

ASTM E54.09 Homeland Security Applications; Response Robots Ground Tests: Dexterity and Strength

Version 2022A



**STARTS AT 10:00 AM EST
WASHINGTON, DC TIME**

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Internet
RobotTestMethods.nist.gov

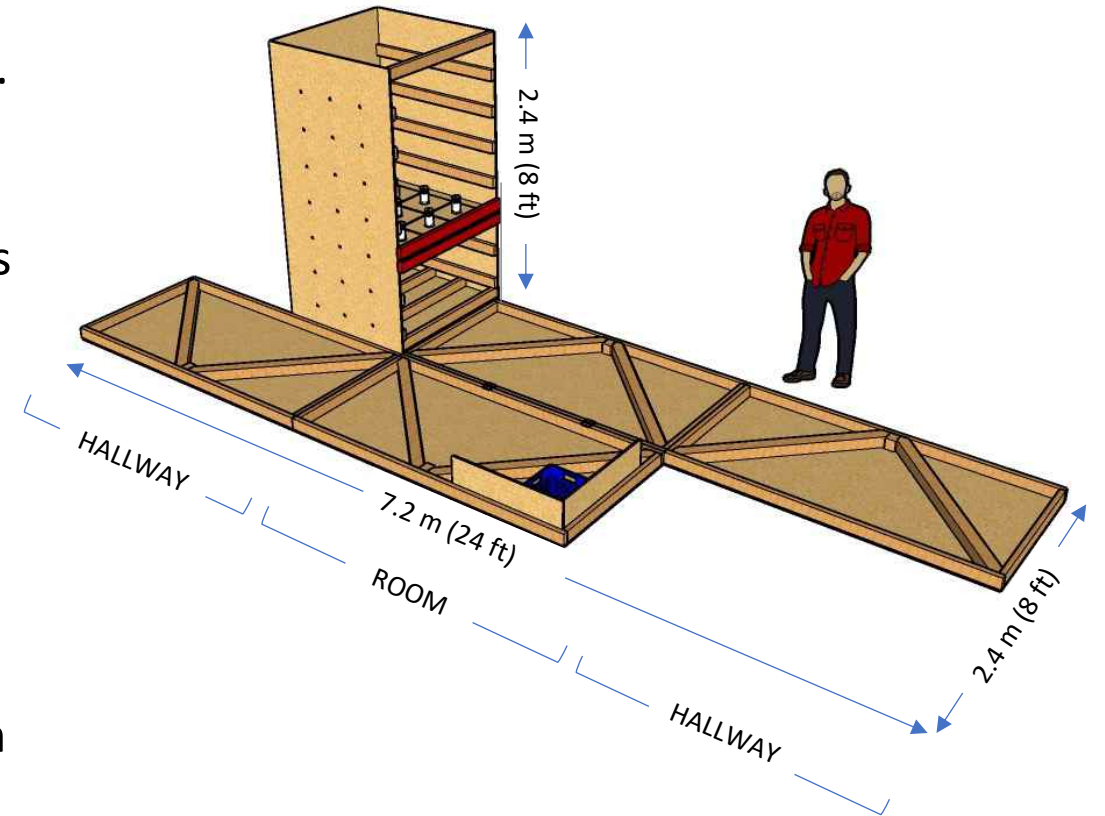


Email
RobotTestMethods@nist.gov

Measure Robot Capabilities and/or Operator Proficiency

Dexterity and Strength Classification Tests

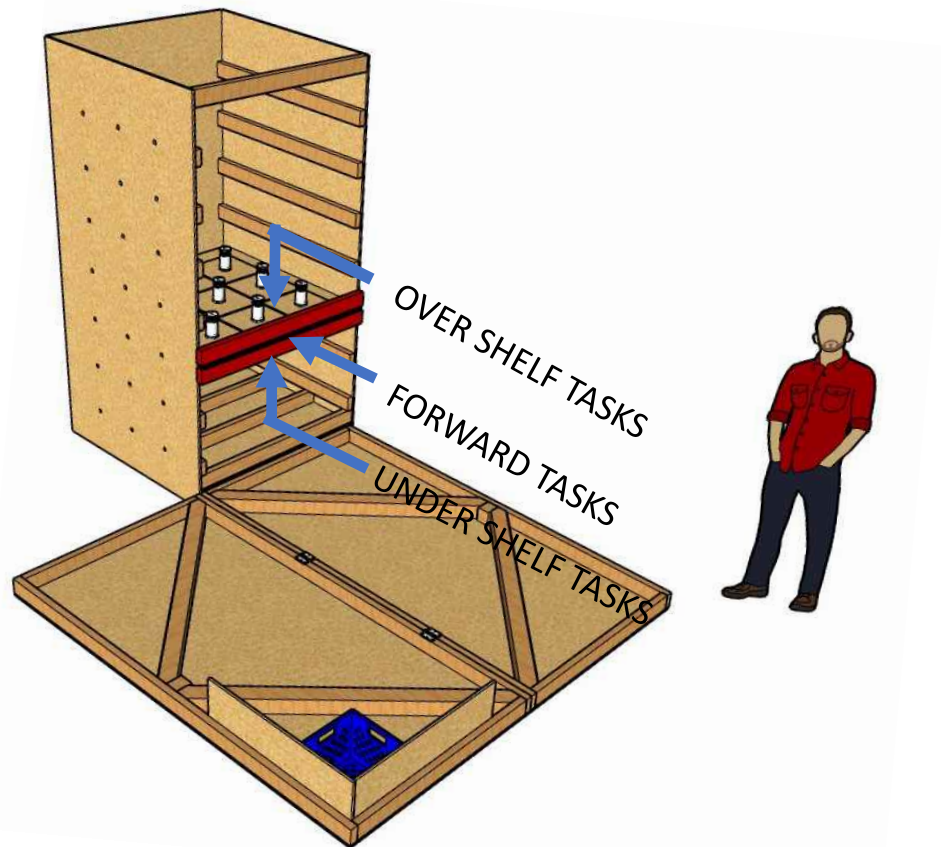
- Validate a comprehensive and easy to replicate set of classification tests for manipulator dexterity and strength.
- Encourage coordinated joint control with inverse kinematics using Linear and Omni tasks at various reaches along with weighted Stow-Carry-Place tasks.
- Include the diagonal rail terrain to add limited ground complexity with easy fabrication (they drop in):
 - Compensate for unknown chassis orientation with dexterous manipulation and auto-leveling features.
 - Encourage stability at maximum reach with uncertain ground contacts that affect the center of gravity.
 - Maintain situational awareness of the surrounding ground terrain during all dexterity tasks.



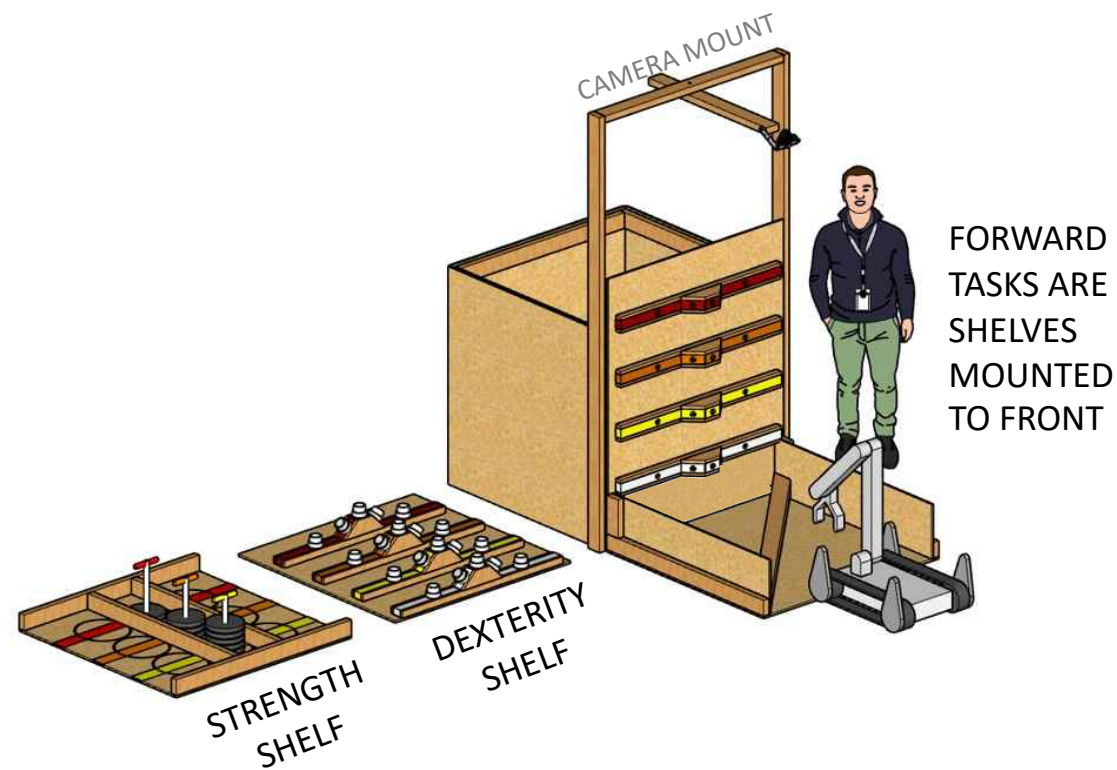
Responders with larger robots use this zig-zag lane with K-rail terrain and tall task shelves abutting the center square "room." Surrounding walls are typically added to contain the robot.

Incremental Task Elevations and Orientations

Dexterity and Strength Classification Tests



A full-size shelf apparatus and square center "room" terrain can contain all the dexterity and strength tasks.



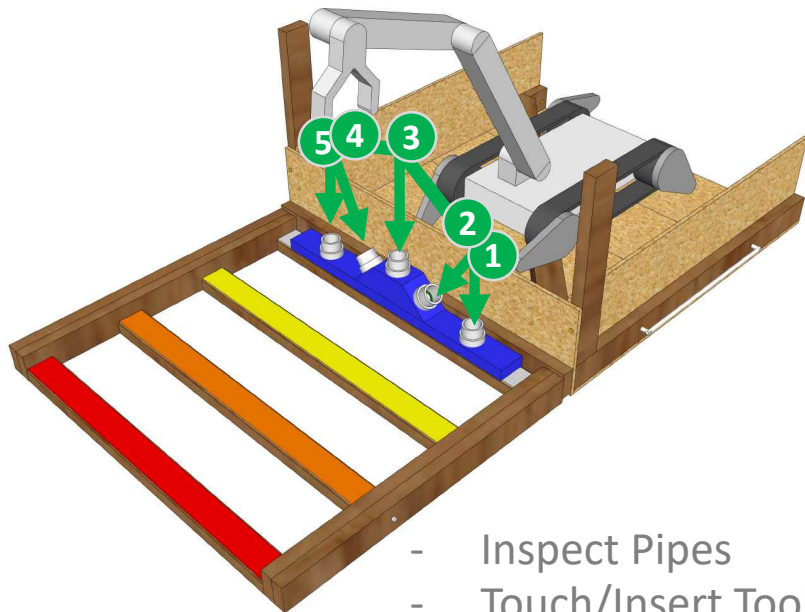
Smaller robots need only one corner of the "room" terrain and shorter elevations.

Complementary Tasks in Similar Trials

Dexterity and Strength Classification Tests

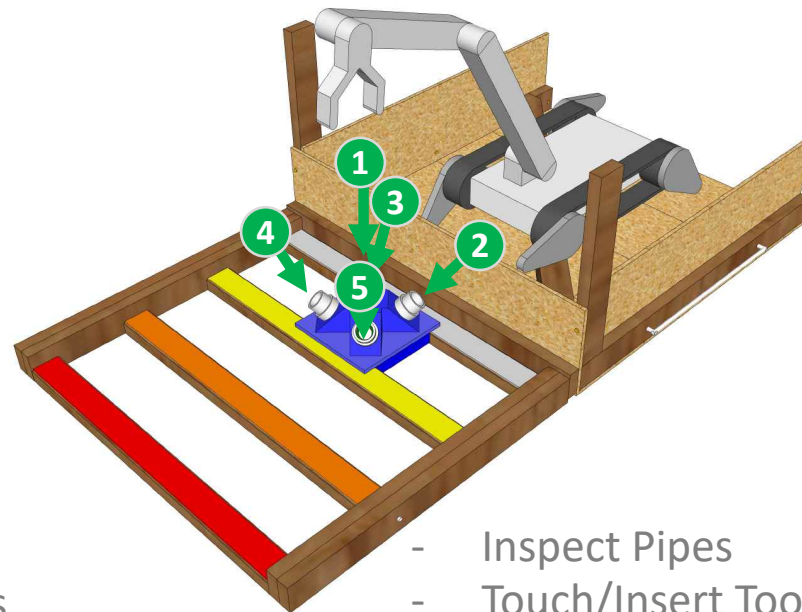
Individual trials are 5 tasks at each horizontal and vertical reach

LINEAR TASKS



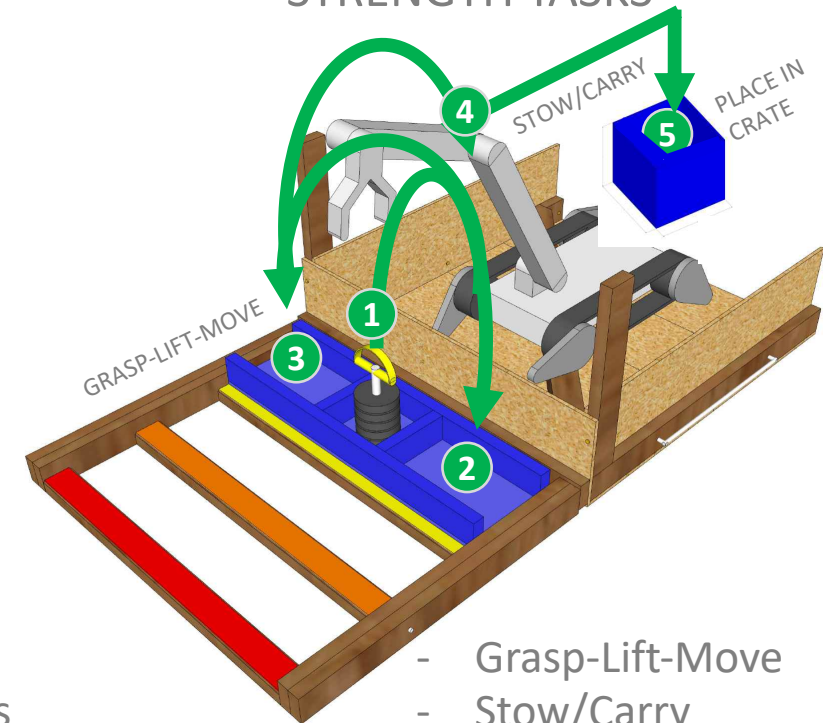
- Inspect Pipes
- Touch/Insert Tools
- Extract & Place Objects

OMNI TASKS



- Inspect Pipes
- Touch/Insert Tools
- Extract & Place Objects

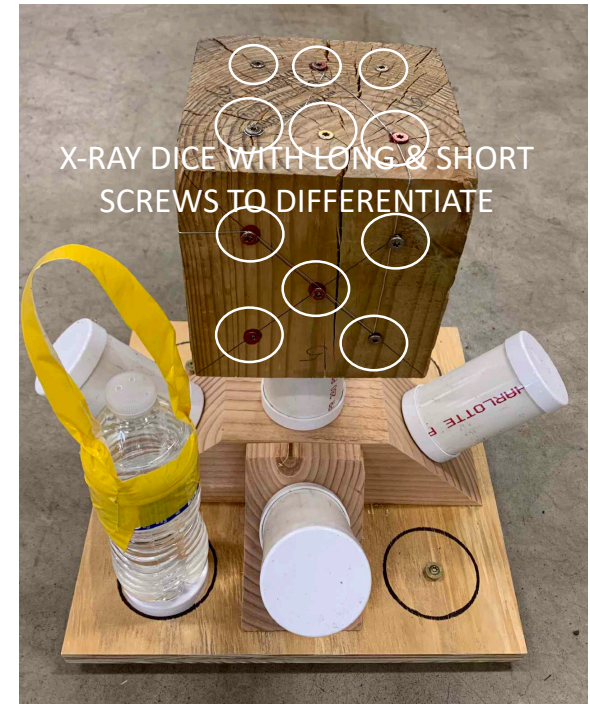
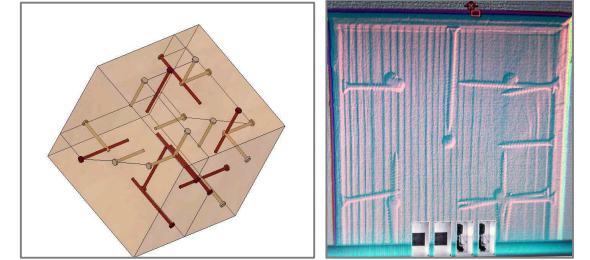
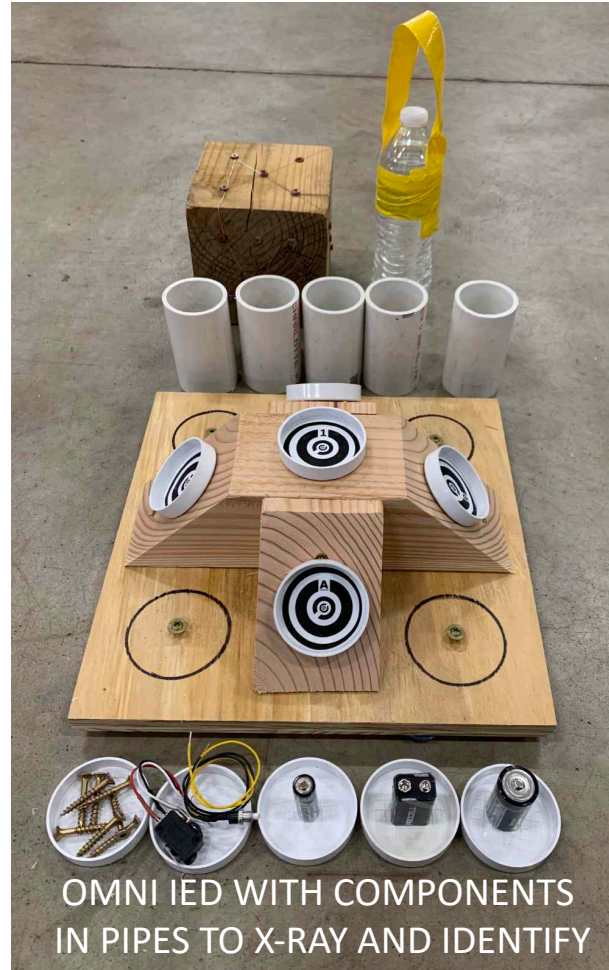
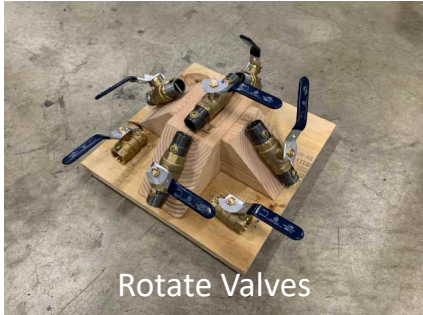
STRENGTH TASKS



- Grasp-Lift-Move
- Stow/Carry
- Place in Crate

More Operational Tasks

Dexterity & Strength Classification Tests



Task Shelves with Diagonal Terrain

Dexterity & Strength Classification Tests

CABINET & HINGED K-RAIL TERRAIN



FOLD UP TO MOVE AND STOW



SLIDE-IN TASK SHELF



OPTIONAL CASTERS TO MOVE



Task Shelves with Diagonal Terrain

Dexterity & Strength Classification Tests

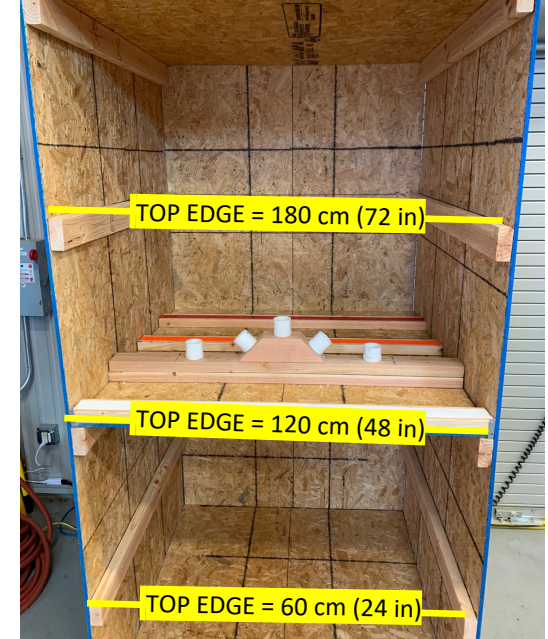
CABINET BASE UNDERSIDE



OPTIONAL CASTERS



SHELF SUPPORT ELEVATIONS



Linear Task Apparatus

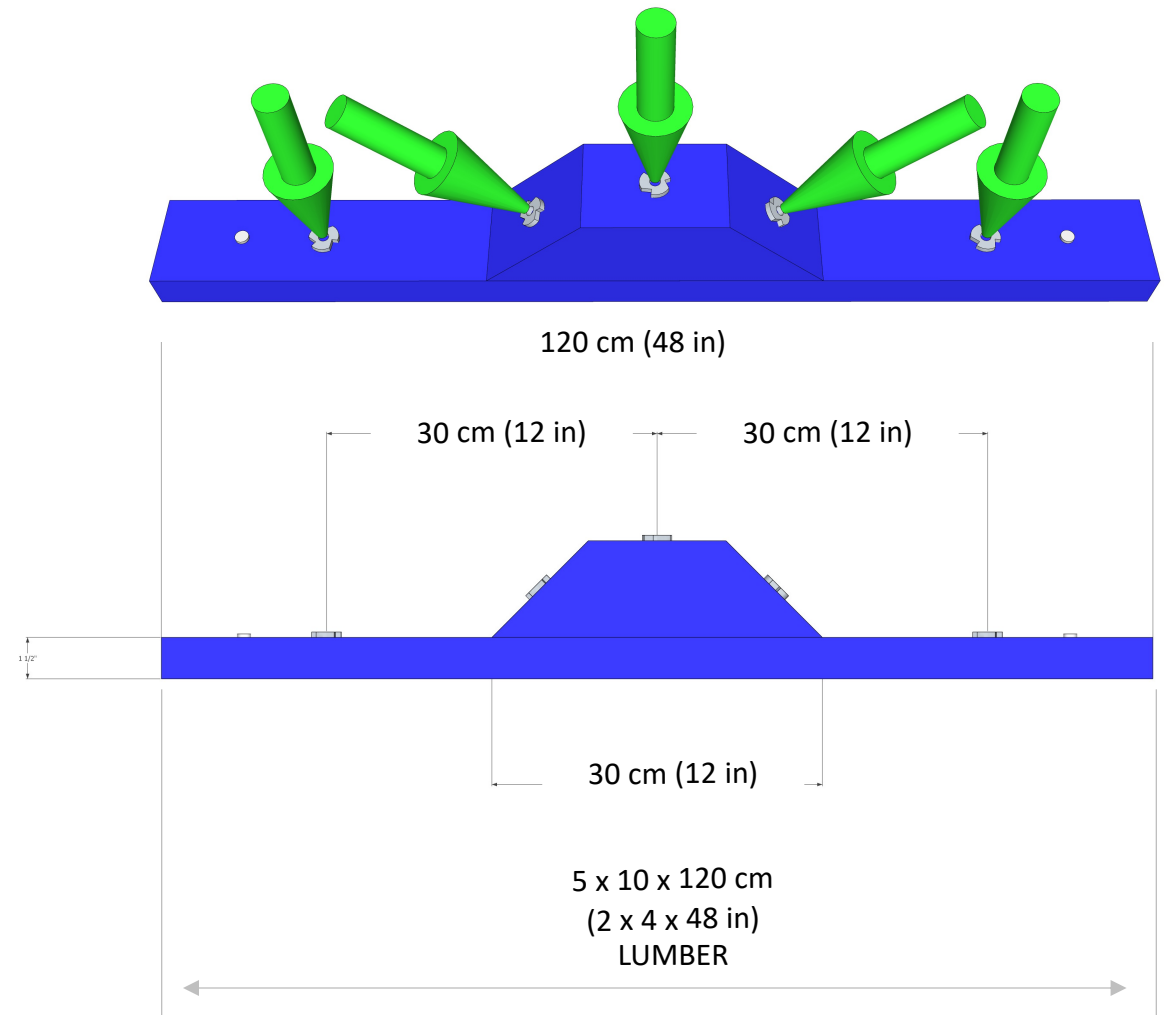
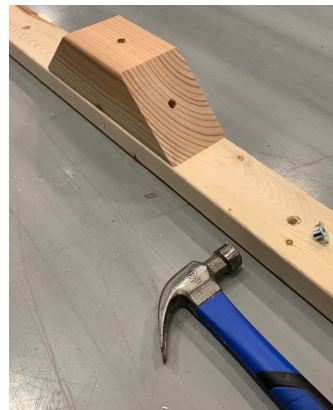
Dexterity and Strength Classification Tests

- The linear apparatus has 5 different positions and orientations along a line. There are 3 perpendicular positions at different elevations and 2 angled orientations.
- It measures the basic reach and dexterity of the robot at 30 cm (1 ft) incremental reach distances and elevations.
- The apparatus should have 8 mm (5/16 in) holes at the dimensions shown.
- Inserting similar sized T-Nuts protect the holes from damage from tools and provide a consistent clearance between the tool and the hole diameter.



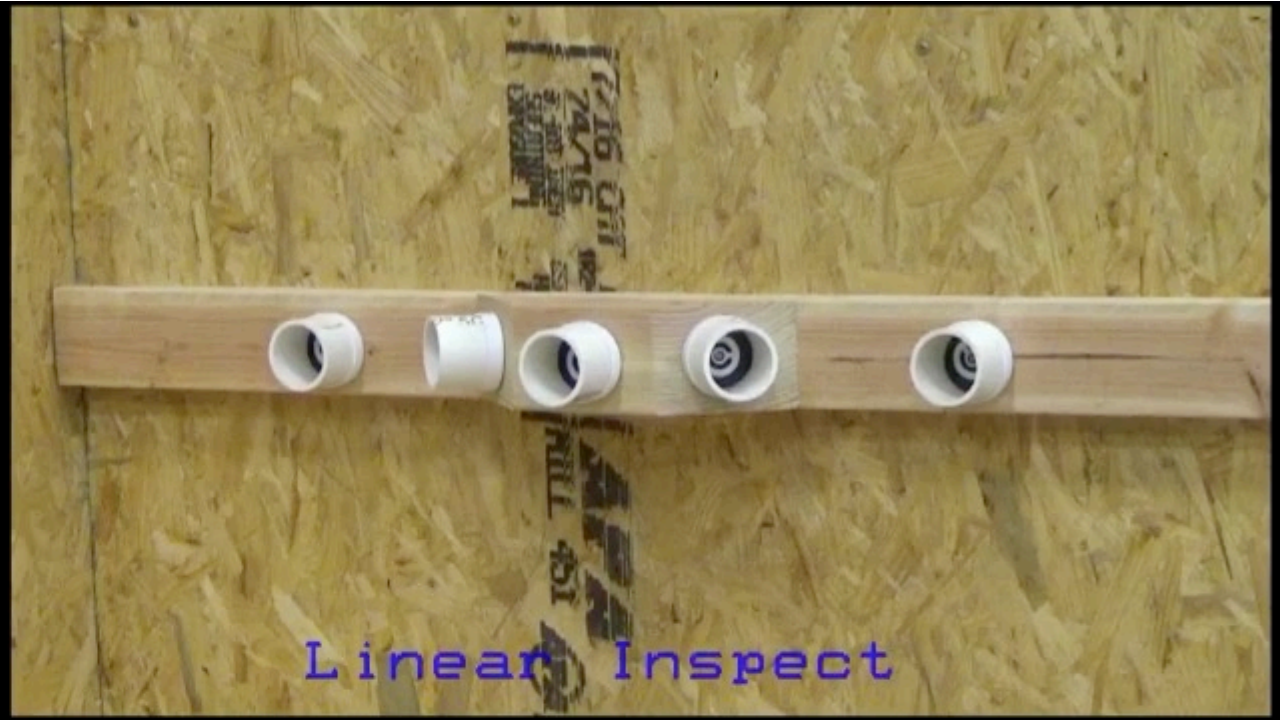
T-Nuts 8 mm (5/16 in) threaded

<https://www.amazon.com/gp/product/B06XCK35C1/>

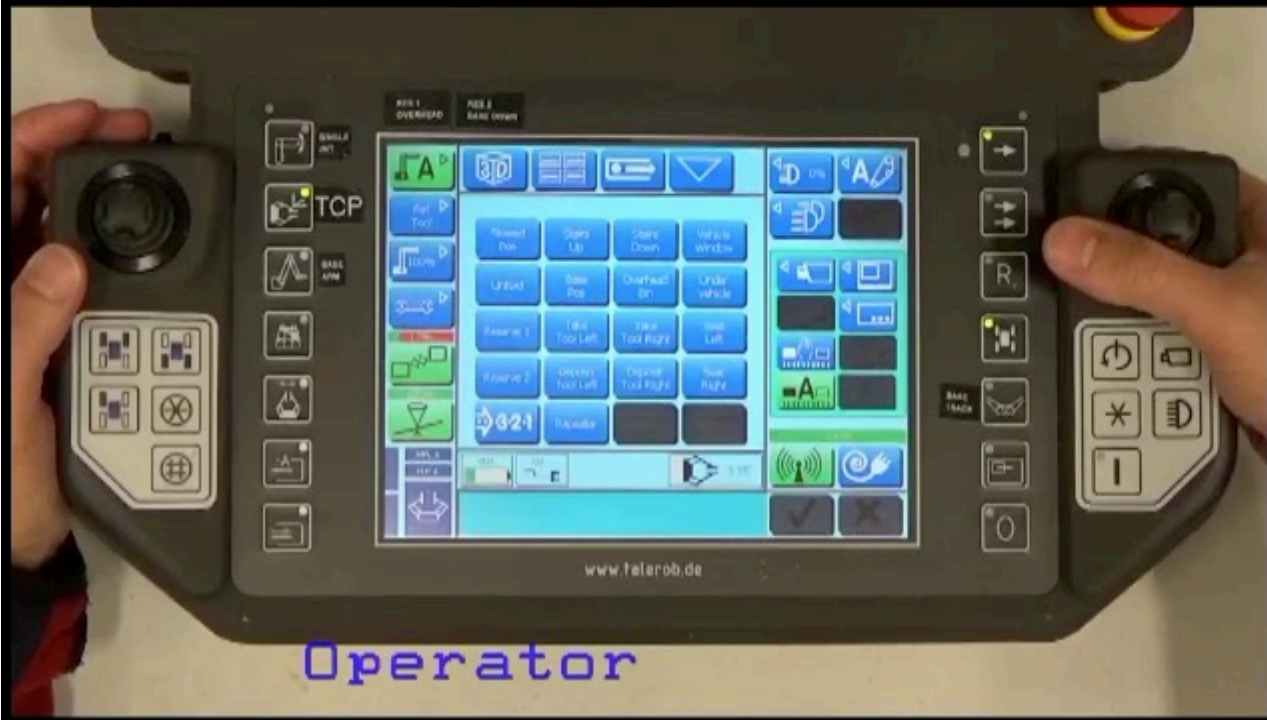




TeleMax Pro



Linear Inspect



Operator



Lane Overview

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TeleMax Pro



Linear Inspect

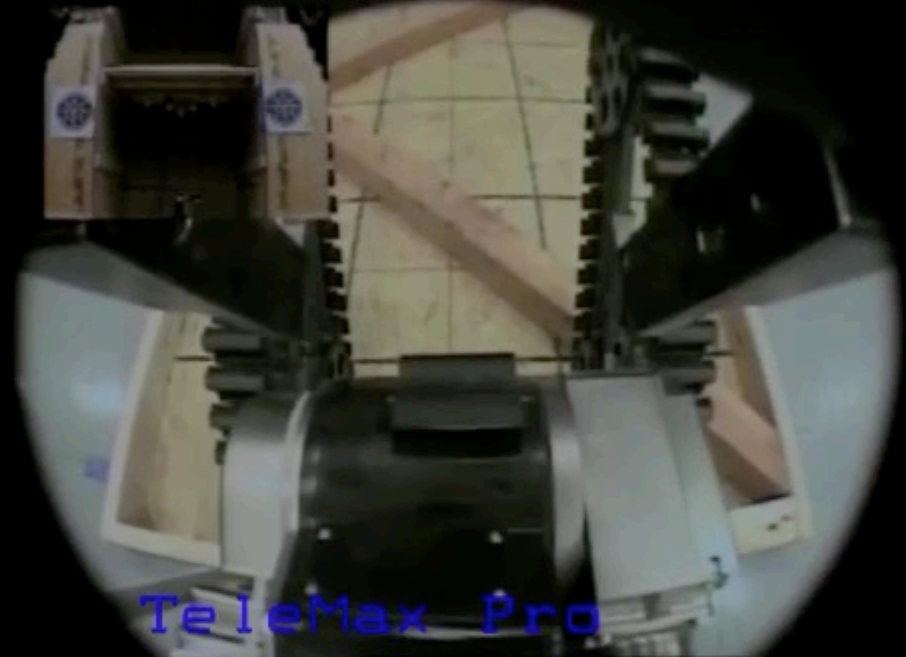


Operator

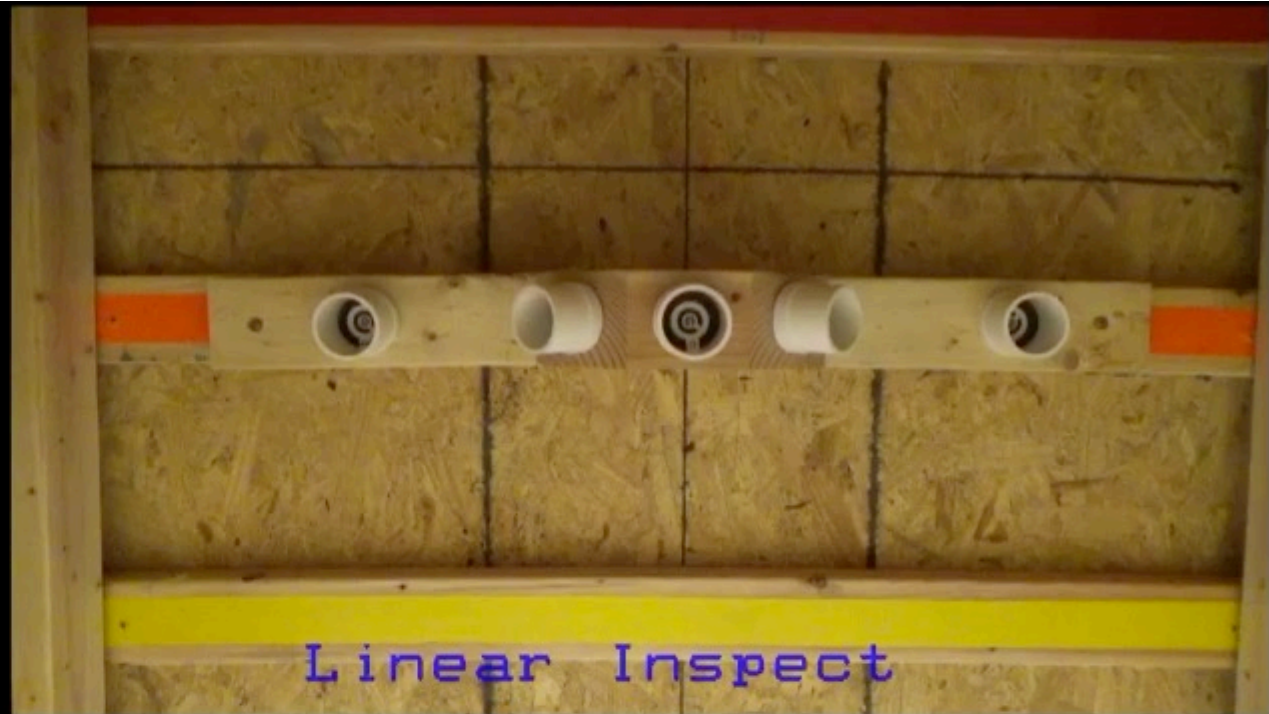


Lane Overview

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TeleMax Pro



Linear Inspect



Operator



Lane Overview

Omni Task Apparatus

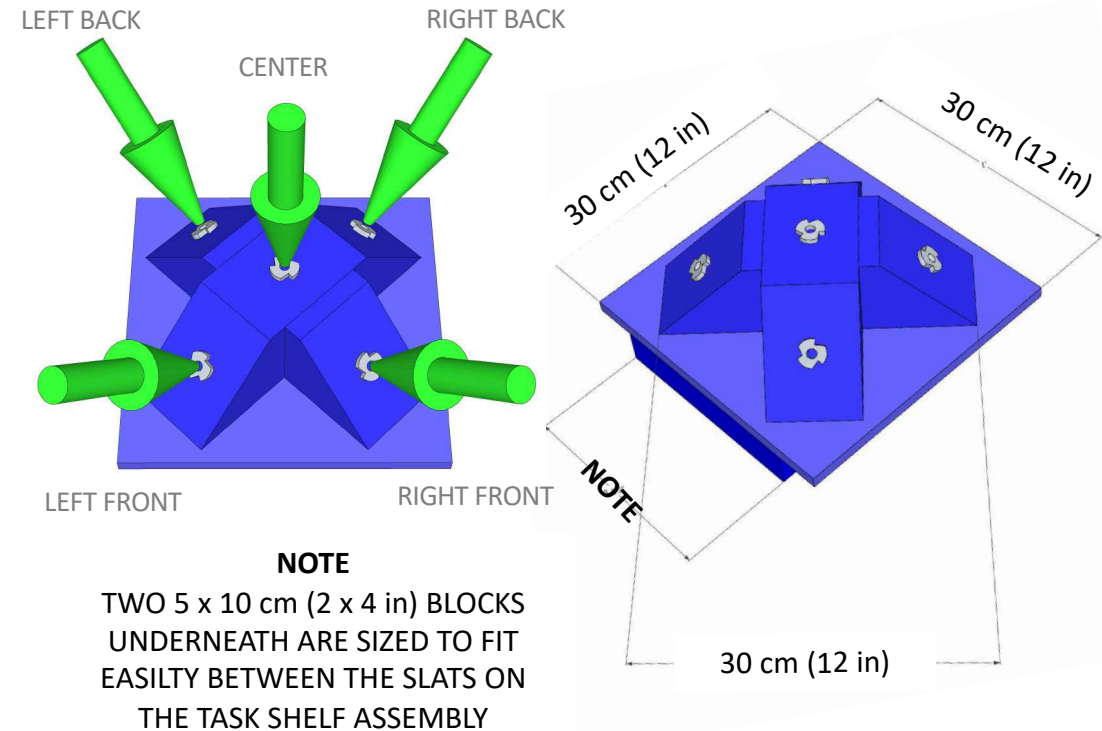
Dexterity and Strength Classification Tests

- The omni apparatus has 5 different positions and orientations around a point. There is 1 center position that is similar to the center of the linear apparatus. There are 4 more angled orientations.
- It measures the advanced reach and dexterity of the robot at 30 cm (1 ft) incremental reach distances and elevations.
- The apparatus should have 8 mm (5/16 in) holes centered on each face.
- Similar sized T-Nuts protect the holes from damage from tool placements and provide a consistent clearance between the tool and the hole diameter.



T-Nuts 8 mm (5/16 in) threaded

<https://www.amazon.com/gp/product/B06XCK35C1/>





TeleMax Pro



Omni Inspect



Operator

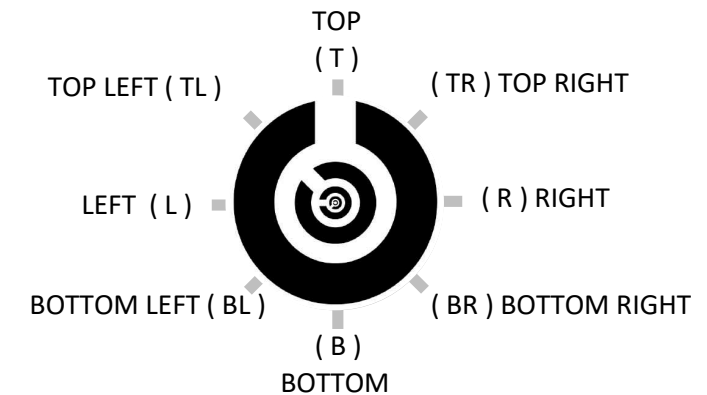


Lane Overview

Non-Contact Linear and Omni Inspection Tasks

Dexterity and Strength Classification Tests

- The “Directed Inspection” tasks measure the reach space of the robot without the difficulties associated with interacting with the environment. They are performed in both the Linear and Omni orientations at 30 cm (1 ft) incremental reach distances and elevations.
- Each alignment position and orientation is close to the approach point necessary for related tasks requiring contact such as Touch/Insert Tools, Rotate, and Extract.
- Align with the 5 cm (2 in) diameter pipe so the inner edge of the largest visual acuity ring is completely visible. The targets can be downloaded and printed on paper or sticker sheets.
- Each pipe has 5 increasingly small ring gaps to identify based on their orientations (random combinations of 8 orientations).
- Score up to 5 points per task = 25 points total:
 - 1 point for successful alignment with the outer ring showing the gap oriented to the Top (always).
 - 1 point for each smaller gap orientation identified correctly.



50 mm (2 in) inside diameter PVC Pipe
<https://www.amazon.com/PVC-Pipe-Sch-Inch-White/dp/B072Q9M54Z/>

Acuity Targets to Cut and Insert

Dexterity & Strength Classification Tests

LINEAR TASKS

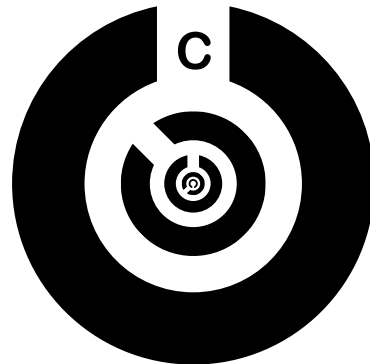
LEFT PERPENDICULAR



LEFT ANGLED



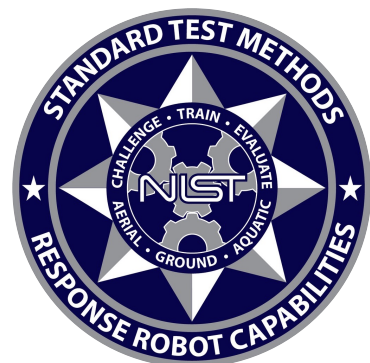
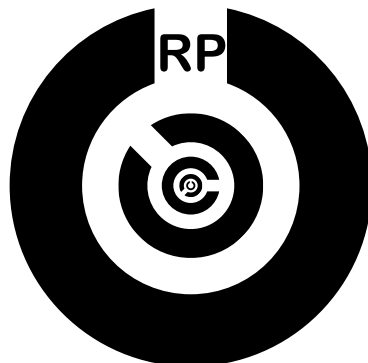
CENTER



RIGHT ANGLED

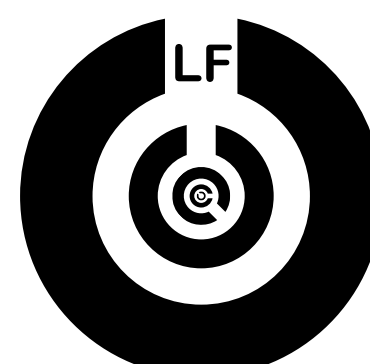


RIGHT PERPENDICULAR

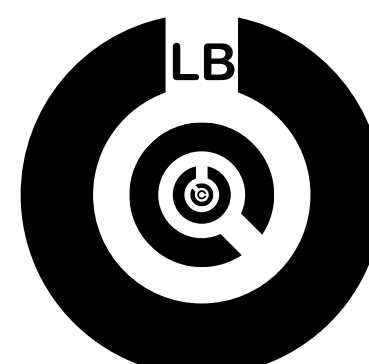


OMNI TASKS

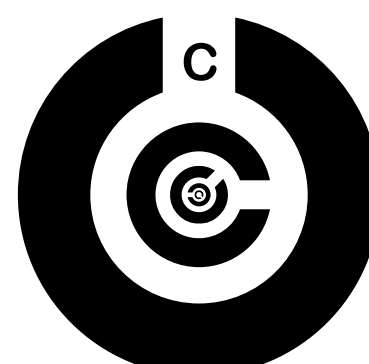
LEFT FRONT



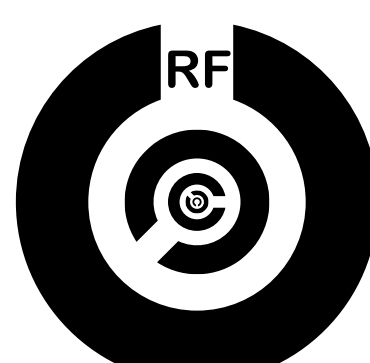
LEFT BACK



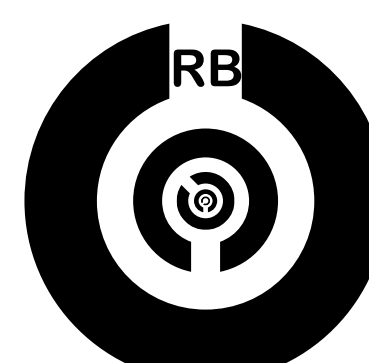
CENTER



RIGHT FRONT



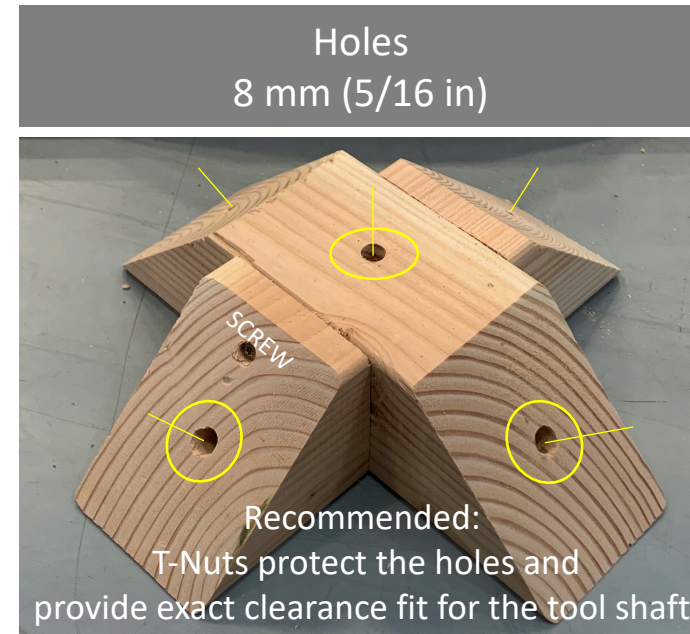
RIGHT BACK



“Touch or Insert Tool” Tasks

Dexterity and Strength Classification Tests

- The “Touch/Insert Tool” tasks measure the reach space of the robot for using tools of various kinds. They are performed in both Linear and Omni orientations at 30 cm (1 ft) incremental reach distances and elevations.
- The task requires the robot to position and orient the tool tip perpendicular to the hole in the apparatus, then insert the tool into the hole. A Torx T-25 tool, a window-breaker tool, or any shaft with 4-5 mm diameter can be easily inserted into the 8 mm (5/16 in) hole diameter.
- Successful insertion requires the tool tip to recess at least 25 mm (1 in). Partial points are awarded for simply touching the tool tip to the hole at some angle that doesn’t allow insertion.
- Score up to 5 points per task = 25 points total:
 - 1 point for touching the tool tip to the hole at any angle.
 - 4 points for inserting the tool 25 mm (1 in) into the hole.



T-Nuts 8 mm (5/16 in) threaded

<https://www.amazon.com/gp/product/B06XCK35C1/>



<https://www.amazon.com/Channellock-T253a-Professional-Torx-Screwdriver/dp/B00XNBRYUC/>

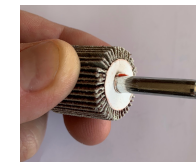
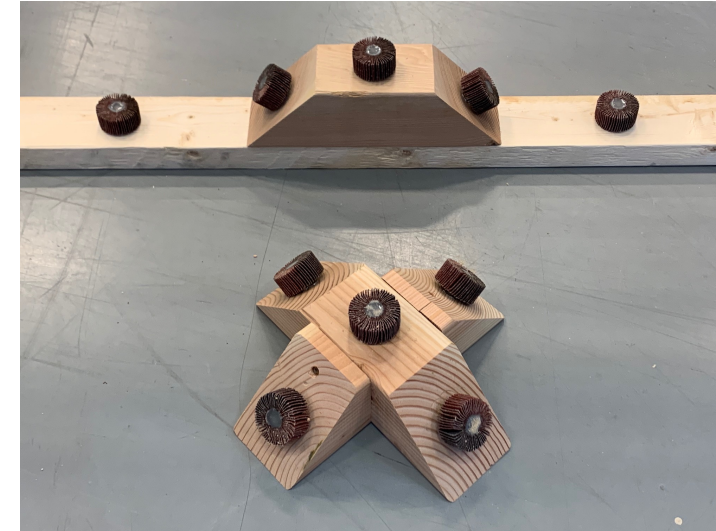


https://www.amazon.com/dp/B08GKSF247/?coliid=I2PMBEMSOTZA5X&colid=3RUGTGF8AJBSU&psc=1&ref=lv_ov_lig_dp_it_im

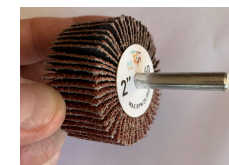
“Extract and Place Object” Tasks

Dexterity and Strength Classification Tests

- The “Extract and Place” tasks measure the reach space of the robot for precisely grasping objects. They are performed in both Linear and Omni orientations at 30 cm (1 ft) incremental reach distances and elevations.
- The task requires the robot to position and orient the gripper to grasp and extract the objects pre-placed in the apparatus. Any grasp object with a 6 mm (1/4 in) diameter shaft can be used to fit into the 8 mm (5/16 in) hole or T-Nut diameter.
- Successful extraction requires the the object to be completely removed from the hole. Successful placement of the object requires it to be in the crate. Dropped objects cannot re-grasped and placed in the crate.
- At the start of the trial the crate must be pre-positioned behind the start area at least 120 cm (4 ft) from the terrain. It can be moved by the robot anywhere at any time during the trial.
- Score up to 5 points = 25 points total:
 - 1 point for extracting the object from the apparatus.
 - 4 points for placing the object in the crate.



Small Round Abrasive Flap Wheel Sanders
Grasp Object: 25 mm (1 in) diam high friction cylinder
Shaft: 6 mm (1/4 in) diameter, at least 25 mm (1 in) long
<https://www.amazon.com/dp/B07ZRG9Y13/>



Large Round Abrasive Flap Wheel Sanders
Grasp Object: 50 mm (2 in) diam high friction cylinder Shaft: 6 mm (1/4 in) diameter, at least 25 mm (1 in) long
<https://www.amazon.com/gp/product/B0821B4R2N/>



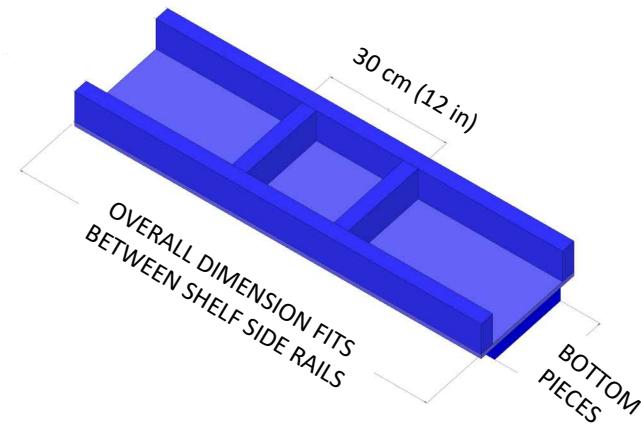
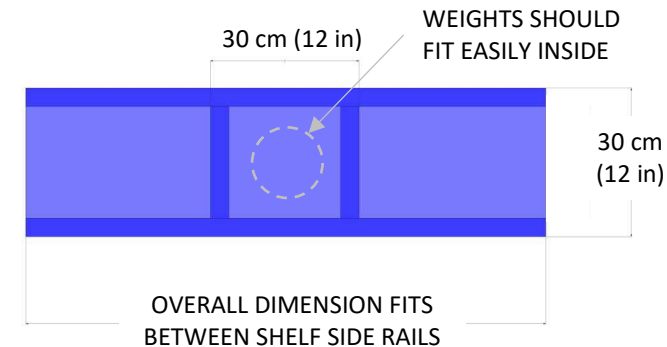
Glue your own grasp object onto a disc pad holder
ANY SOLID/CONVEX SHAPE (not magnetic, sticky, etc.)
Shaft: 6 mm (1/4 in) diameter, at least 25 mm (1 in) long
https://www.amazon.com/dp/B07D33NG4M/?coliid=I32UQ5G00LD8Q6&colid=3RUGTGF8AJBSU&psc=1&ref_=lv_ov_lig_dp_it

Strength Apparatus

Dexterity and Strength Classification Tests

- The strength task apparatus has 3 positions along a line in which to place the weights with lumber borders to lift over. The weights are placed manually in the center location at the start of the trial.
- Any weights with handles can be used, including typical exercise plates of 1 or 2 kg (2.5 or 5 lbs) that fit easily into the center with at least 5 cm (2 in) space all around.
- Choose the maximum weight for each reach distance and elevation that enables **COMPLETING ALL 5 TASKS**.
- The Pipe T shown holds incrementally increasing stacks of weighted plates. It can be made from typical 19 mm (3/4 in) plumbing pipes with outer diameters of less than 25 mm (1 in) fit into the center holes of the weighted plates. The pieces shown all threaded so screw together by hand.
- An optional rope can be looped through the top pipe and knotted to make a more universal grasp handle.

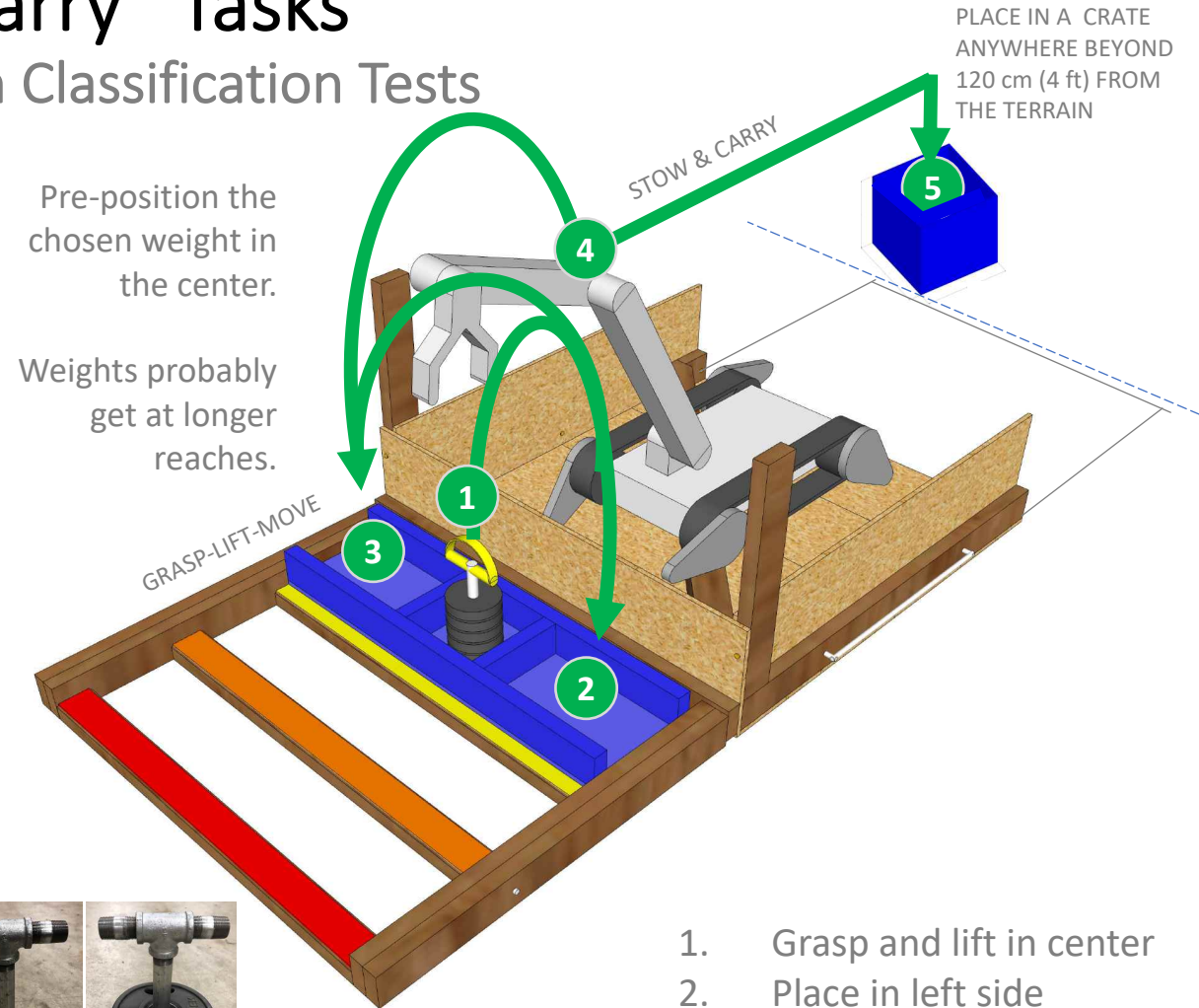
WEIGHTED TASK TRAY



“Lift-Stow-Carry” Tasks

Dexterity and Strength Classification Tests

- This “Lift-Stow-Carry” tasks measure the maximum weight the robot can hold with its gripper within the terrain. The tasks are performed at incremental reach distances and elevations.
- Choose a weight for the intended reach distance and elevation that allows for COMPLETION OF ALL FIVE TASKS. Note the stow and carry tasks may be equally challenging because the terrain can change robot orientations quickly.
- Each chosen weight must be measured with a spring scale and captured at the start of the trial video.
- Pre-position the weight in the center tray. It should fit easily inside the containment. Farther reaches can use less weight.
- Pre-position the crate behind the start area at least 120 cm (4 ft) from the terrain.
- Score the maximum weight (kg/lb) to complete all 5 tasks.

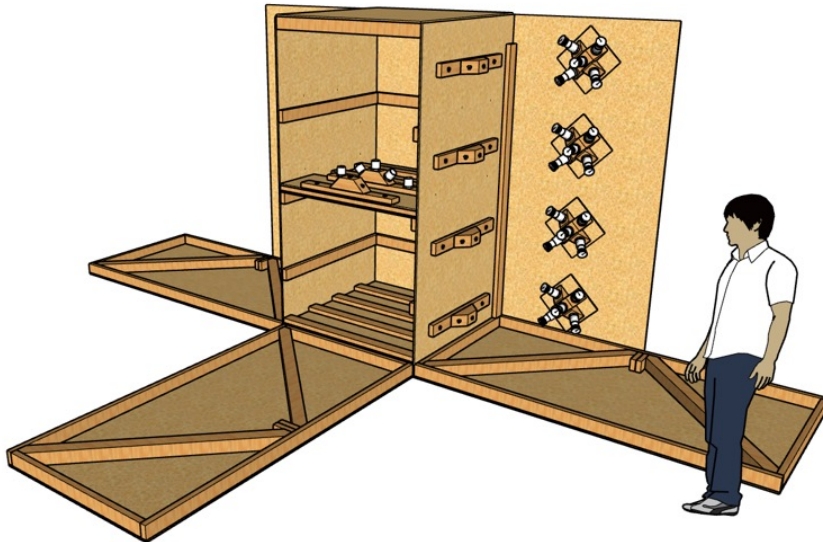


- Pipe T with optional rope handle
- Weight-lifting plates with 25mm (1 in) center holes – Use any weights that fit easily into center containment such as 1 or 2 kg (2.5 or 5 lb) plates.

1. Grasp and lift in center
2. Place in left side
3. Place in right side
4. Stow and carry out
5. Place in the crate

Sample Trial Form

Dexterity & Strength Classification Tests



Touch and Insert Tool: LINEAR TASKS

DEXTERITY TASKS

120 cm (48 in)

Torx T25 Shaft
4.5 mm (0.17 in)

Robot Make: _____
Robot Model: _____
Robot Config: _____
Operator Code: _____ VO Code: _____
Facility: _____
YYYY-MM-DD: _____
Start Time (2400): _____ End: _____

APPARATUS SCALE
120 CM (4 FT)
240 CM (8 FT)
(CIRCLE ONE)

SCORING MARKS
POINTS
COMPLETE PARTIAL MISSED
LP LA C RA RP = 16 POINTS
5 5 5 1 0

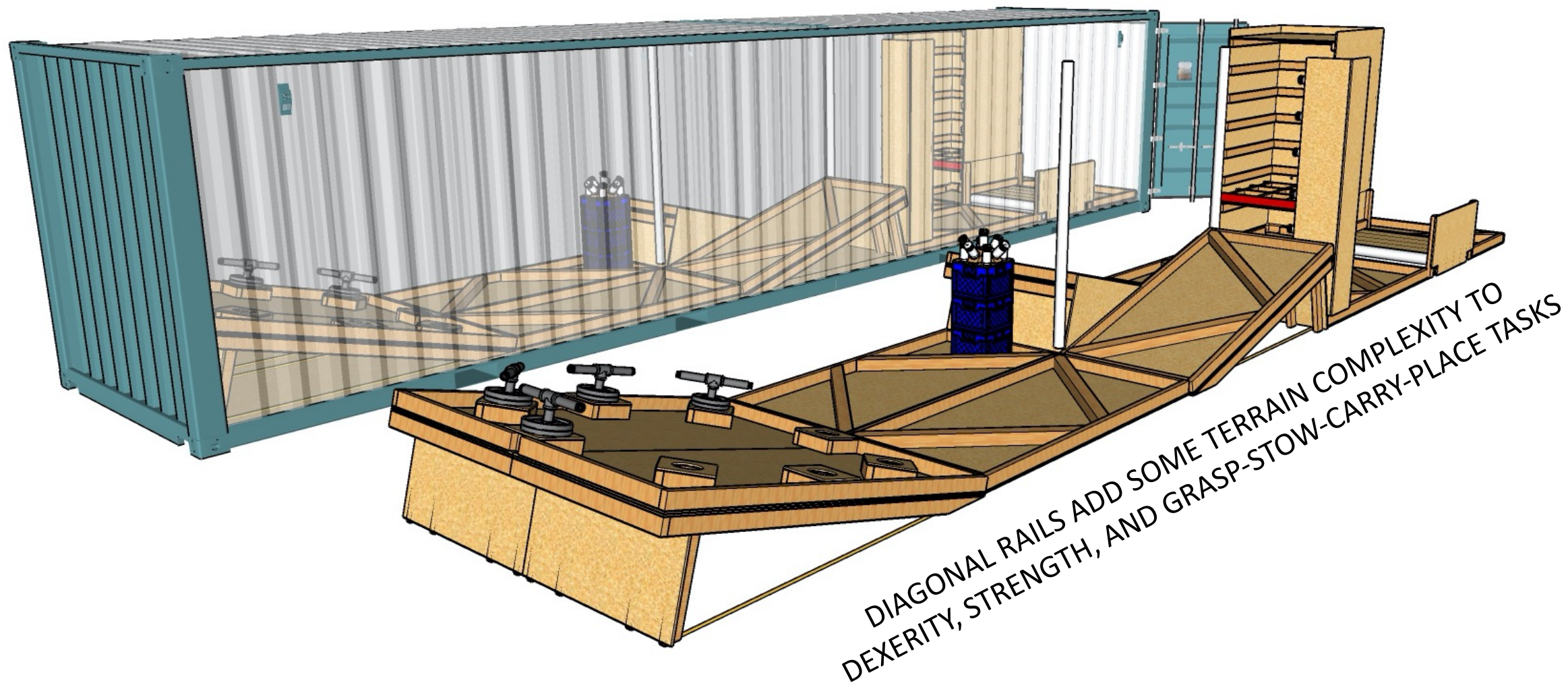
LIGHTING
LIGHTED 300+ LUX
DARK < 1 LUX
(CIRCLE ONE)

TIME LIMITS
5 MIN 10 MIN
(CIRCLE ONE OR FILL IN)

HEIGHT	FORWARD WALL TASKS					OVER SHELF TASKS					UNDER SHELF TASKS				
	TASK POINTS (OF 25)	TOTAL	TASK POINTS (OF 25)	TOTAL	TASK POINTS (OF 25)	TOTAL	TASK POINTS (OF 25)	TOTAL	TASK POINTS (OF 25)	TOTAL	TASK POINTS (OF 25)	TOTAL			
180 CM (6 FT)	LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP				
120 CM (4 FT)	LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP				
60 CM (2 FT)	LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP				
0 CM (0 FT)	LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP		LP LA C RA RP				

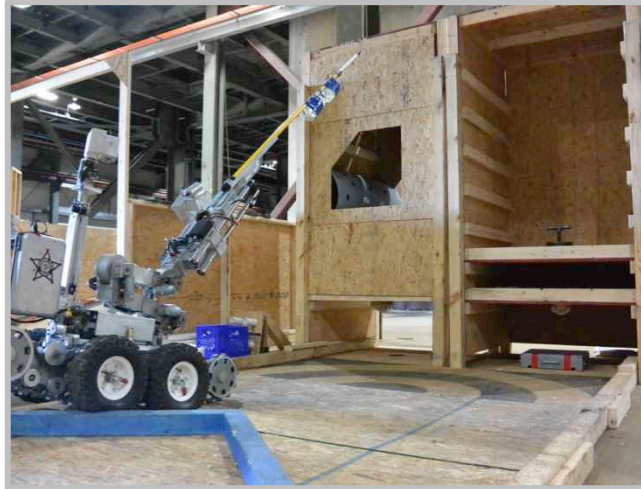
Shipping Container Facility

Dexterity & Strength Classification Tests



Embedded Scoring Tasks in Scenarios

C-IED/EOD Essential Mission Tasks



Dexterity: Omni Tasks

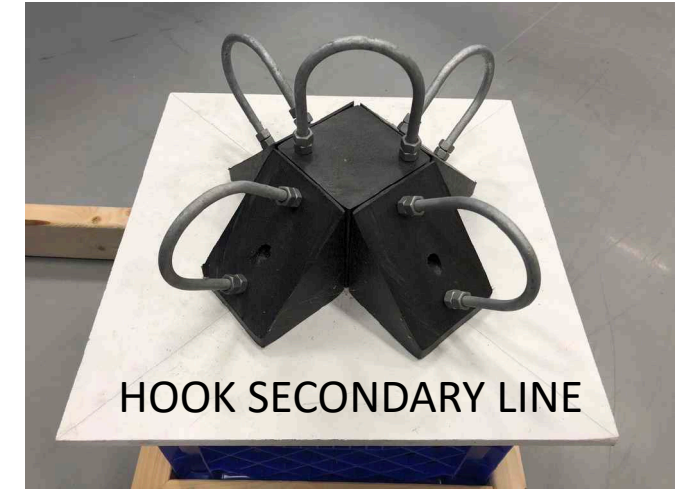
C-IED/EOD Essential Mission Tasks

PIPE TASKS

- TOUCH
- ROTATE
- EXTRACT
- PLACE
- INSPECT



PRESS OVERSIZED SWITCH



HOOK SECONDARY LINE



E-STOPS

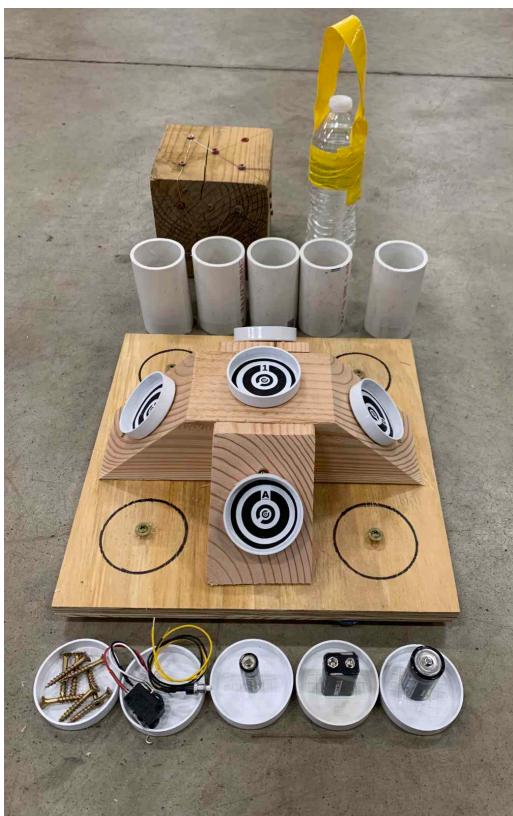


DRY GRANULAR (SAND) SMALL PARTS (NUTS)
SOFT GRASP (PAPER OR COTTON)
WET (BLUE CHALK & Water) LARGE PARTS (BLOCKS)

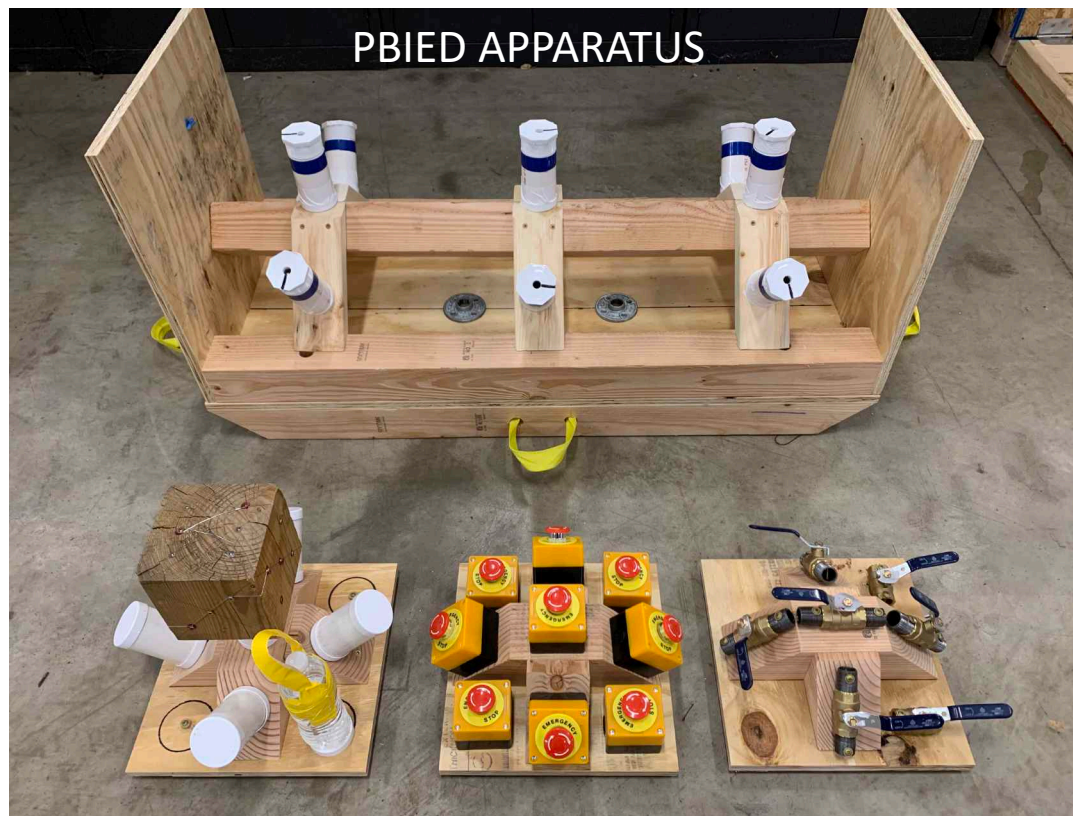
Dexterity: Packages, PBIED, and Other Tasks

C-IED/EOD Essential Mission Tasks

Weighted PBIED Sled with Tow and Roll Over Tasks



OMNI IED WITH COMPONENTS
IN PIPES TO X-RAY AND IDENTIFY

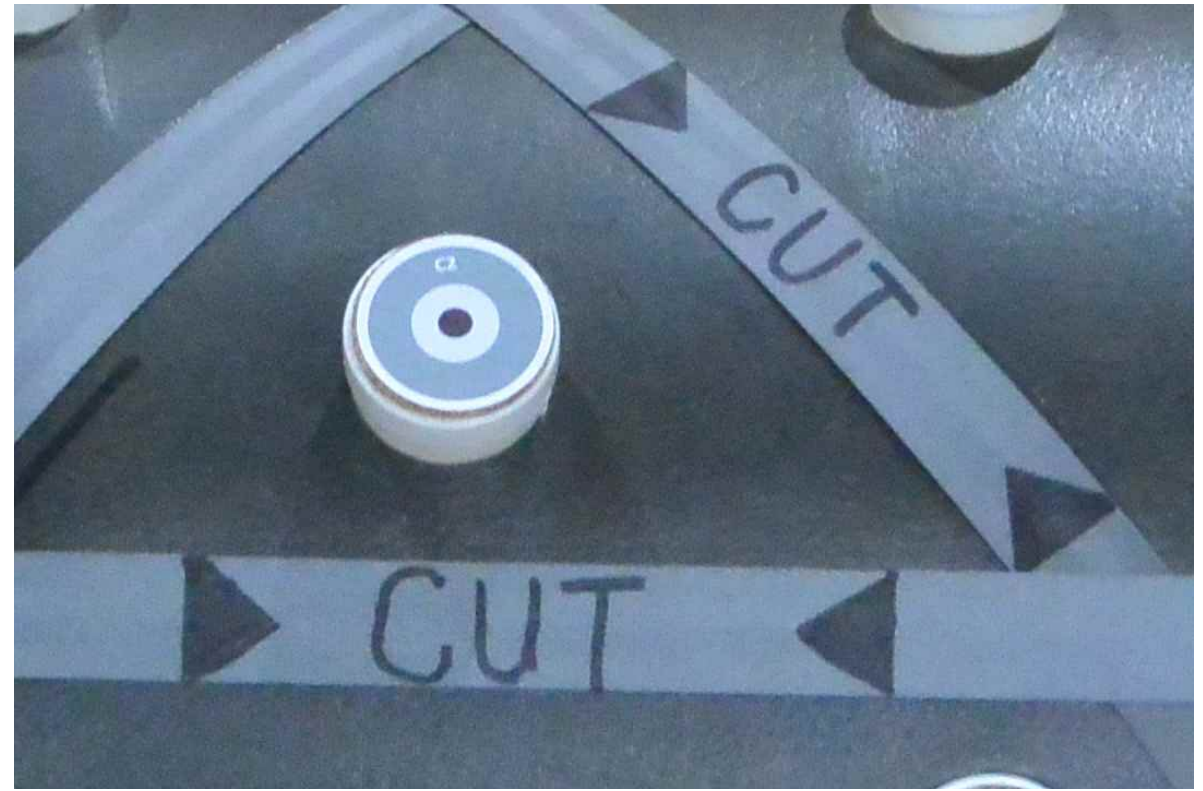
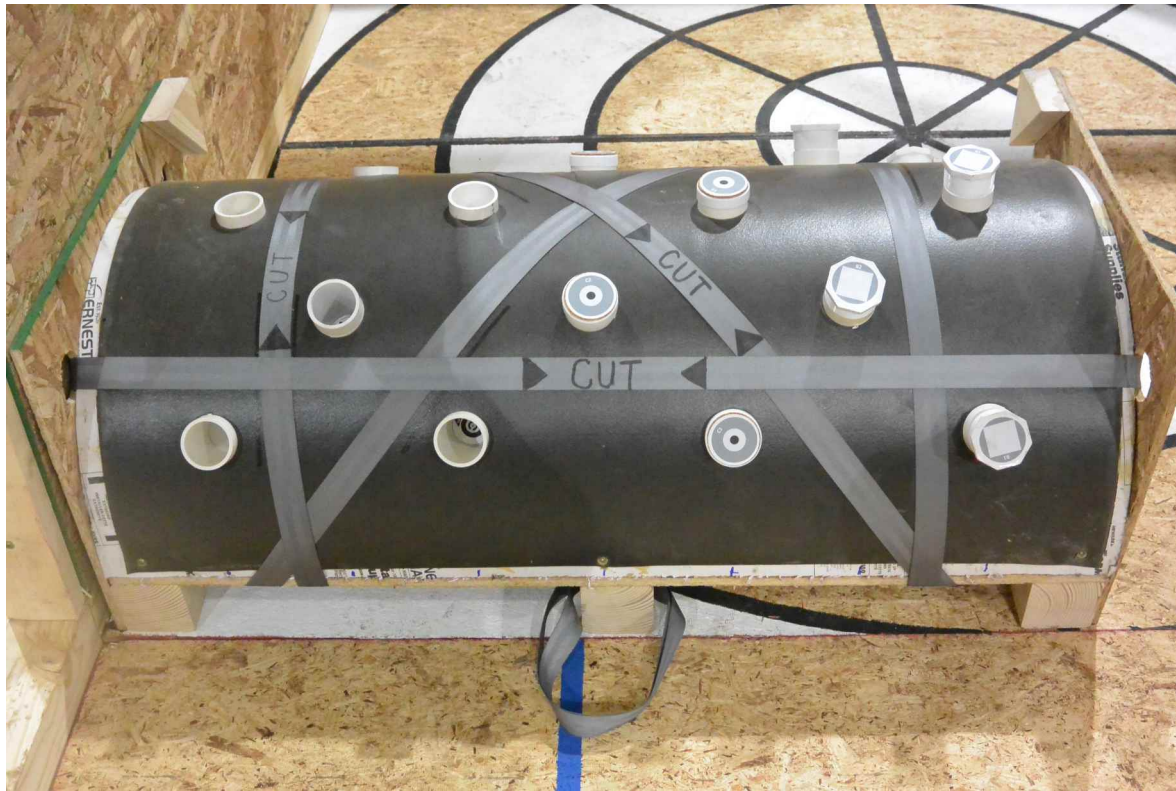


OMNI
IED

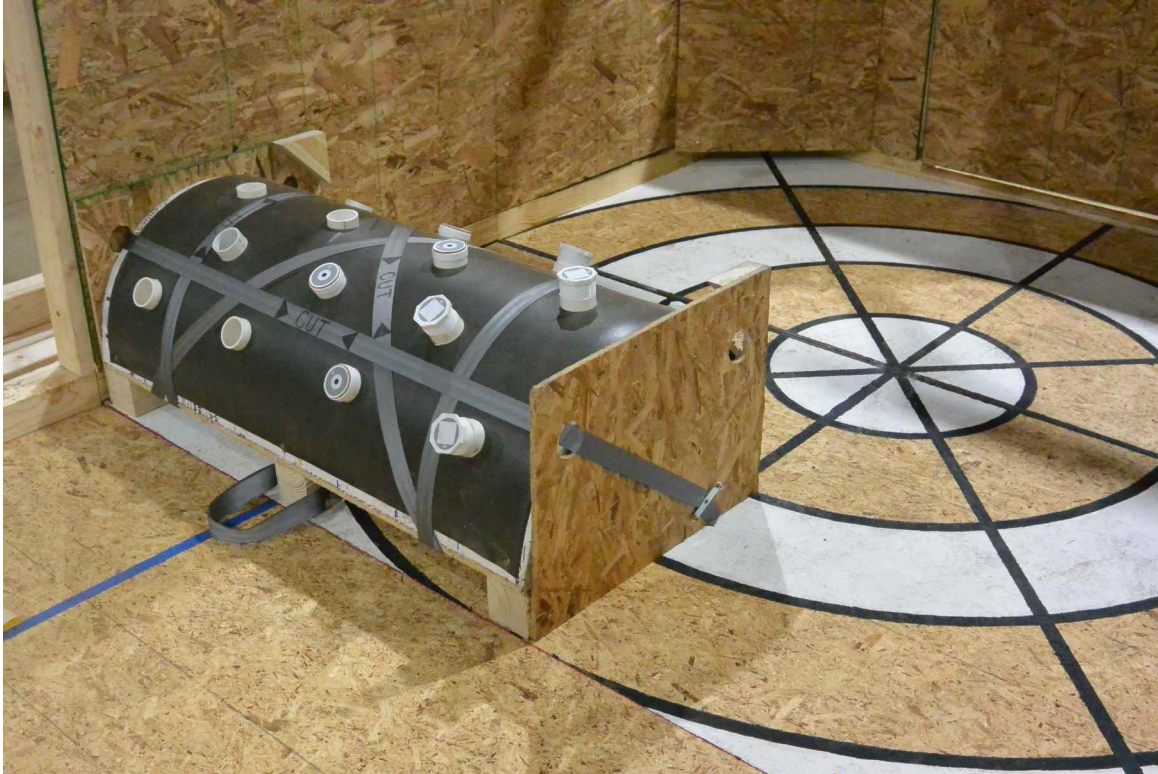
OMNI
E-STOPS

OMNI
VALVES

Dexterity: PBIED Cut Ropes/Straps C-IED/EOD Essential Mission Tasks

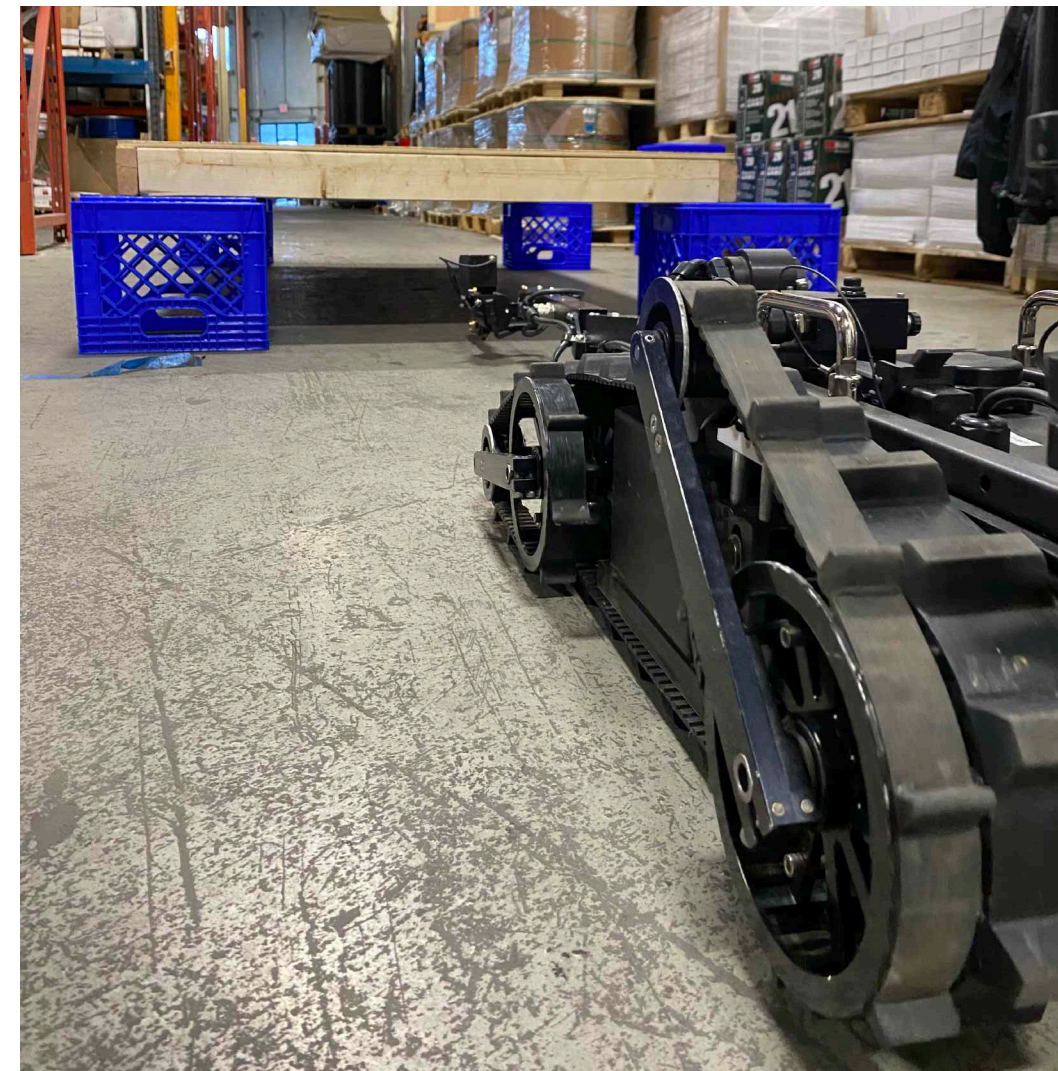


Strength: PBIED Drag or Lift/Roll C-IED/EOD Essential Mission Tasks



Vehicle Underbody Inspection

C-IED/EOD Essential Mission Tasks

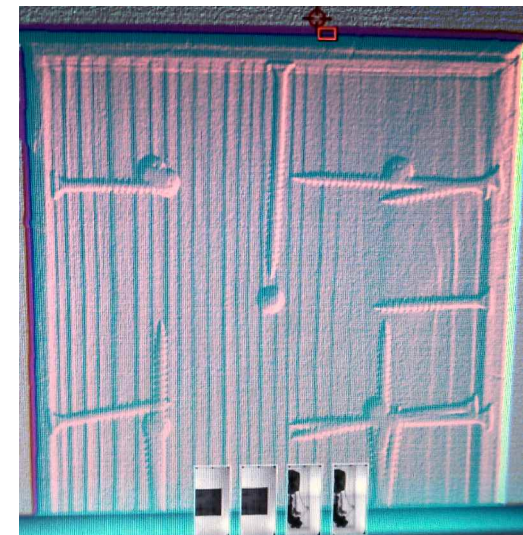
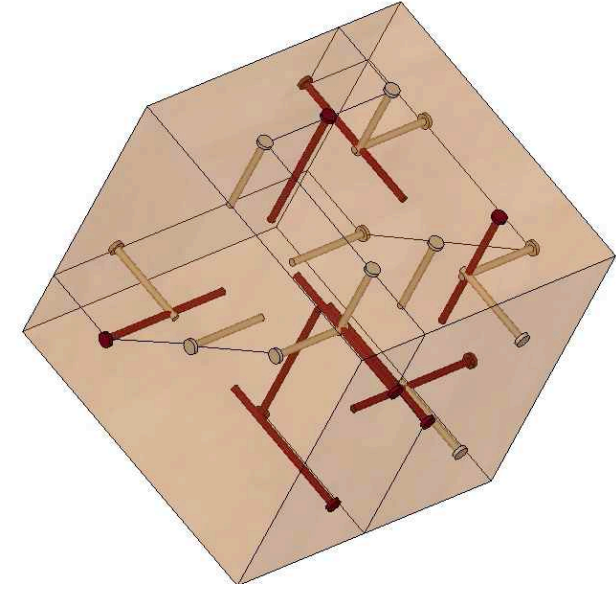


Place MWB Disruptor C-IED/EOD Essential Mission Tasks



X-Ray Dice

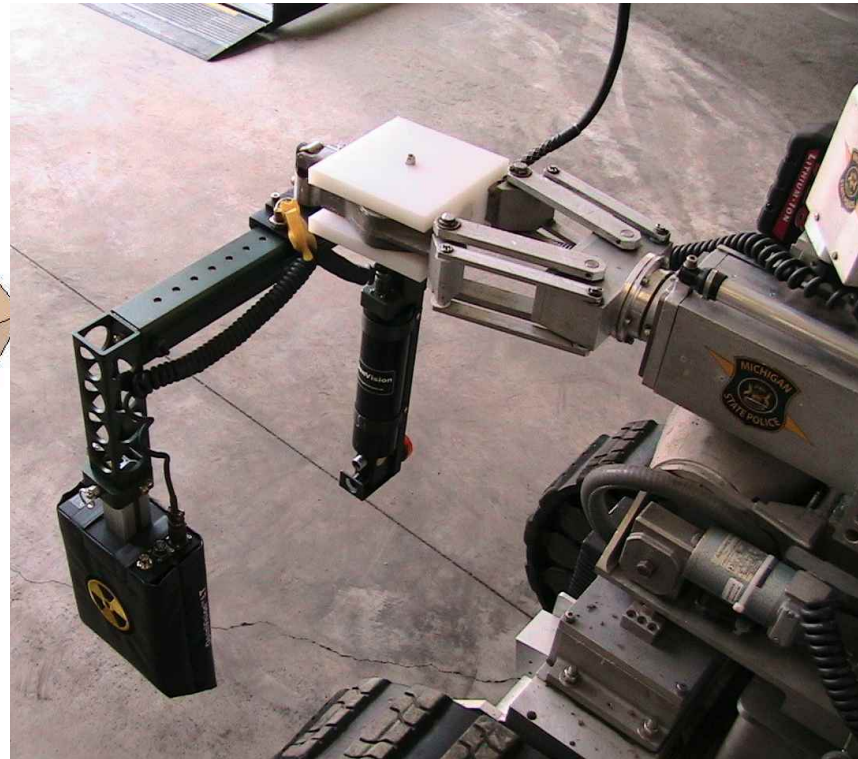
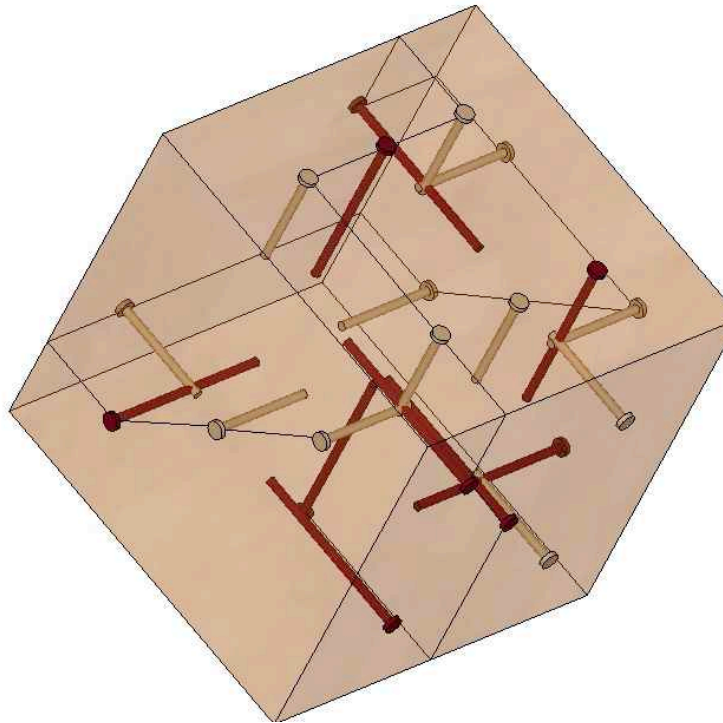
C-IED/EOD Essential Mission Tas



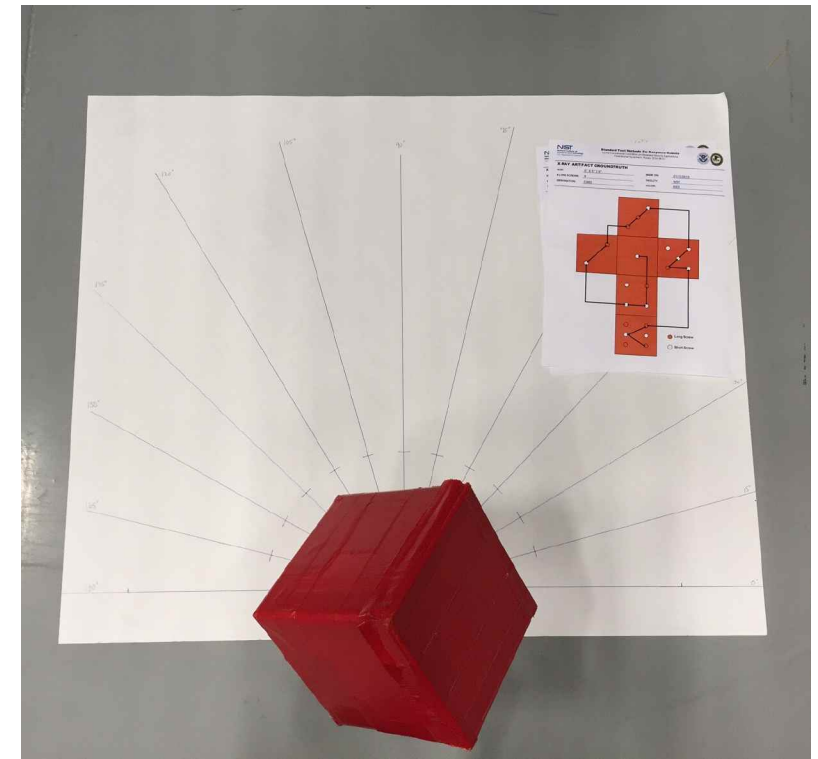
X-Ray Dice

C-IED/EOD Essential Mission Tasks

Continuous Imaging

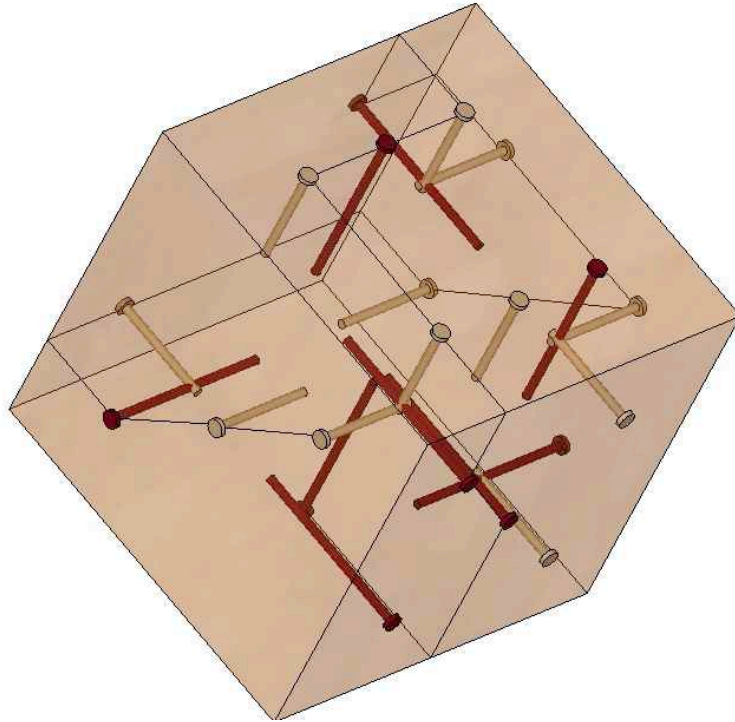


Series of Single Images



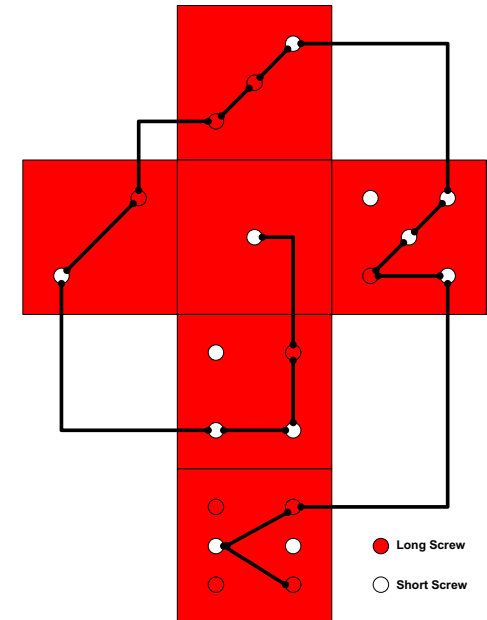
X-Ray Dice

C-IED/EOD Essential Mission Tasks



X-RAY ARTIFACT GROUNDTRUTH

SIZE:	<u>4" X 4" X 4"</u>	MADE ON:	<u>01/13/2015</u>
# LONG SCREWS:	<u>9</u>	FACILITY:	<u>NIST</u>
DESIGNATION:	<u>C663</u>	COLOR:	<u>RED</u>





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