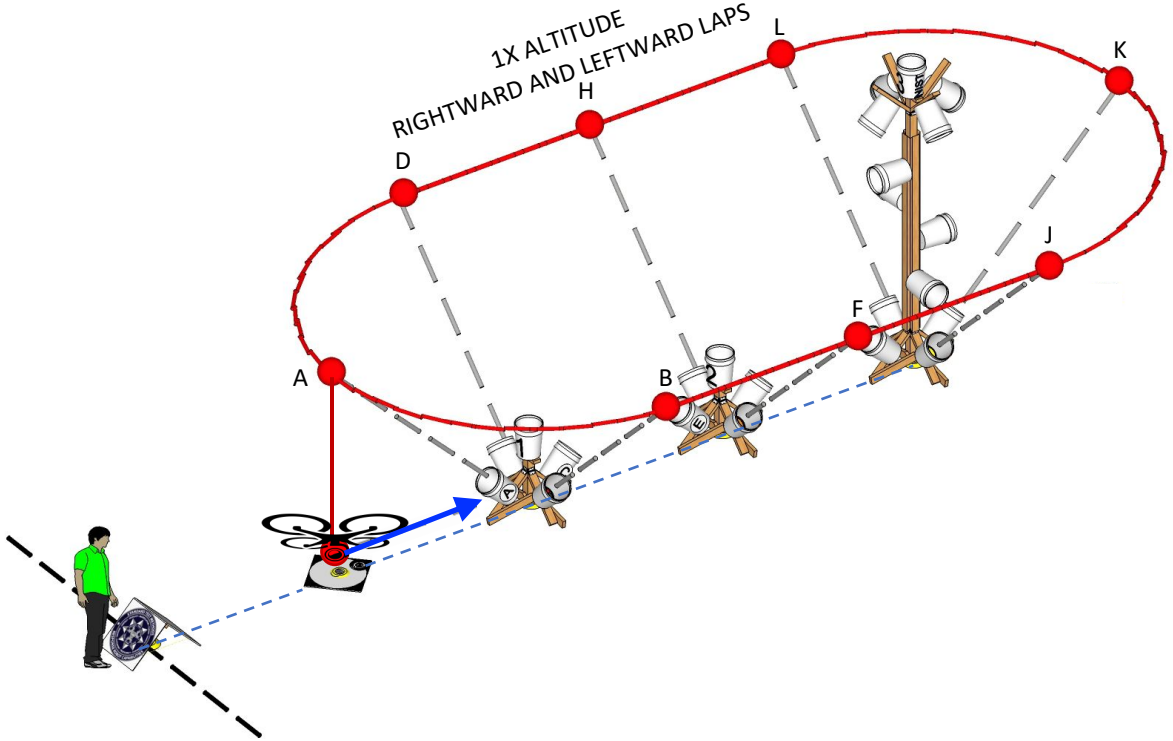

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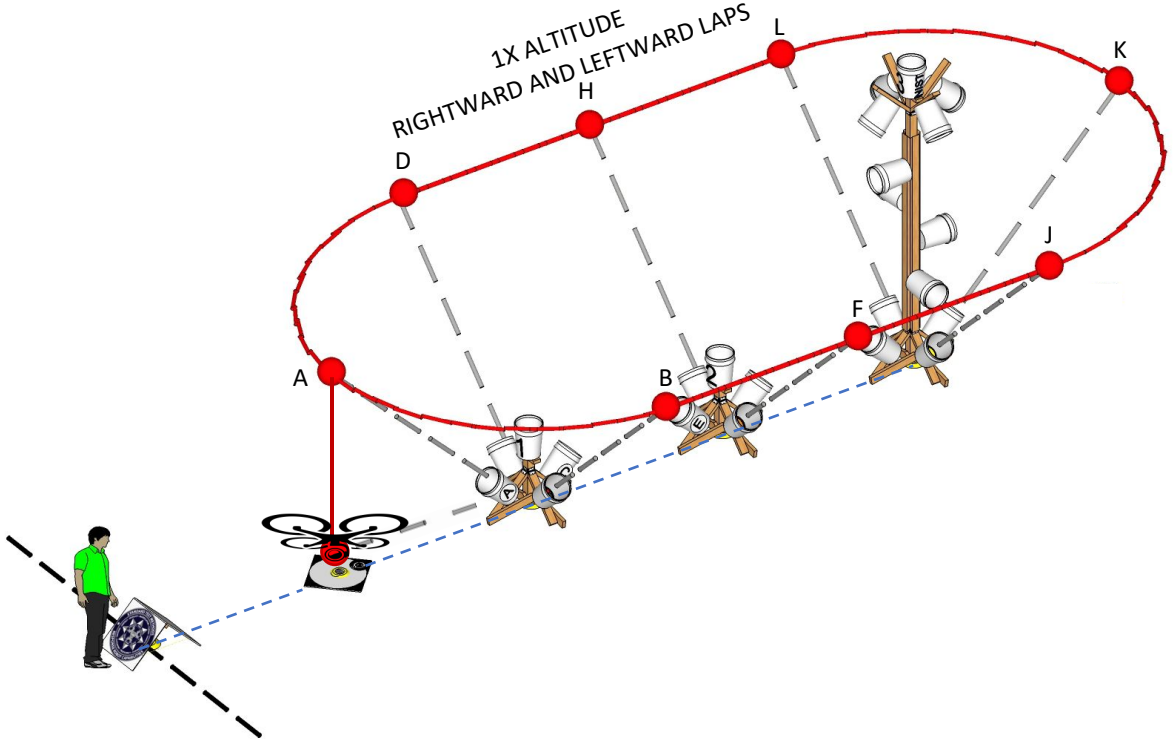

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Align and identify the visual acuity targets with increasingly small concentric C gaps in one of eight directions.

FLIGHT PATH MAN PAY

START THE TIMER when the drone is centered over the tall post Bucket 3 at 2X, use Bucket 1 and 2 to set radius

1. ORBIT RIGHTWARD at 2X ---- Buckets 1 I J K L
2. ORBIT LEFTWARD at 2X ------ Buckets 1 I L K J

DESCEND TO X ALTITUDE

3. ORBIT RIGHTWARD at X ----- Buckets 2 I J K L
4. ORBIT LEFTWARD at X ----- Buckets 2 I L K J

MAN: 20 points = 20 Bucket Alignments

PAY: 100 points = 20 Bucket Alignments and Targets

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FLIGHT PATHS

SPIRAL

MAN 1-5 LETTER IDENTIFIERS

ALIGNED

See the entire inscribed ring inside the buckets to evaluate successful alignments. The letters are bucket identifiers.

PAY 1-5 VISUAL ACUITY TARGETS

NOT ALIGNED

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

Spiral

Maneuvering (MAN 4) and Payload Functionality (PAY 4)

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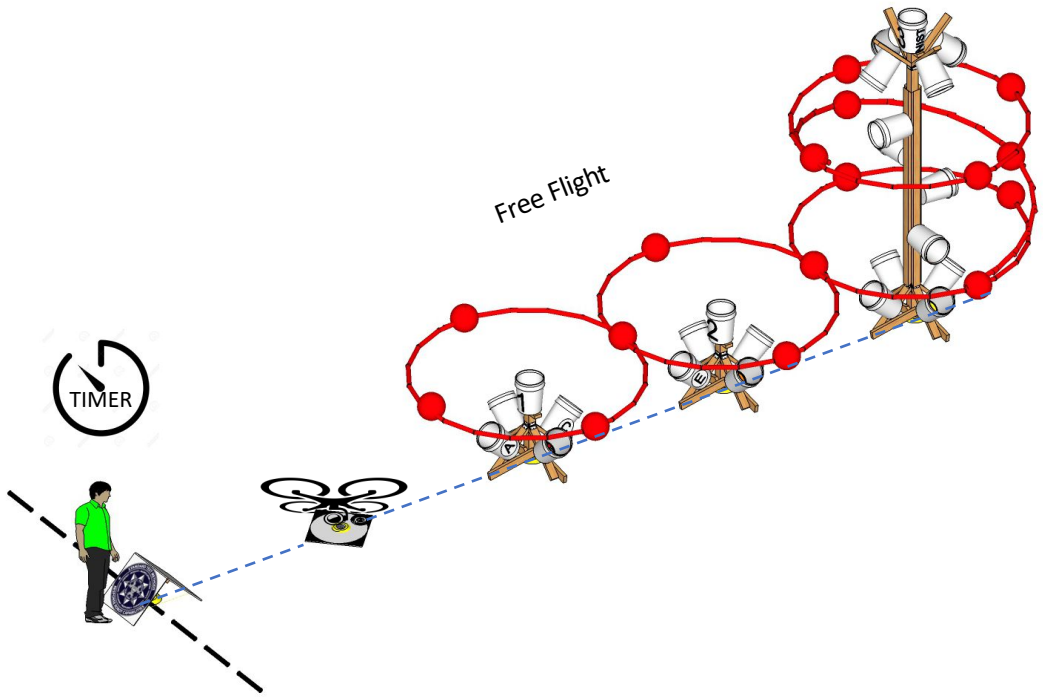

FLIGHT PATH MAN PAY

START THE TIMER when the drone launches from the Launch Platform
FLY ANY ALTITUDE AND RADIUS around the stands

1. SPIRAL Stand 1 ---------- Buckets A B C D
2. SPIRAL Stand 2 ---------- Buckets E F G H
3. SPIRAL Stand 3 Downward ---------- Buckets I J K L
4. SPIRAL Stand 3 Forward ---------- Buckets M N O P
5. SPIRAL Stand 3 Upward ---------- Buckets Q R S T

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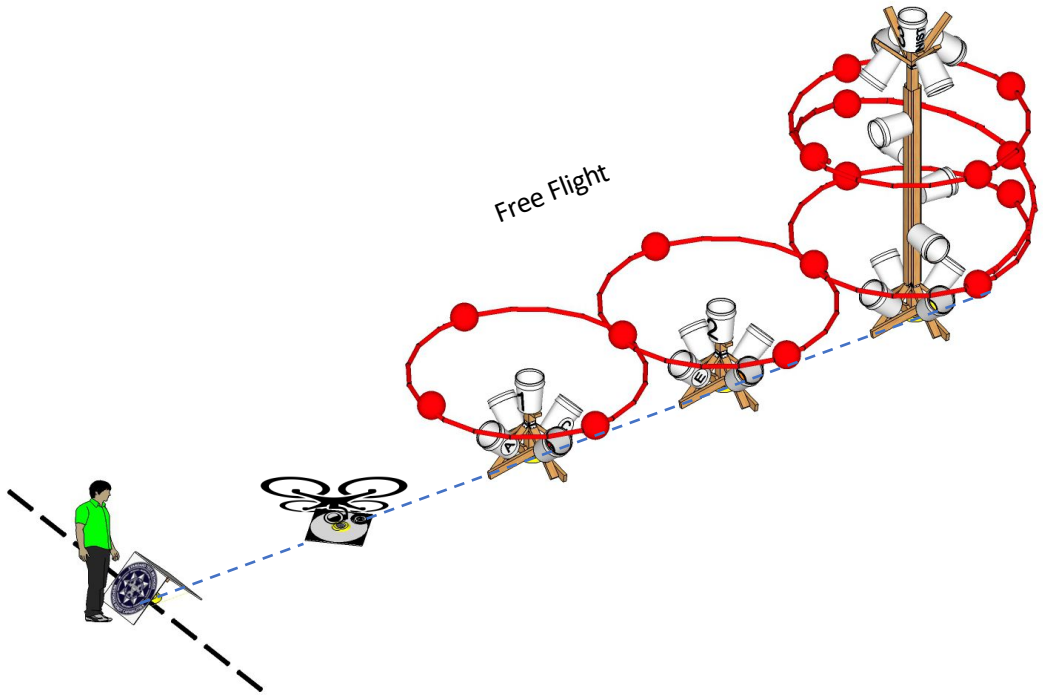

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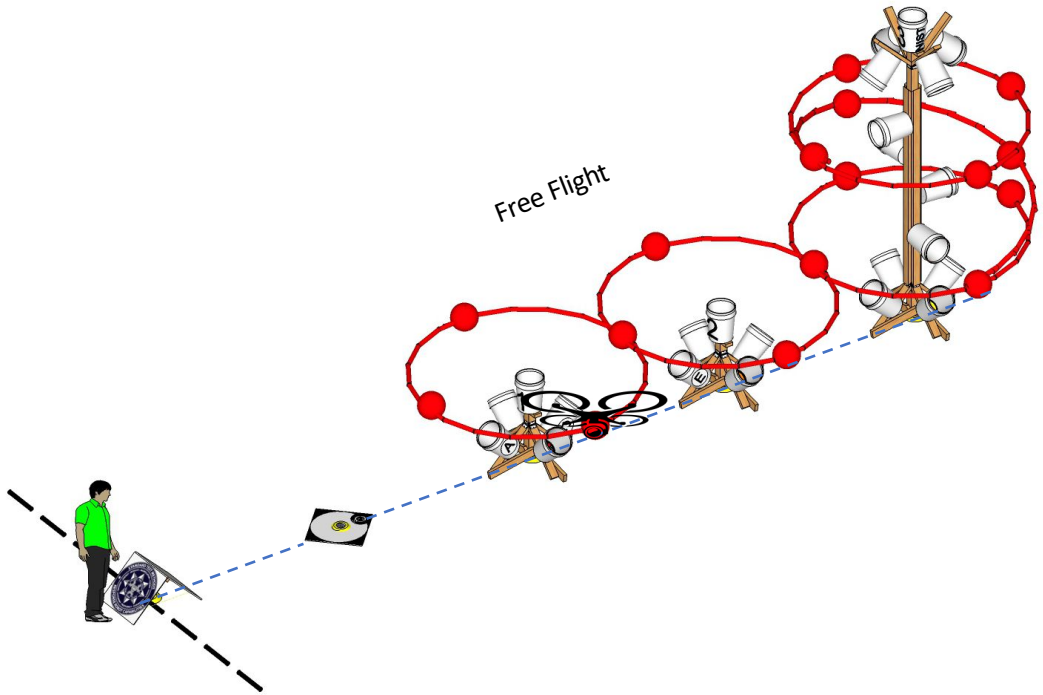

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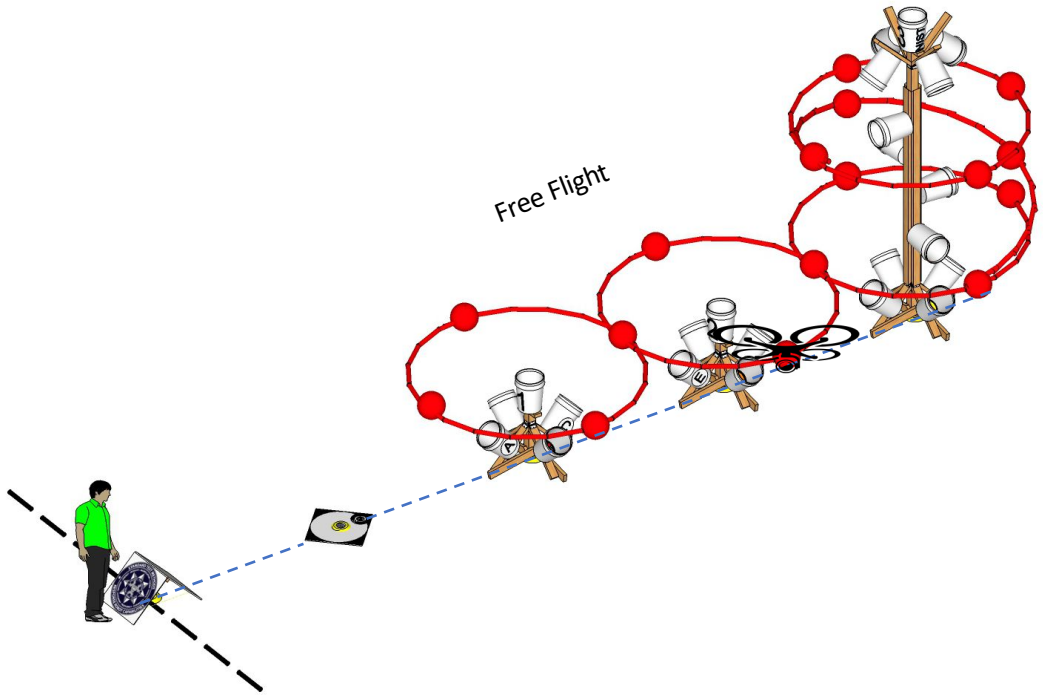

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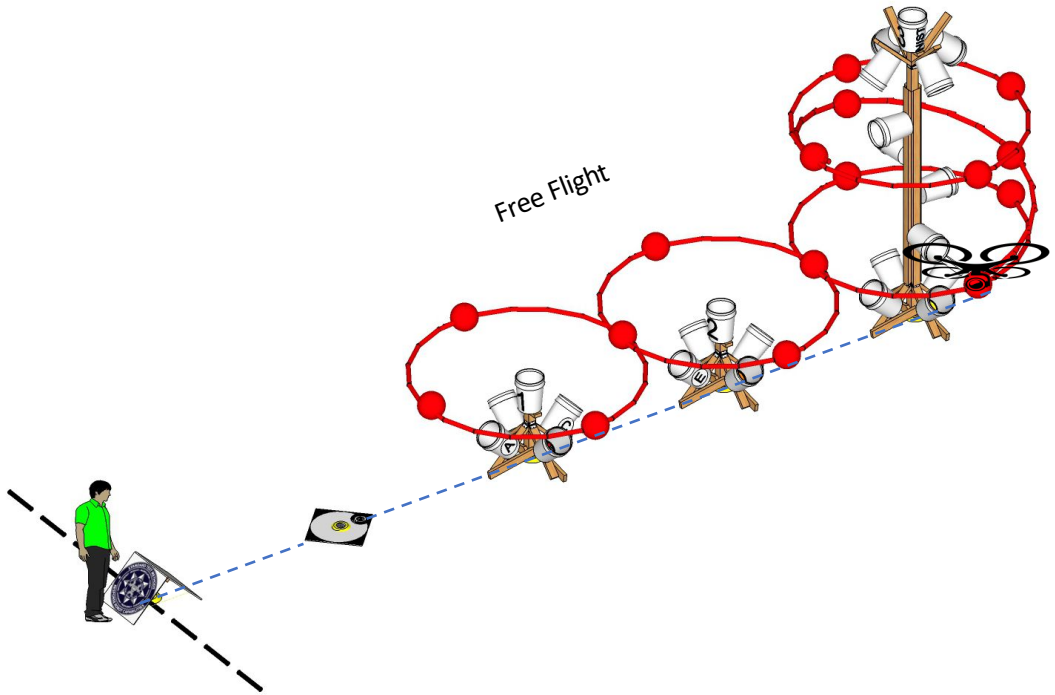

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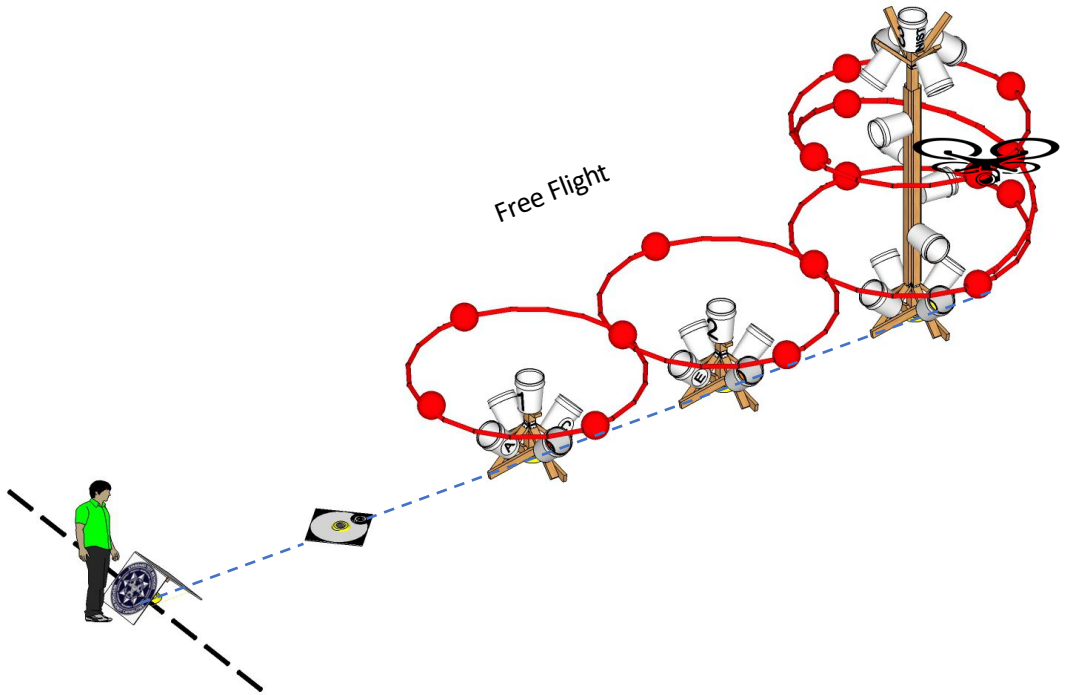

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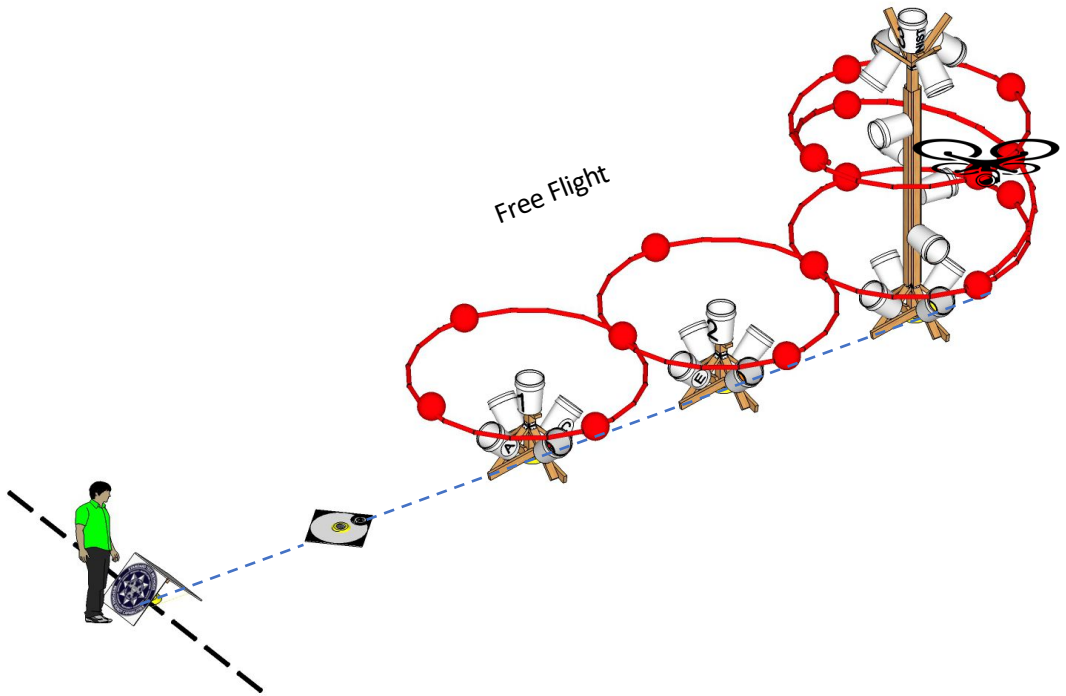

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FLIGHT PATHS

SUSTAIN SPEED

MAN 5 FLY FAST TO A STABLE HOVER

ALIGNED

Fly at maximum sustained speed on a line both horizontally and vertically. Align to see the entire inscribed ring inside the buckets.

MAN 5 FLY FAST TO A STABLE HOVER

Fly at maximum sustained speed on a line both horizontally and vertically. Align to see the entire inscribed ring inside the buckets.

NOT QUITE ALIGNED

Sustain Speed

Maneuvering (MAN 5)

FLIGHT PATH

MAN

START TIMER AT X ALIGNED WITH BUCKET 3 AND BUCKET 2G

1. FLY STRAIGHT AND LEVEL 5X DOWN RANGE
2. ALIGN WITH BUCKET 4
3. RETURN AND ALIGN OVER BUCKET 3 AND BUCKET 2G
4. CLIMB VERTICALLY TO 6X ALTITUDE (5X PATH)
5. ALIGN WITH BUCKET 3
6. RETURN AND ALIGN OVER BUCKET 3 AND BUCKET 2G

CONTINUE FOR 5 LAPS or until the timer expires

MAN: 20 points = 20 Paths (2-way), 10 Bucket Alignments

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Maneuvering (MAN 5)

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FLIGHT PATHS

DELIVER

PAY 5 HOVER STABLY AND DELIVER ACCURATELY

ALIGNED

Hover stably with the payload, fly the designated 5X path, and PLACE or DROP the payload as close to the center of the drop zone as possible.

Deliver

Payload Functionality (PAY 5)

PAY 5 HOVER STABLY AND DELIVER ACCURATELY

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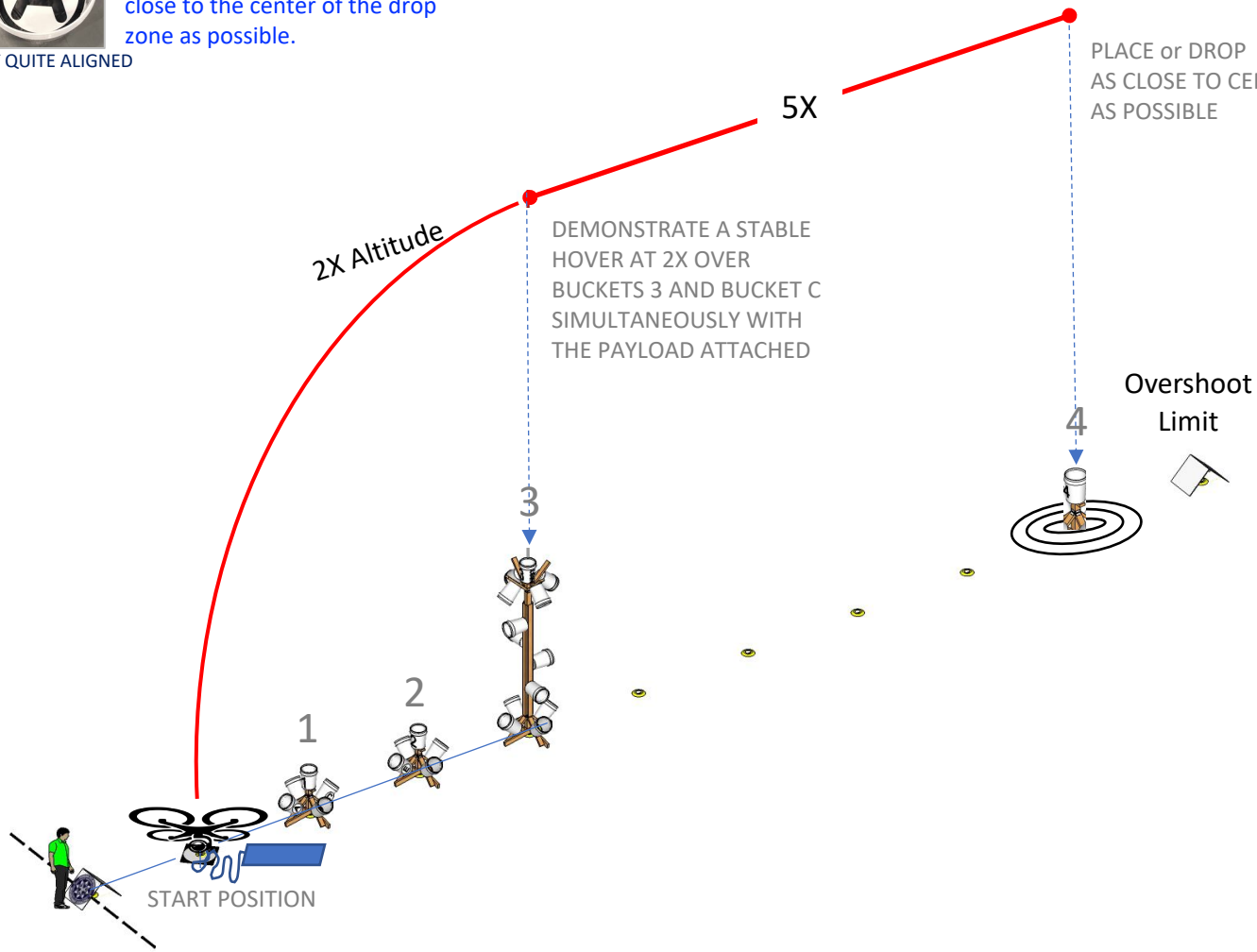

FLIGHT PATH

PAY

1. START TIMER AT LAUNCH FROM PLATFORM
2. FLY TO 2X, ALIGN WITH BOTH BUCKET 3 AND BUCKET 1C
3. FLY 5X DOWN RANGE, ALIGN WITH BUCKET 4
4. PLACE or DROP THE PAYLOAD IN CIRCLE CENTER
5. PAUSE TIMER AND RETURN TO START AGAIN

REPEAT FOR 5 DELIVERIES or until the timer expires

PAY: 100 points = 5 Centered Drops or Placements

Scoring: (on the line, but not over the line, is "in")

- 20 points for a 4ft diameter (2ft radius)
- 16 points for a 8ft diameter (4ft radius)
- 12 points for a 12ft diameter (6ft radius)
- 8 points for a 16ft diameter (8ft radius)
- 4 points for a 20ft diameter (10ft radius)

100 points maximum

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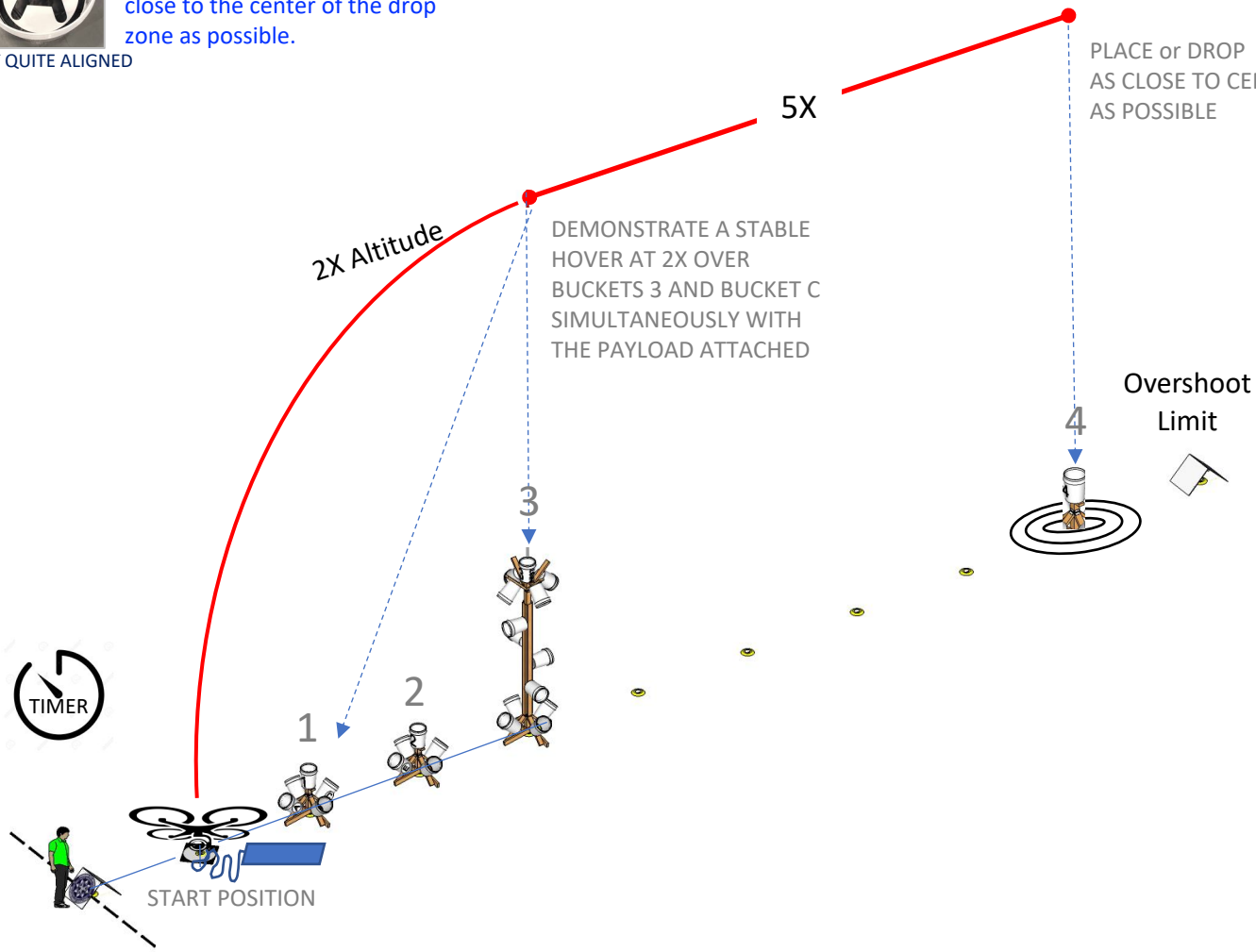

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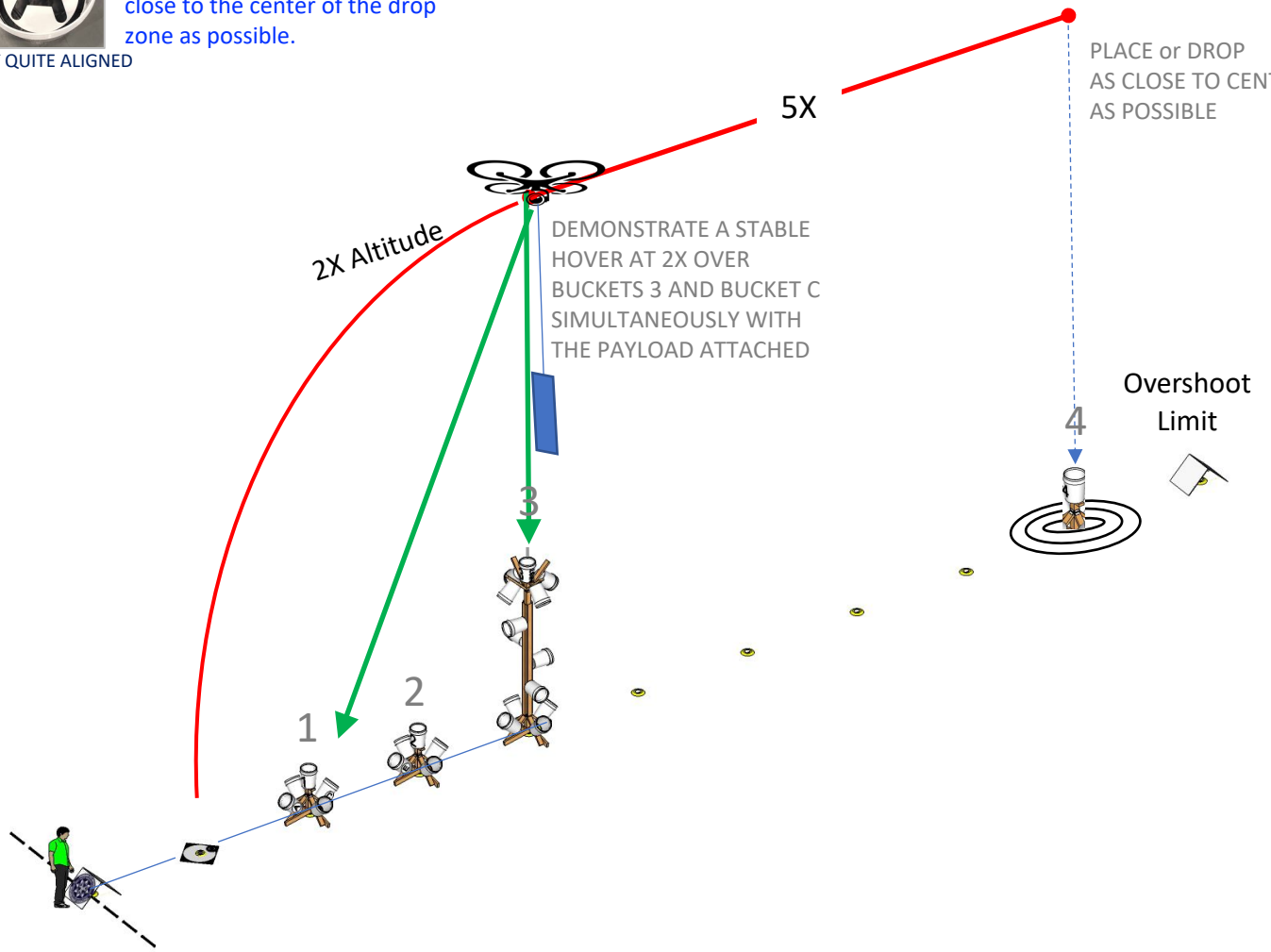

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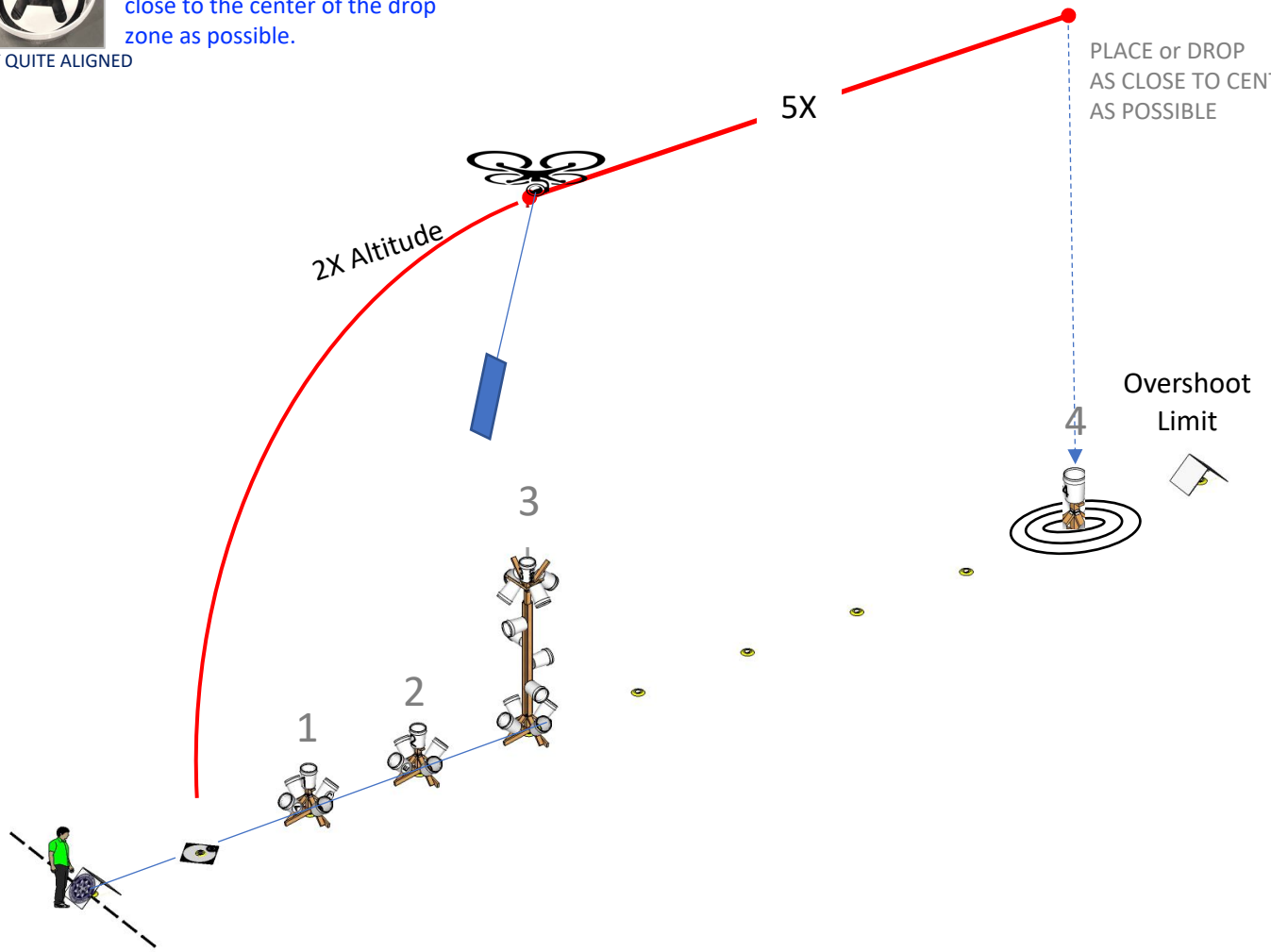

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5. PAUSE TIMER AND RETURN TO START AGAIN

PAY: 100 points = 5 Centered Drops or Placements

Scoring: (on the line, but not over the line, is "in")

- 20 points for a 4ft diameter (2ft radius)
- 16 points for a 8ft diameter (4ft radius)
- 12 points for a 12ft diameter (6ft radius)
- 8 points for a 16ft diameter (8ft radius)
- 4 points for a 20ft diameter (10ft radius)

100 points maximum

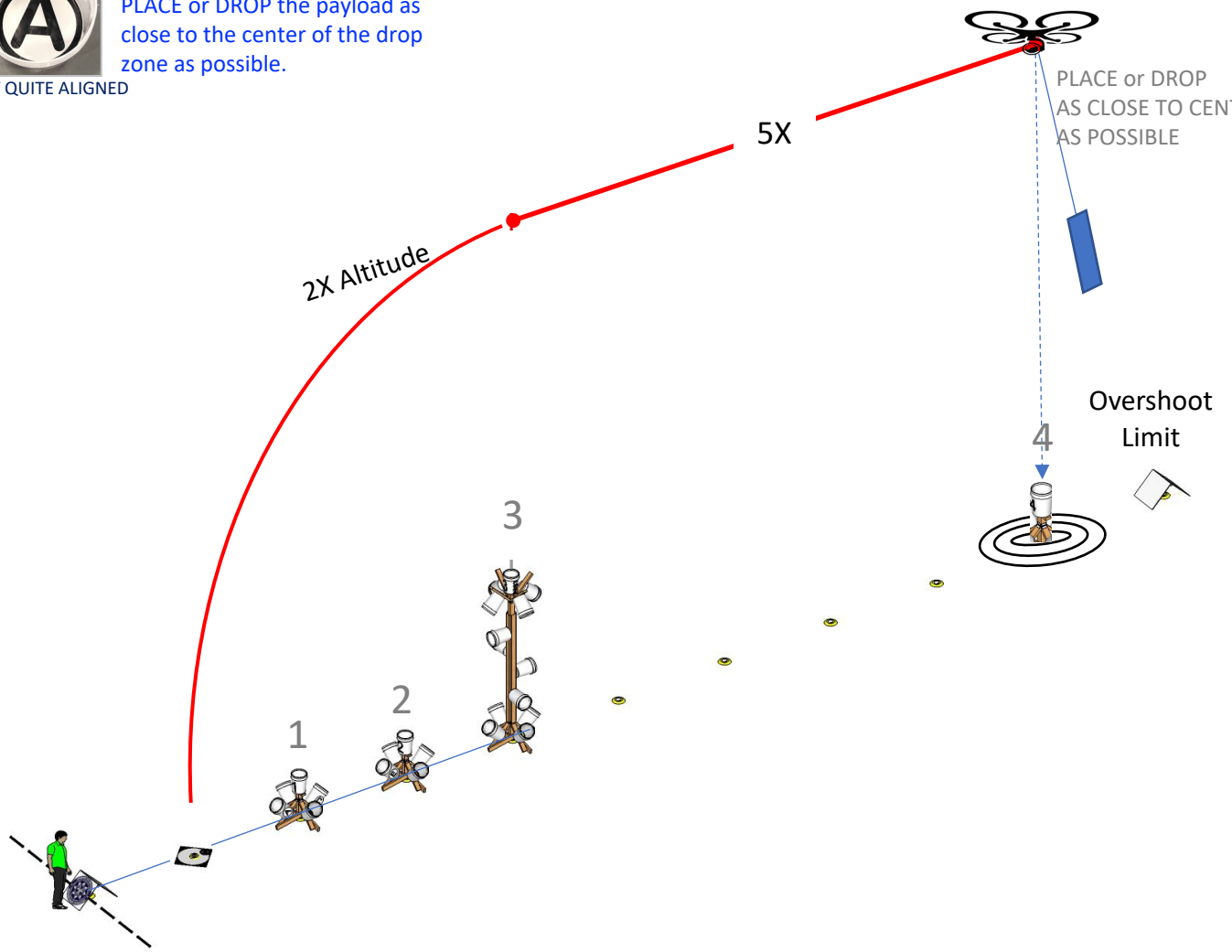
Deliver

Payload Functionality (PAY 5)

PAY 5 HOVER STABLY AND DELIVER ACCURATELY

Hover stably with the payload, fly the designated 5X path, and PLACE or DROP the payload as close to the center of the drop zone as possible.

NOT QUITE ALIGNED



FLIGHT PATH

PAY

1. START TIMER AT LAUNCH FROM PLATFORM
2. FLY TO 2X, ALIGN WITH BOTH BUCKET 3 AND BUCKET 1C
3. FLY 5X DOWN RANGE, ALIGN WITH BUCKET 4
4. PLACE or DROP THE PAYLOAD IN CIRCLE CENTER
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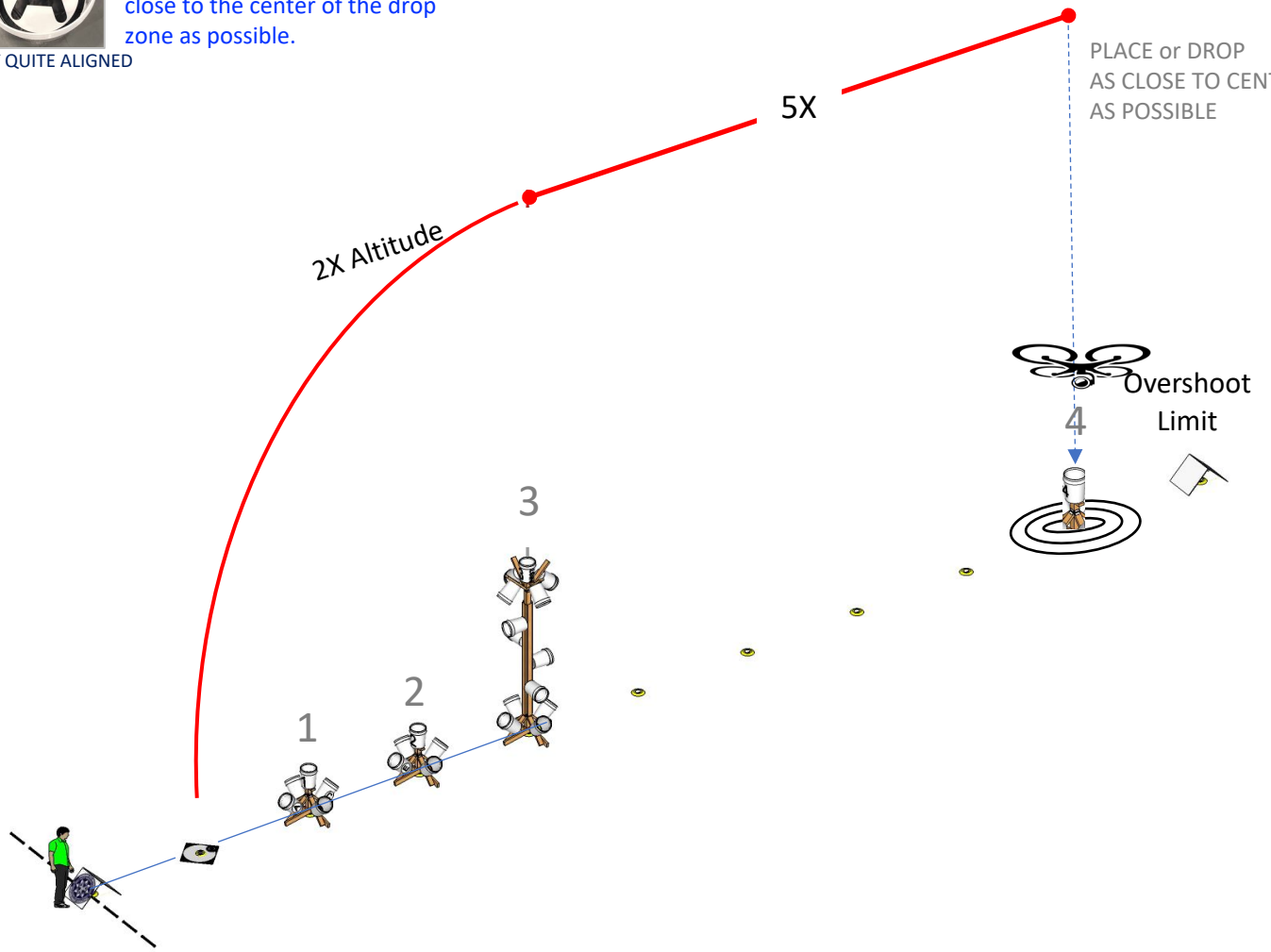

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(on the line, but not over the line, is considered "in")

FLIGHT PATHS

SENSING

MAN 1-5 LETTER IDENTIFIERS

ALIGNED

See the entire inscribed ring inside the buckets to evaluate successful alignments. The letters are bucket identifiers.

PAY 1-5 VISUAL ACUITY TARGETS

NOT ALIGNED

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

Practice-Evaluate-Compare Onboard Sensing Capabilities

Point and Zoom Cameras (SEN 1-5)

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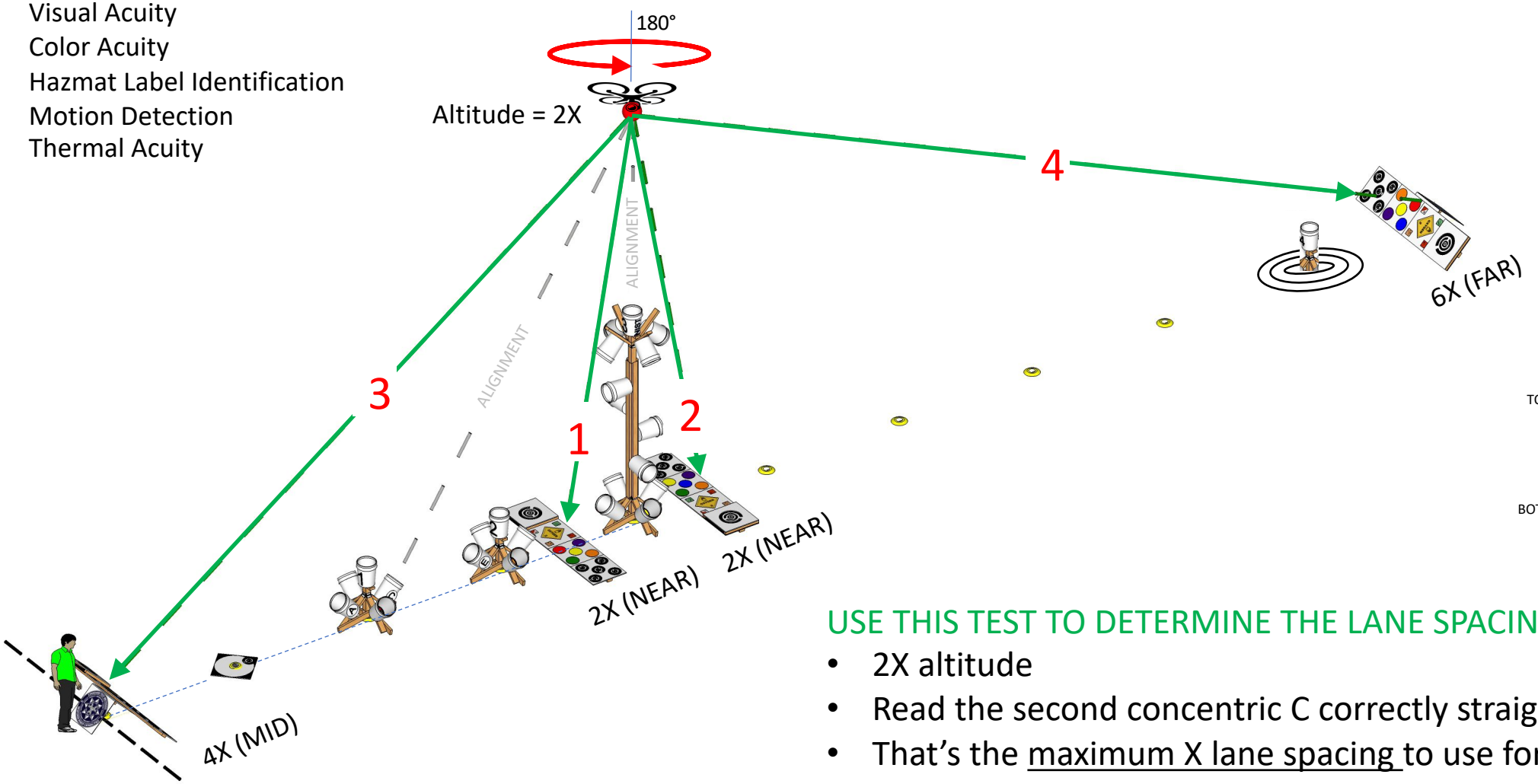

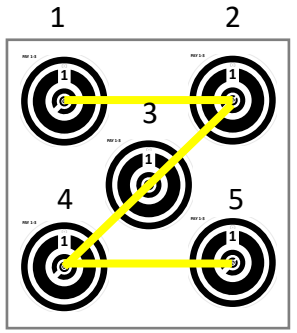

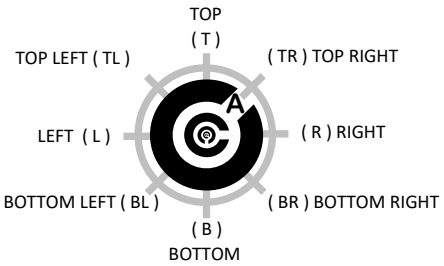

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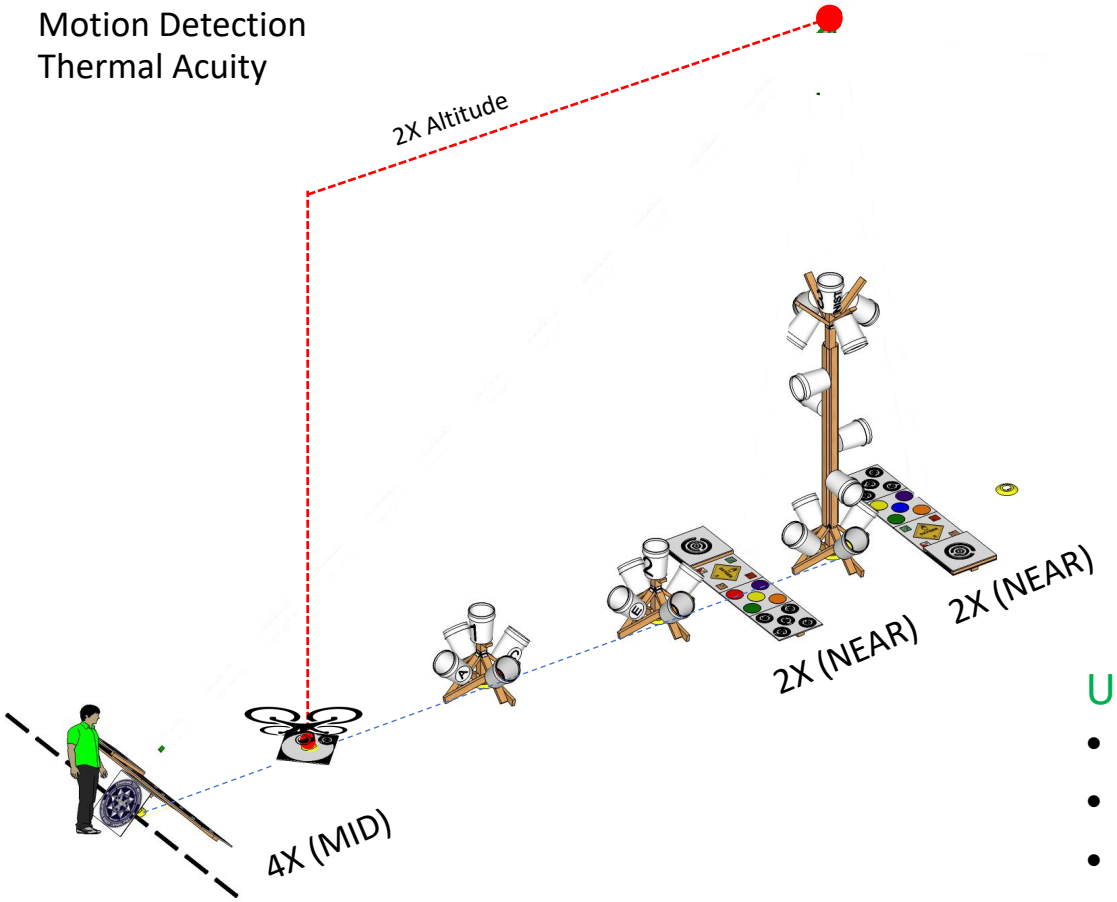

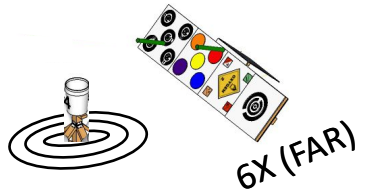

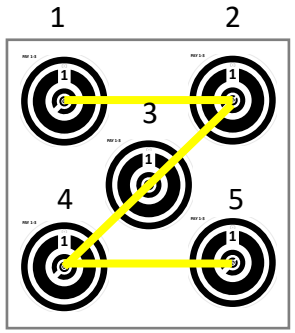

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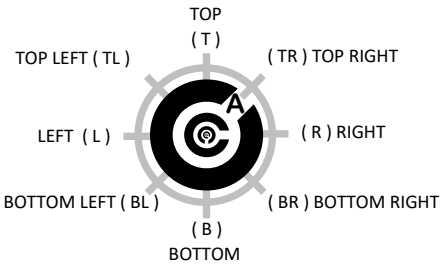

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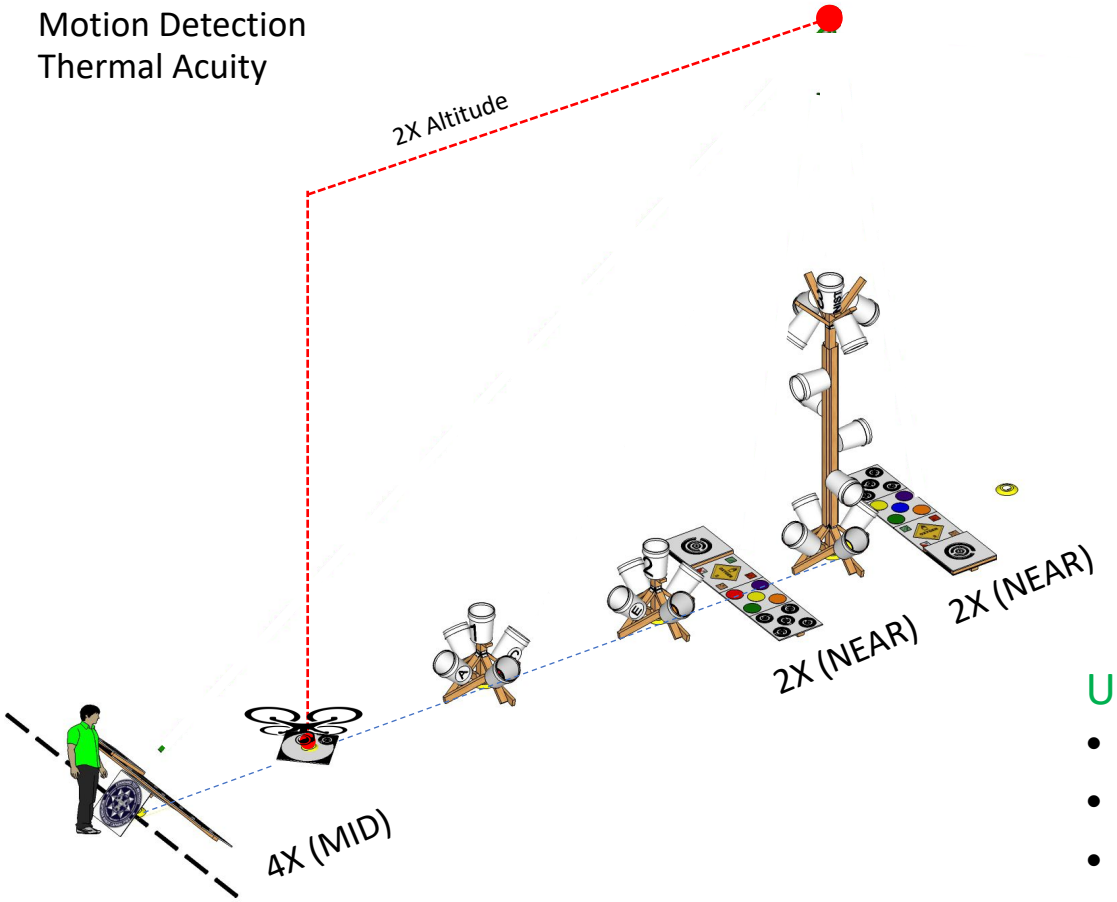

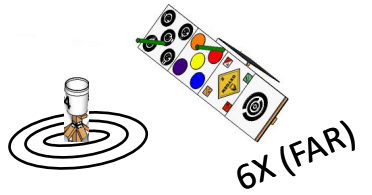

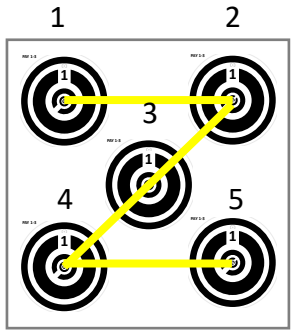

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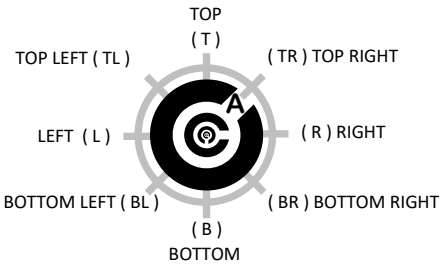

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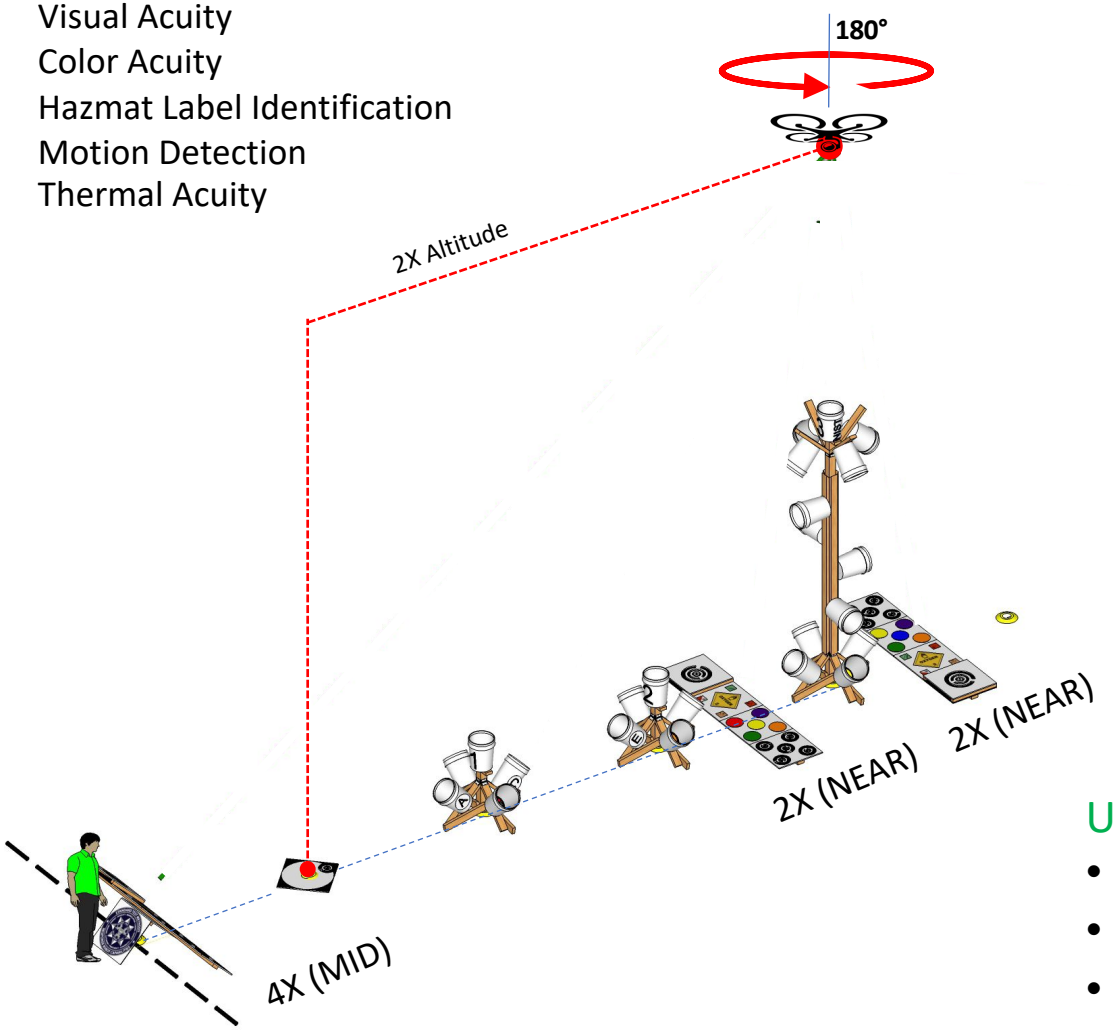

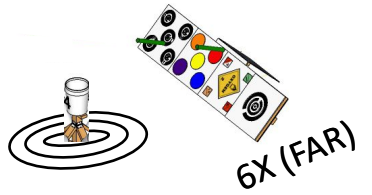

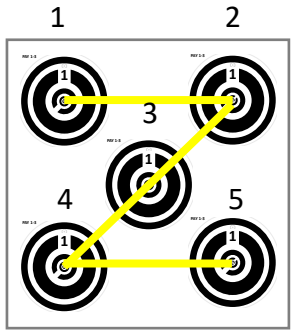

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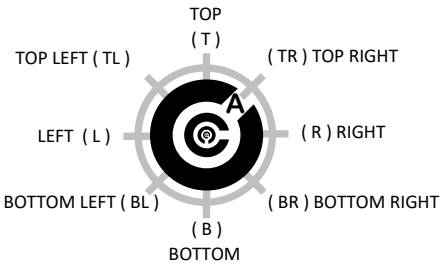

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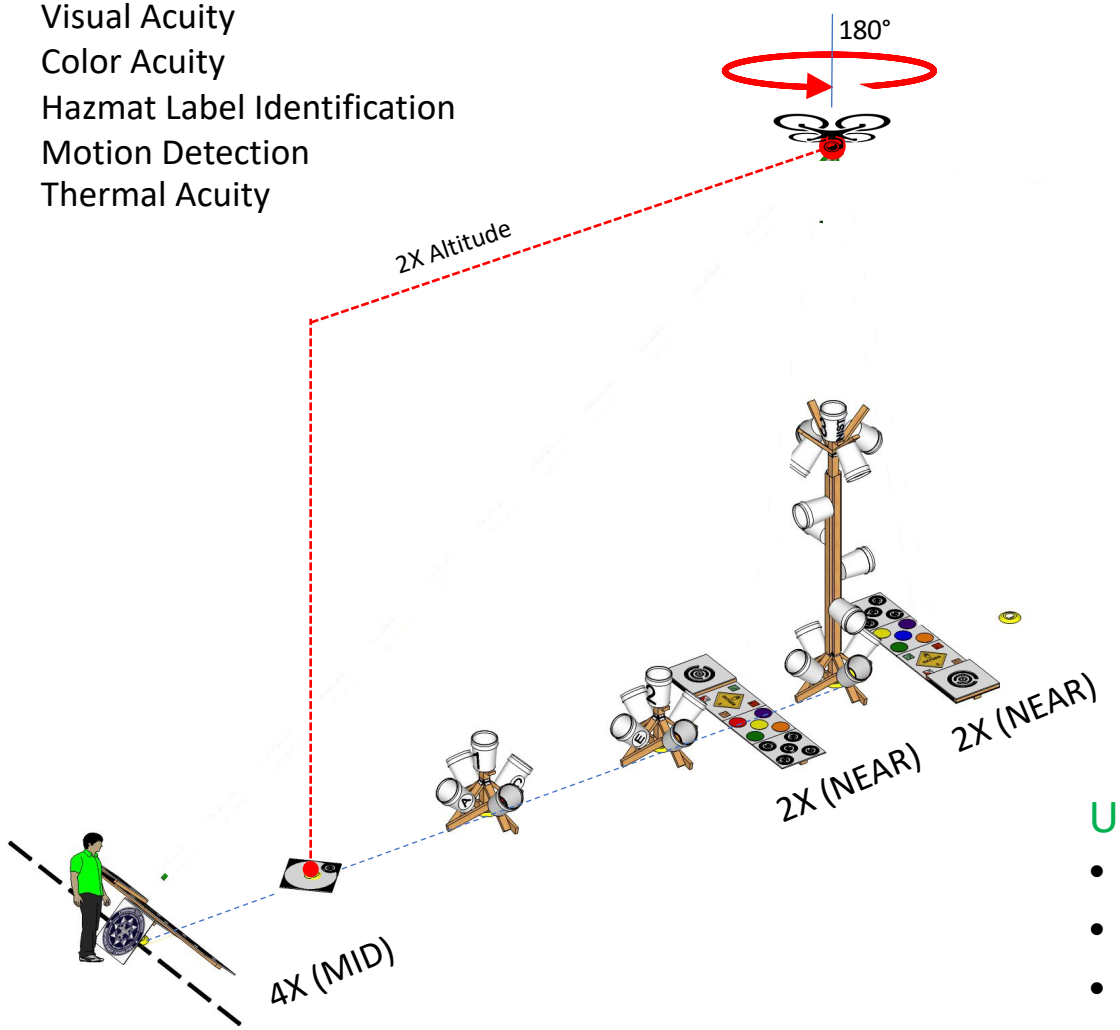

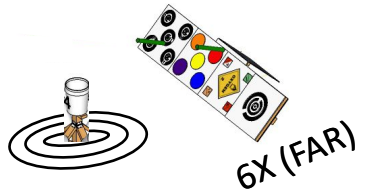

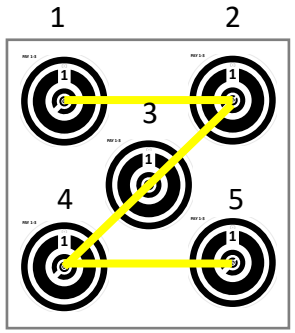

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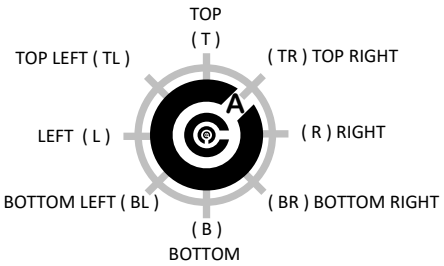

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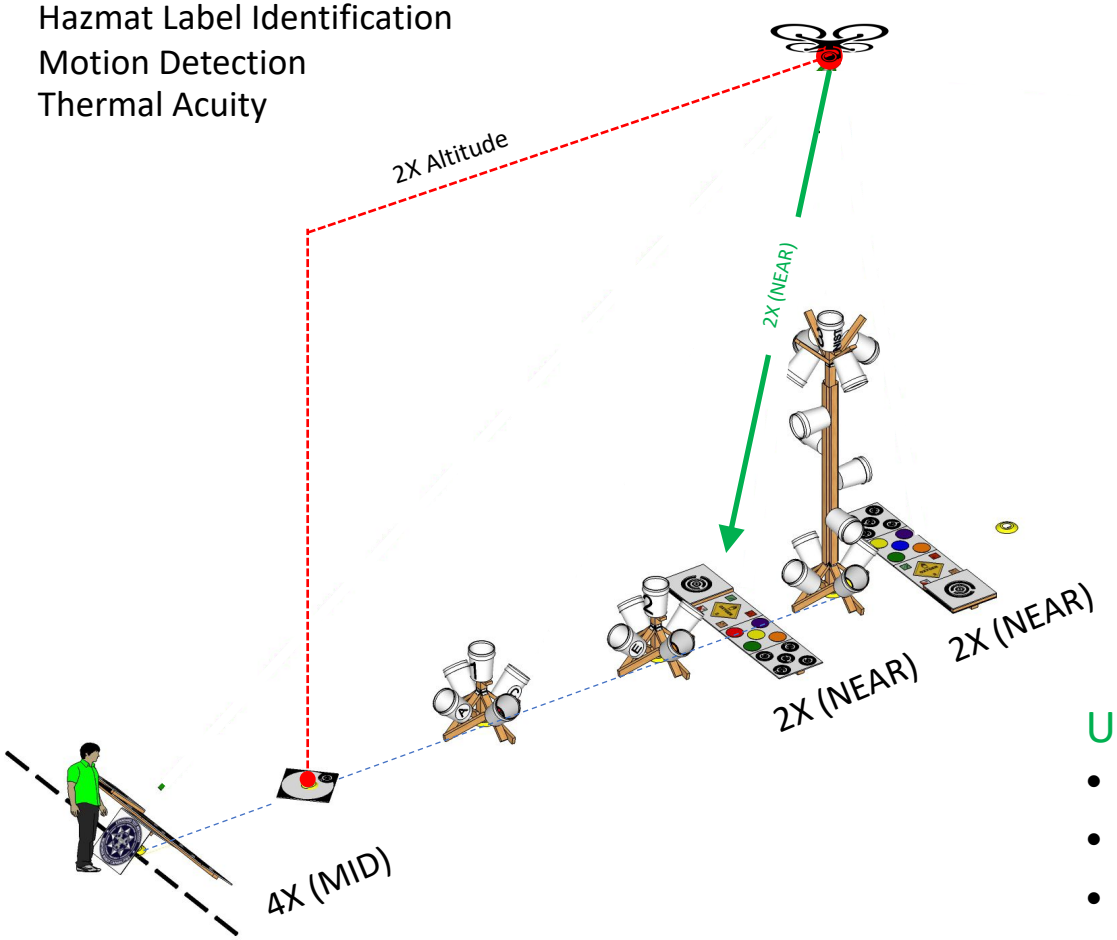

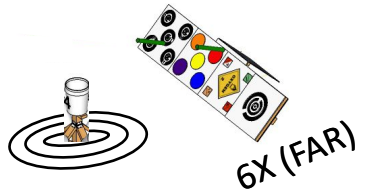

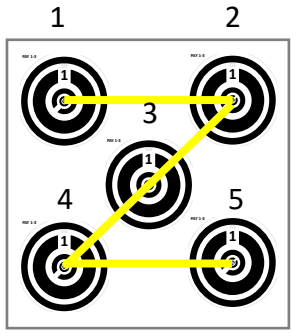

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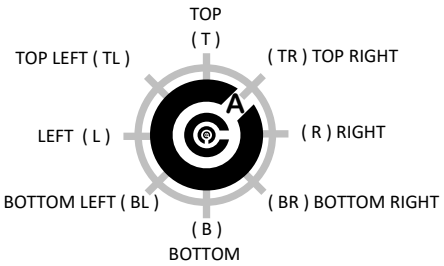

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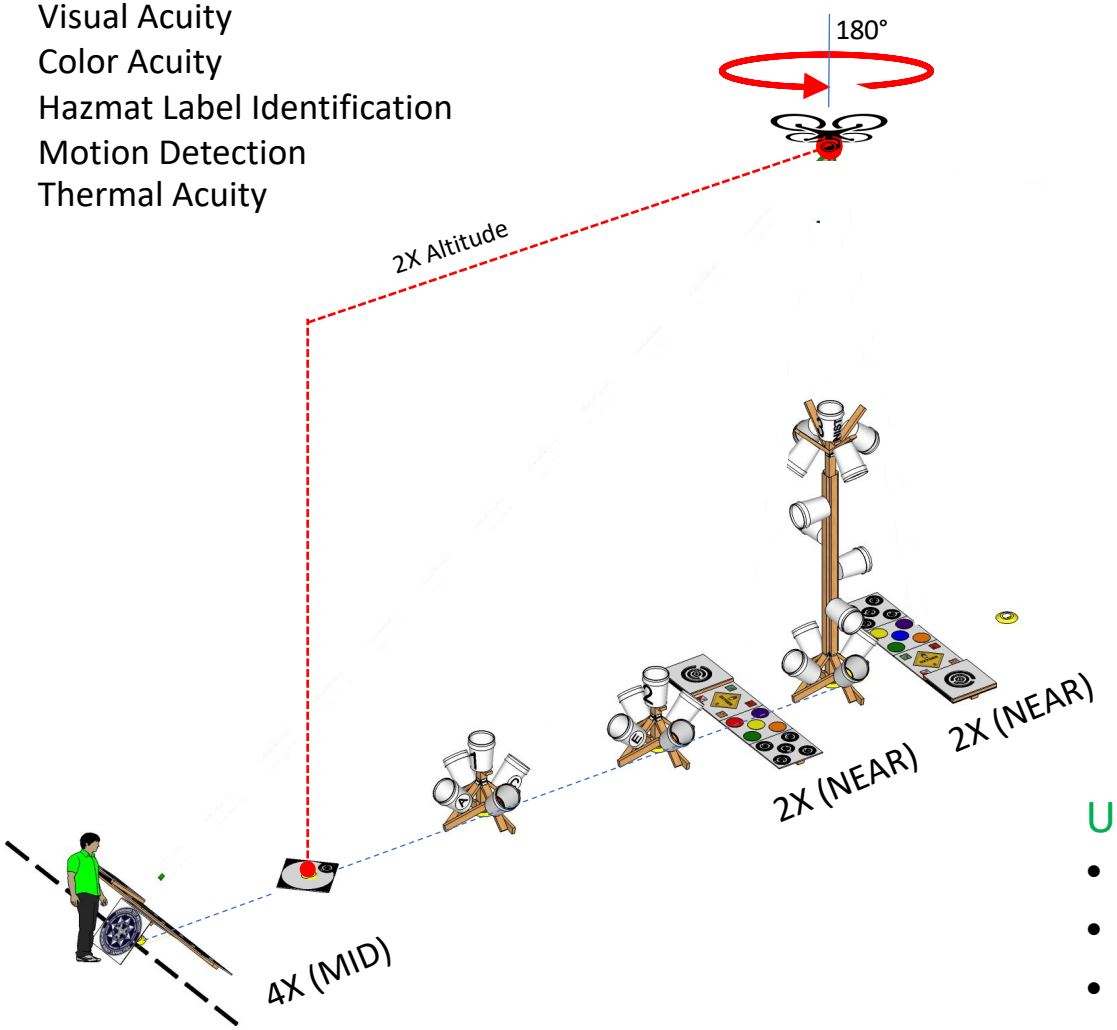

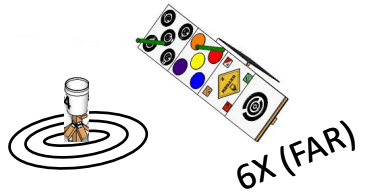

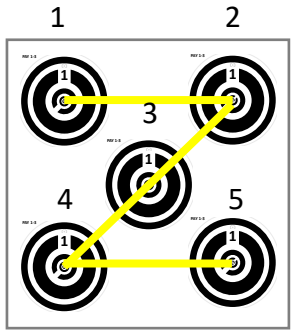

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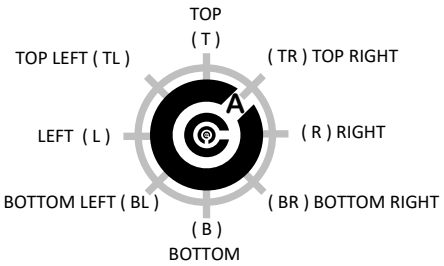

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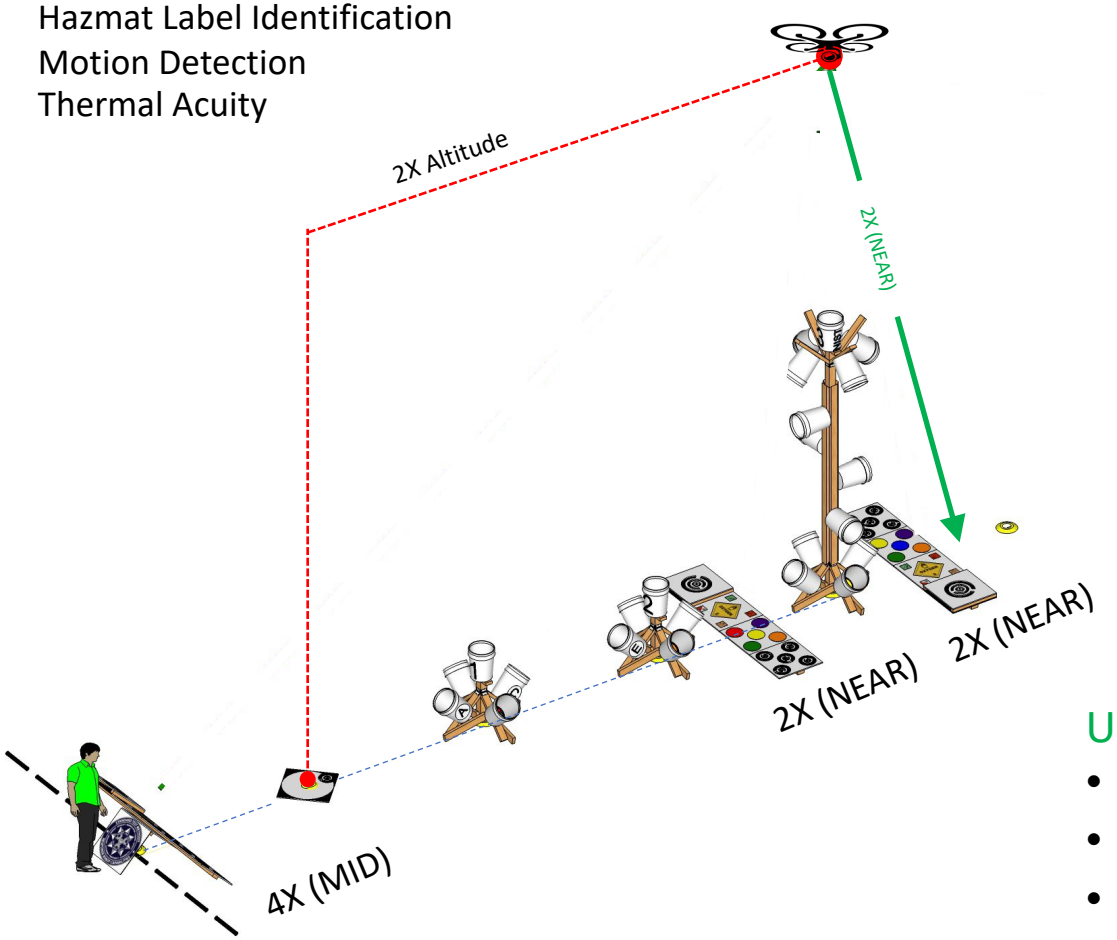

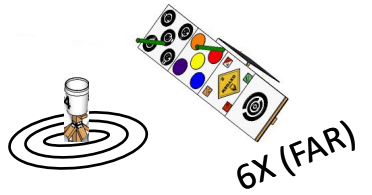

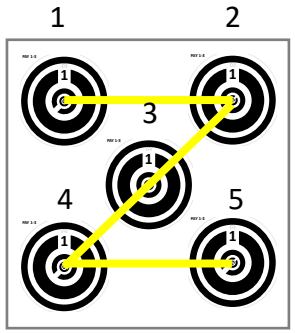

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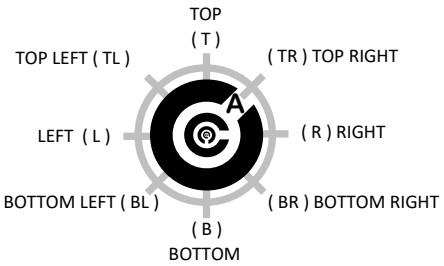

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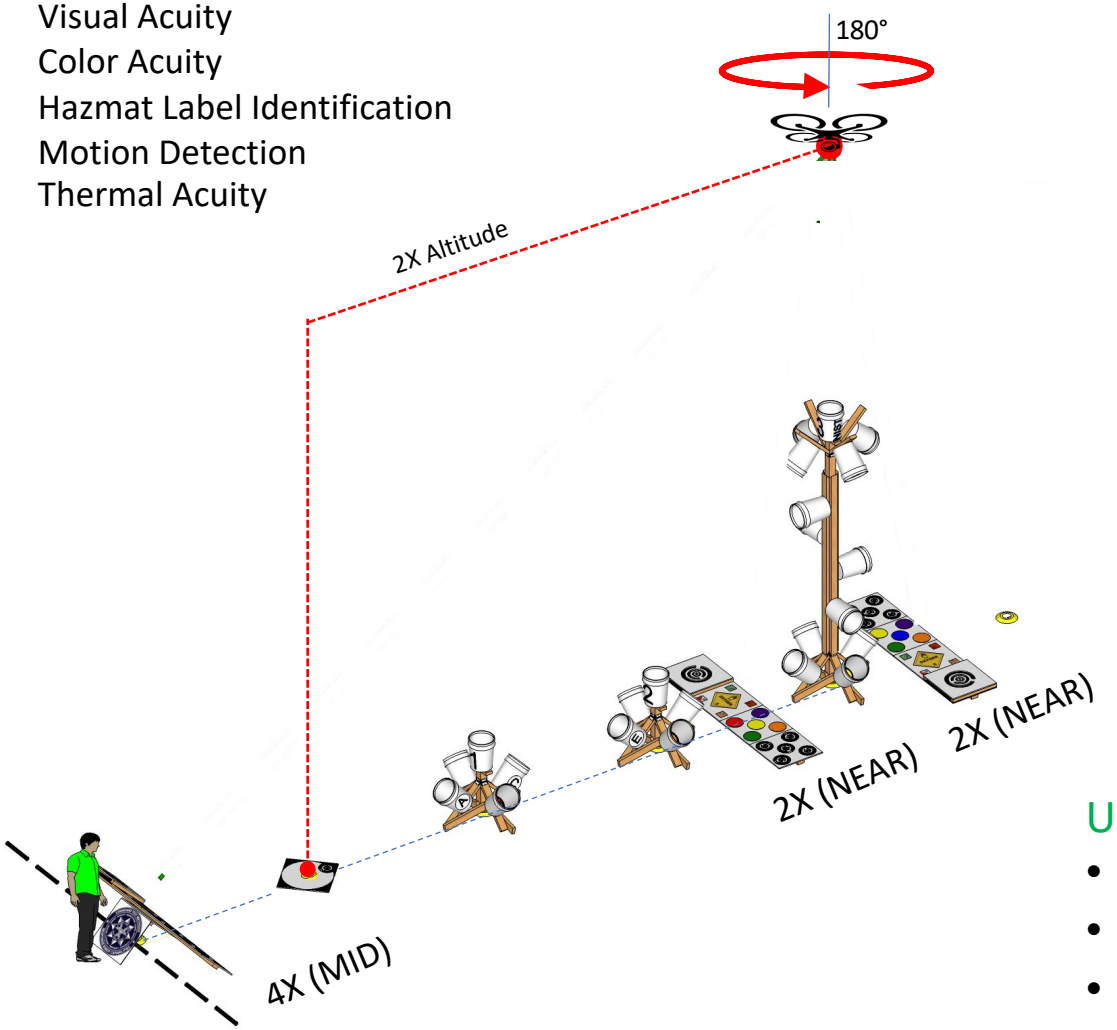

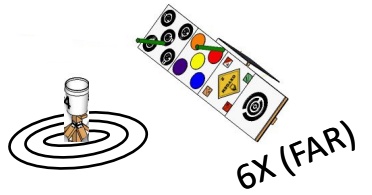

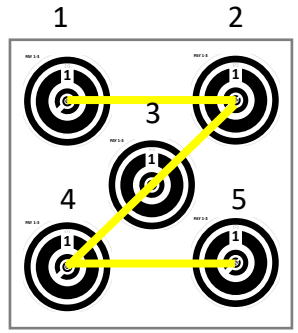

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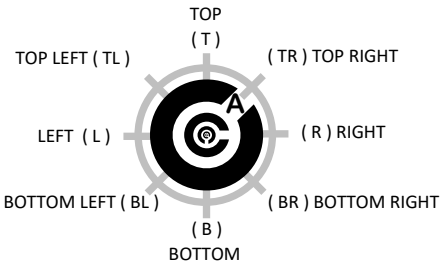

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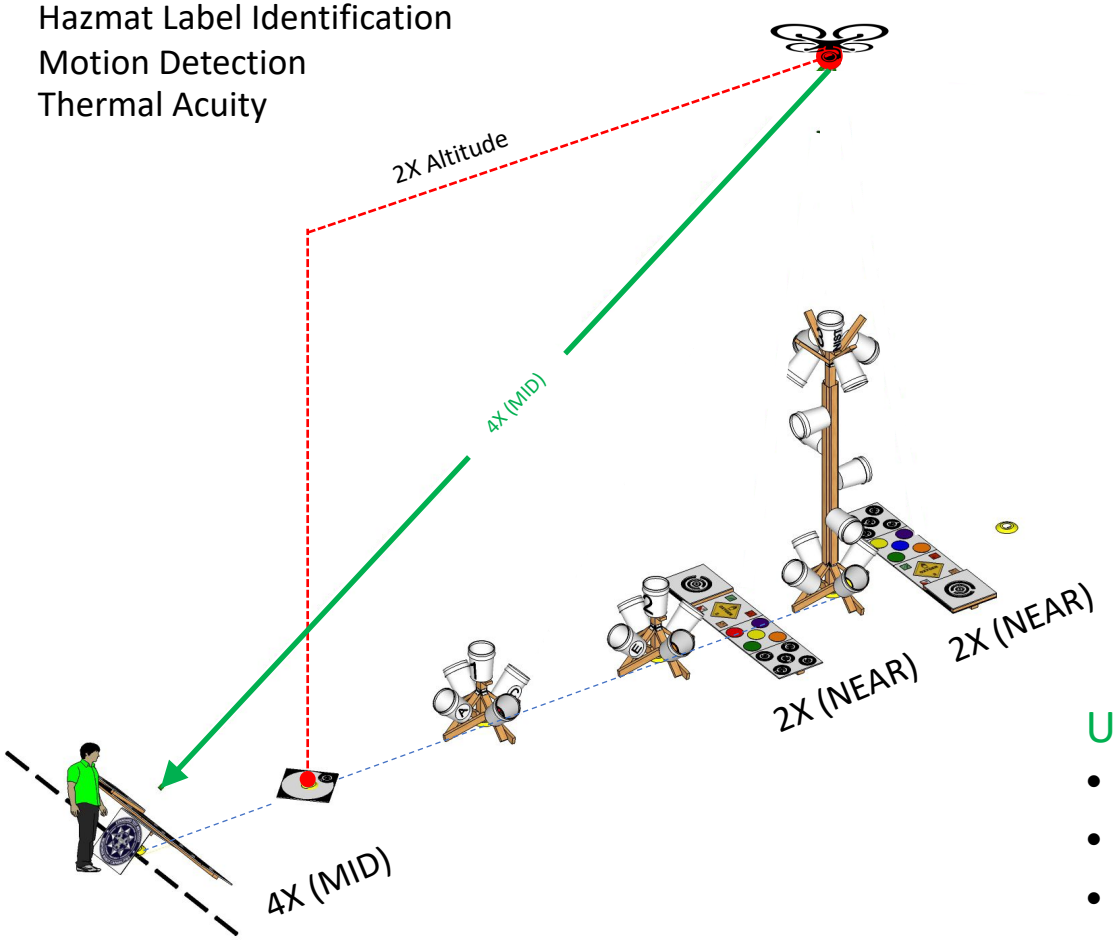

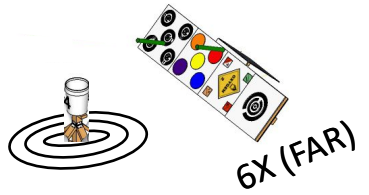

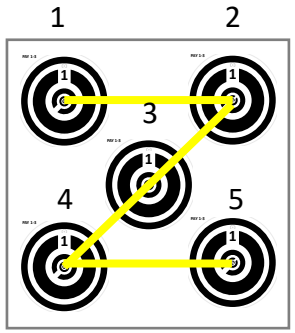

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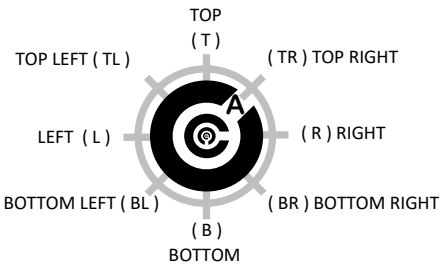

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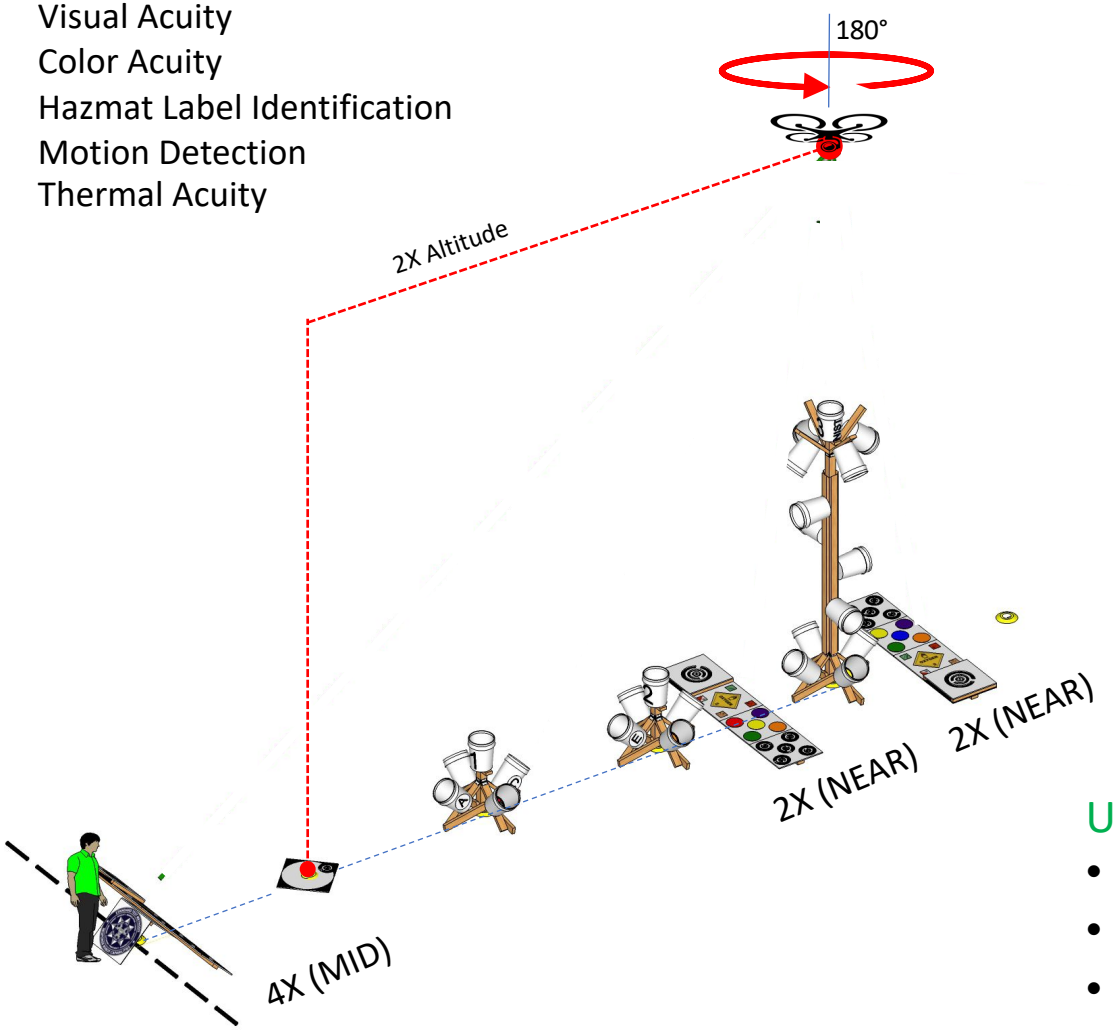
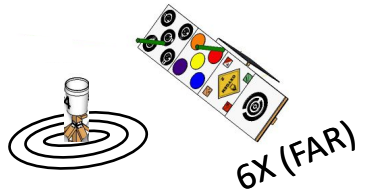
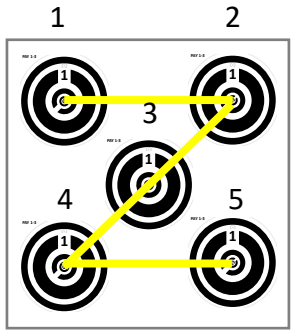
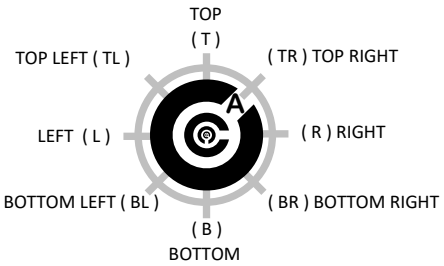






READ IN "Z" ORDER



USE THIS TEST TO DETERMINE THE LANE SPACING FOR AIRCRAFT

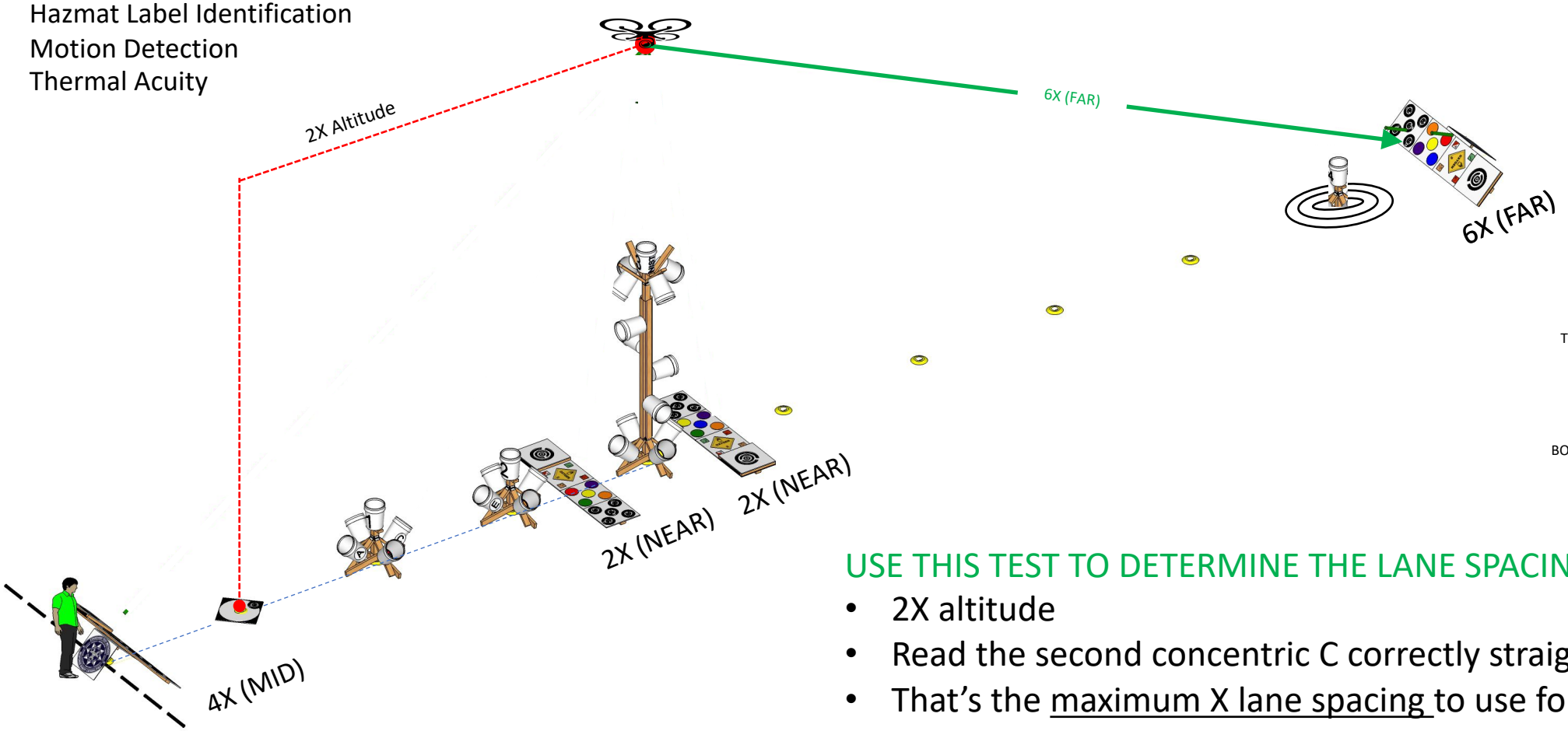
- 2X altitude
- Read the second concentric C correctly straight down
- That's the maximum X lane spacing to use for that aircraft

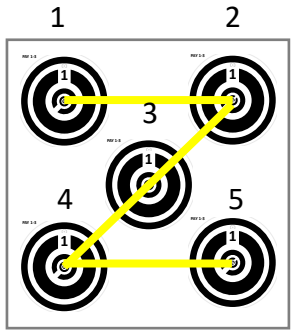
*If your training aircraft has only a fixed camera, or limited range of motion, position the aircraft and identify as many targets as possible. Performance is never compared across aircraft anyway.

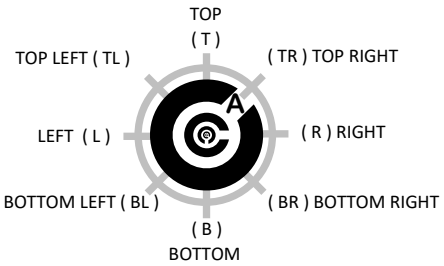
Practice-Evaluate-Compare Onboard Sensing Capabilities

Point and Zoom Cameras (SEN 1-5)

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







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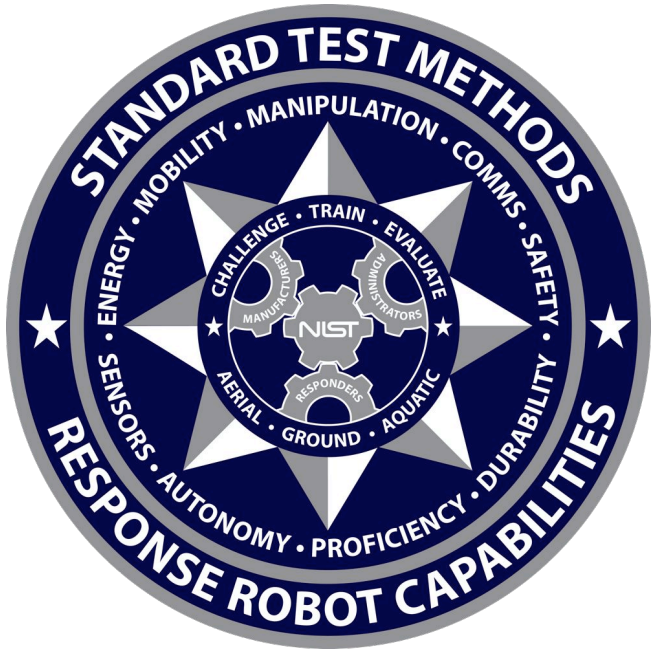

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