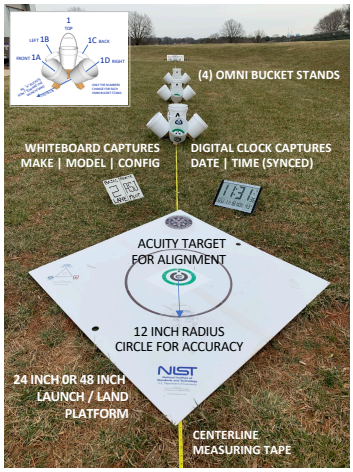
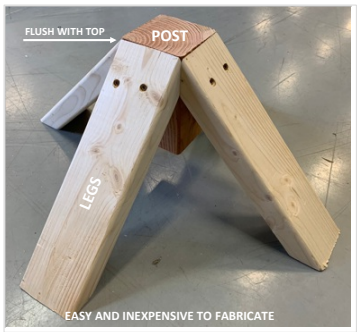
NIST sUAS Open Test Lane

Fabrication Guide

Version 2020B





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DOWNLOAD STICKERS, FORMS, AND VIDEOS TO PRACTICE SCORING

Acknowledgements

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

The NIST Team includes:

Adam Jacoff, Raymond Sheh, Kamel Saidi, Kenny Kimble, and Ann Virts.

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

Disclaimer

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

Measurement Units

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

Collaborators

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Introduction

This guide describes how to fabricate a NIST sUAS Open Test Lane for evaluating Maneuvering and Payload Functionality in open spaces. The test lane is designed to be inexpensive and easy to deploy, stow, and transport. The standard lanes use omni-directional bucket stands made of 7.5 liter (2-gallon) white buckets with white sticker targets inside. Similar omni-directional bucket stands made with black buckets and black stickers are used to embed scoring into operational scenarios to add repeatable measures of performance. These bucket stands are lightweight and small enough to carry two in each hand. They also stack on each other to stow. Visual acuity targets are the initial identification tasks, but additional operationally significant sticker targets can be inserted on disks to randomize and evaluate onboard sensors similarly.

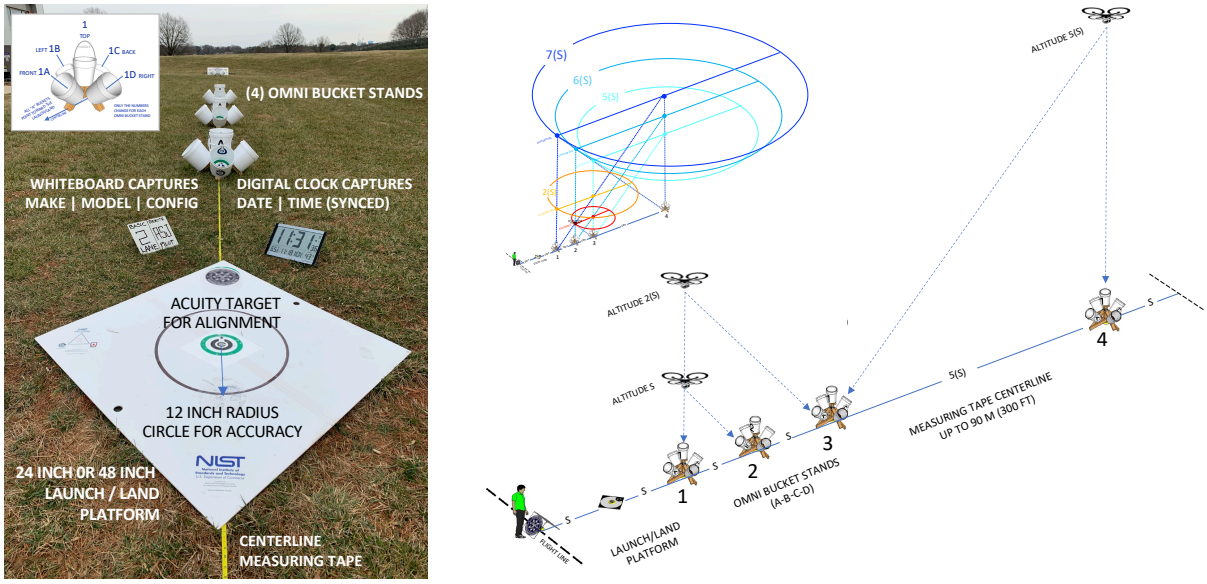


FIGURE 1) This Open Area Lane supports both Maneuvering (MAN) and Payload Functionality (PAY) test methods along with several other tests at various altitudes.

POSITION TEST
Hovers and maneuvers along the centerline of the first three stands at S and 2(S) altitudes.

TRAVERSE TEST
Sideways flying ovals around the first three stands at S distance and altitude.

ORBIT TEST
Orbits around omni bucket stand #3 at S altitude. There are options for 2(S), 5(S), 6(S), and 7(S) as well.

SPIRAL TEST
Free flight downward inspections of all four omni-bucket stands at any altitude.

RECON TEST
Fly straight and level along the centerline at S altitude with checks during acceleration and deceleration.

Figure 2: The lanes are scalable to fit on a basketball/tennis court or any room with a 25ft ceiling.

Stowing and Transport

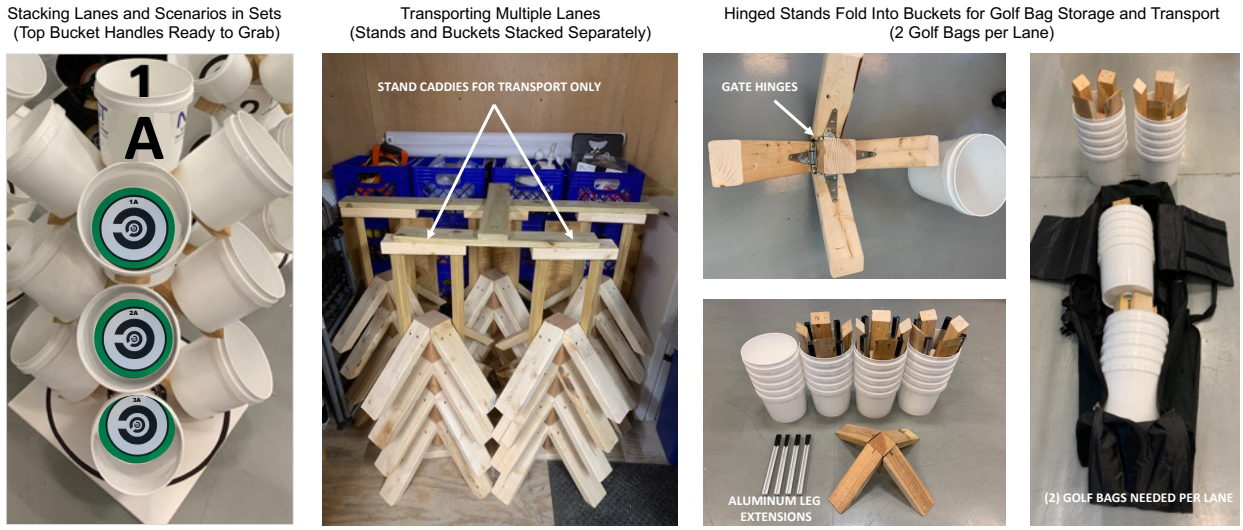


Figure 3: LEFT) These small omni bucket stands can be stacked, stowed, and ready to lay out in minutes with their associated Launch/Land Platform and a measuring tape. CENTER LEFT) For multiple lane transport, the stands can be stacked in fabricated caddies with the buckets stacked separately. CENTER RIGHT) The stands can have gate hinges at the joints to stow even smaller. RIGHT) All four hinged stands and buckets fit into two golf bags for transport. The Launch/Land Platform needs to be cut down into 12in strips with duct-taped seams acting as "accordion hinges" to fit in the golf back along with all the buckets. The sensor panels can be cut down and taped similarly. So an entire Open Test Lane fits into two golf bags.

Figure 4: LEFT) The legs shown hinged underneath using 4 optional gate hinges -- $4 each. CENTER) The hinges are a bit harder to assemble, you need a bit extender, but they provide for the most compact stowing. The even fit into their associated bucket stack. RIGHT) They're probably mostly useful if you are transporting the lanes in a vehicle or as checked baggage on airlines (like anybody else would do such a thing!).

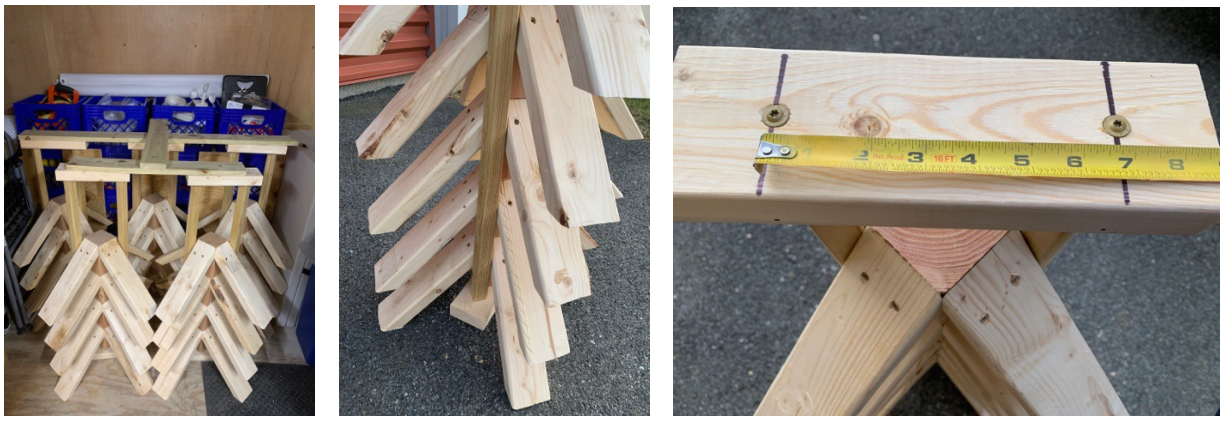


Figure 5: LEFT) For multiple lane transport, stands stack in sets without buckets in fabricated carry caddies. CENTER) The carry caddie is made of 5x5x30cm (2x4x12in) top and bottom pieces, with 5x5x90cm (2x2x36in) balusters placed vertically between where the stand legs meet. RIGHT) The balusters are spaced about 18cm (7in) apart so the balusters nest in between the legs against the center posts. Unscrew the top to insert the stands and replace for carrying.

Figure 6: LEFT) We use crates to store, transport, and organize the myriad of associated tools and administrative items needed to conduct a comprehensive field exercise. A single lane doesn't require any of this stuff. They can be strapped in stacks for transport and easy carrying -- the strap top is the handle – and it keeps the contents from falling out. The cool truck and trailer are optional upgrades, but highly recommended!

Figure 7: Our crates include the following categories (top to bottom, left to right):

1A) 300ft measuring tapes,
1B) 100ft measuring tapes,
1C) Power cord GFCI adaptors,
1D) Duct tape (white, blue, others),

2A) Headlamps for night operations,
2B) Squares for fabrication,
2C) Digital clocks (synced to NIST),
2D) Straps and magnets,

3A) Weather station and mount,
3B) Post levels (can't have too many!)
3C) Disk inserts,
3D) Rope and string,

4A) Clipboards,
4B) Notebooks, paper and toner for printer,
4C) Admin items like whiteboard markers and wipes, stapler and staples, binder clips, lots of pencils.
4D) Chemical hand warmers for thermal targets.

5A-E) 100ft power cord reels… can't have too many!

Omni Bucket Stands

Each standard test lane uses 4 Omni Bucket Stands, a Launch/Land Platform, and a measuring tape centerline. The standard lanes use 7.5 liter (2-gallon) white buckets with white sticker targets inside, scenarios use similar omni bucket stands made with black buckets and black stickers. Both are assembled as shown below.

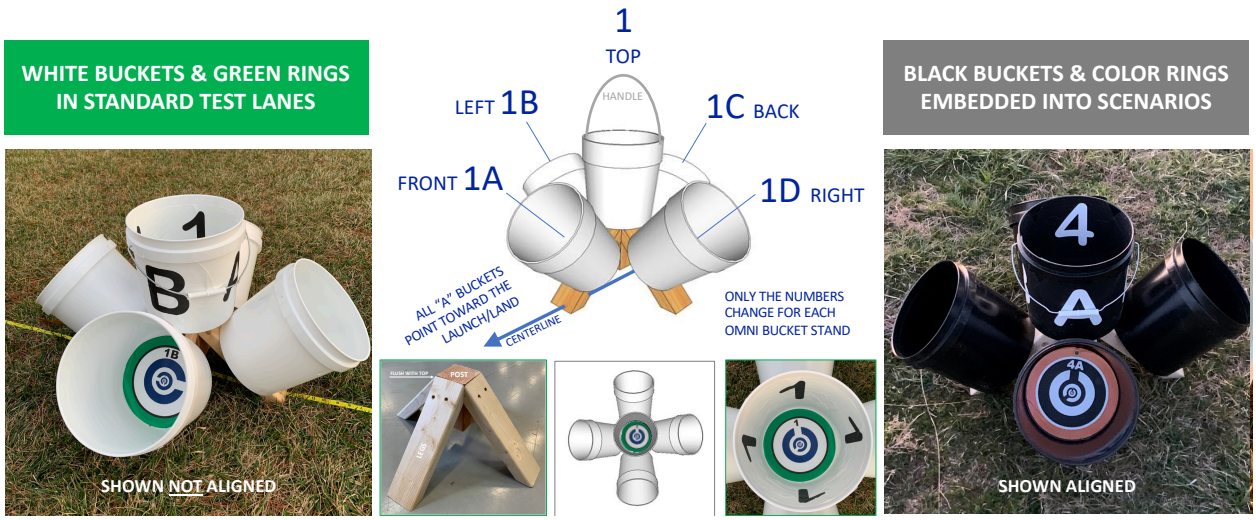


Figure 8: The lettering scheme includes NUMBERS for the top bucket and NUMBERS/LETTERS for the angled buckets in a clockwise rotation. A is the front, B is the left side, C is the back, and D is the right side. This is essentially how firefighters designate the sides of houses. The A bucket ALWAYS points toward the Launch/Land Platform along the centerline in test lanes and generally so in scenarios.

Figure 9: All four angled 5x10x30in (2x4x12in) legs with tapered ends attach aligned to the top of the center post using two 7.5cm (3in) long washer head screws. Start the screws at a 45deg angle into the legs while on the ground before attempting to affix to the center post. The top bucket mounts to the center post end grain using the same two 7.5cm (3in) long washer head screws. These need to be long to carry the weight of the entire assembled stand in the end grain. Leave the handle on the top center bucket only as a carry handle for the assembled bucket stand. The ANGLED BUCKETS SHOULD BE TOUCHING THE TOP BUCKET to support it when stacked. NOTE: Drill small drain holes in the bottom of the buckets if they are to remain outside.
The parts required to construct a lane include the following. See the online USAGE GUIDE for fabrication details and pointers:

Parts Needed

[04] 10x10x15cm (4x4x6in) center post
[16] 5x10x30cm (2x4x12in) legs with 45deg tapers both ends
[50] 7.5cm (3in) screws to affix the legs (2 per leg at top)
[50] 4 cm (1-1/2in) screws to affix the buckets (2 per bucket)
[20] 7.5-liter (2-gal) buckets with 20cm (8 in) diameter bottoms
[52] 20cm (8 in) diameter matte weatherproof polyester stickers.
Download and print the stickers from the online USAGE GUIDE
[16] Big numbers 1-1-1-1 inside each top bucket
[16] Big letters A-B-C-D around each top bucket
[15] Acuity targets 1A-1B-1C-1D inside bottom of all
[02] Perch acuity targets inside and under Bucket 1A only (see picture)
[03] Launch/Land stickers (center, project logo, NIST logo)
Note: A thick black marker can be used instead of stickers to inscribe 2.5cm (1in) rings inside buckets with written letters and numbers on the interior/exterior of the buckets.

Optional Leveling for Uneven Terrains

[01] Post level to orient stand to vertical
[16] Furniture leveling feet with threaded adjustment for
or
[12] Additional leg extensions screwed underneath will compensate for any terrain. Extend the three legs not touching the ground when the stand is level. Mark EACH leg extension before flipping to secure.
or
[32] Slotted leg extensions with hanger bolts enable sliding adjustment with wing nuts to secure when level.

Fabrication Tips

1. Leave the carry handle on the top numbered buckets only as a carry handle for the assembled stand. Remove the handles from all angled/lettered buckets.
2. Use long screws 7.5cm (3 in) with washer heads to affix the top bucket into the center post end grain.This enables the handled bucket to carry the entire weight of the stand without pulling through the bucket or pulling out of the end grain. Washers could be used as well between the screw and the bucket. Place the screws through the largest visual acuity black ring so they hide somewhat while hitting the center post on the diagonal.
3. The angled buckets should be touching the top bucket to support it during stacking. Then attach them with two 4cm (1-1/2in) screws with washer heads to affix the angled buckets. Screw them through the inscribed green alignment ring top and bottom.

Sticker the Buckets First

4. Cut the stickers with big numbers and big letters along the cut lines shown on the stickers to fit well on the interior and exterior of the buckets.
5. Sticker the 4 NUMBERED buckets interior (big numbers) and exterior (big letters) so the numbers and letters align with the four directions and each other.
6. Sticker the 16 LETTERED buckets with full diameter visual acuity targets centered inside the bucket bottom. Be sure it is aligned with one of the number/letter axes.
7. Cut the Perch acuity targets P1 and P2 so the fit inside and outside the 1A bucket only. They should be placed toward the open end of the bucket and upright with the bucket so they will be viewable upright from the Launch/Land Platform. P1 is inside the 1A bucket upper interior wall. P2 is goes under the 1A bucket exterior wall.

Assemble the Stands

8. Attach four 5x10x30cm (2x4x12in) legs even with the top of the 10x10x15cm (4x4x6in) center post using two 7.5cm (3in) washer head screws each. Before affixing to the center post, start both screws into the legs at a 45-degree angle near one tip.
9. Attach the top bucket with its handle using two 7.5cm (3in) washer head screws into the end grain of the center post. The top bucket handle is the carry handle for the assembled omni stand.
10. Attach the angled buckets touching the center bucket to support it when stacked. Use two 4cm (1-1/2in) washer head screws through the top and bottom of the inscribed ring so they hide somewhat.

Figure 10: The total build time for a single lane should be 2-3 hours.

Buckets

These buckets fit 20cm (8in) diameter round stickers with pre-printed alignment rings and visual acuity targets. These also fit 8in round disk inserts with randomizable object stickers. Use WHITE buckets for standard test lanes and WHITE or BLACK buckets for embedding into scenarios. BLACK buckets can be harder to find, so preferred in scenarios. But WHITE buckets already used in standard lanes can also be distributed in scenarios and used similarly to save cost and fabrication time.

ULINE 2 Gallon Pail, $3 each, Need 20 per standard lane or scenario
Part# S-9941W (WHITE) for standard test lanes or S-9941B (BLACK) to blend into shadows in scenarios, or try other colors if better to blend into scenarios.
WHITE: https://www.uline.com/Product/Detail/S-9941W/Pails/Plastic-Pail-2-Gallon-White?model=S-9941W&RootChecked=yes
BLACK: https://www.uline.com/Product/Detail/S-9941BL/Pails/Plastic-Pail-2-Gallon-Black?model=S-9941BL&RootChecked=yes
OTHER: https://www.uline.com/Product/ProductDetailRootItem?modelnumber=S-9941

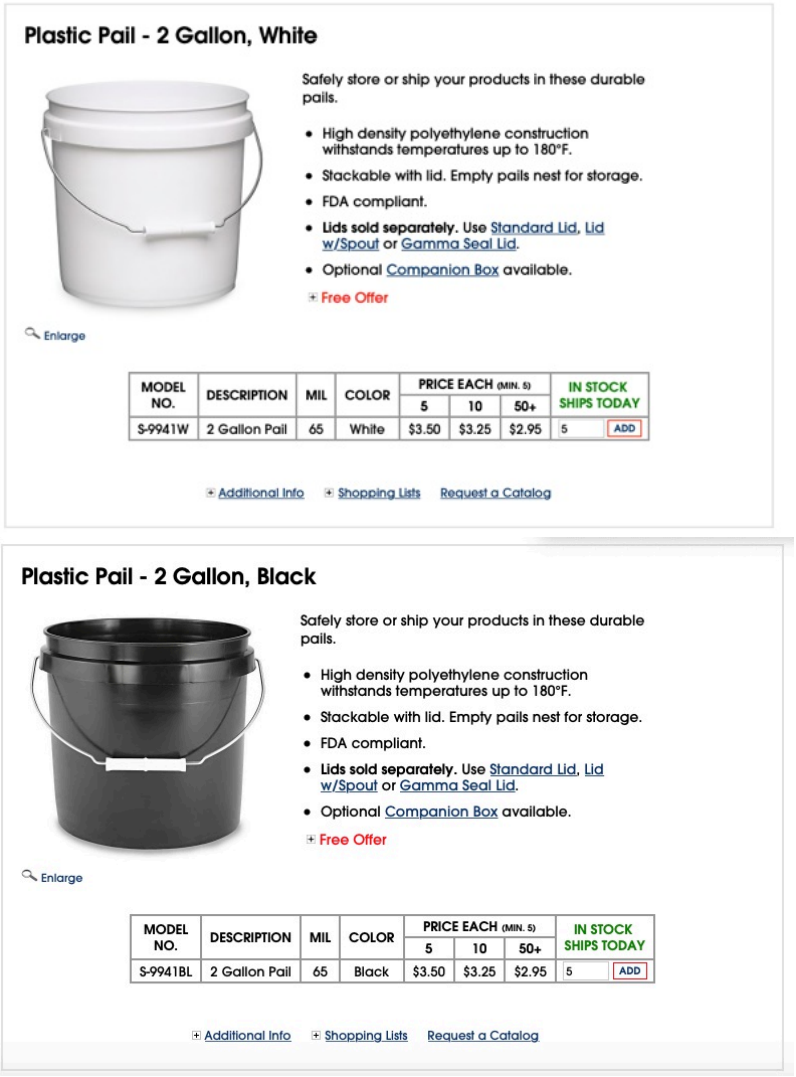


Figure 11: Any buckets can work, as long as they have a 20cm (8in) diameter inside bottom to accommodate the sticker targets.

Visual Acuity Stickers and Other Targets

Figure 12: The online sticker files can be downloaded and printed. There are plenty of operationally significant objects to get started. Of course, you can add your own.

8 INCH ROUND STICKERS FOR BUCKETS AND DISK INSERTS

Any 8in round sticker can work. But these polyester stickers are very forgivable at first placement. They can be easily removed and placed again if not quite centered. They are also waterproof so can last a long time outdoors in rain and sun.

ONLINE LABELS – 8 inch round, waterproof polyester/matte
100 sheets, $50
50 sheets needed for a basic open lane or scenario

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

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

WEBSITE: DOWNLOAD FORMS AND STICKER FILES HERE

Disk Inserts to Randomize Targets

Place stickers on both sides of the disk inserts. They could be a visual acuity chart on one side and operational object on the other (hazmat label, partial license plate, shipping label, etc.). Or if the visual acuity stickers are affixed inside the buckets (so no chance they get set up in the wrong order), then put a different kinds of objects of interest on either side.

Wood 8in round disk x 0.1in thick (preferred)
Amazon, Juvale Unfinished Wood 8" Circle 10-Pack for DIY Crafts, Item# B07C49QVWK
10-pack, $13
Need 10 total for randomization, 20 stickers covering both sides, per scenario.
https://www.amazon.com/dp/B07C49QVWK/?coliid=IR5XU8X86ES5T&colid=24KBO1BGJ06L5&psc=1&ref_=lv_ov_lig_dp_it

Wood 8in round disk x 1/8in thick
Amazon, Craft Parts Direct, Item# PC080010
10-pack, $17
Need 10 total for randomization, 20 stickers covering both sides, per scenario.
https://www.amazon.com/Natural-Unfinished-Round-Circle-Cutout/dp/B00YYCVBS0

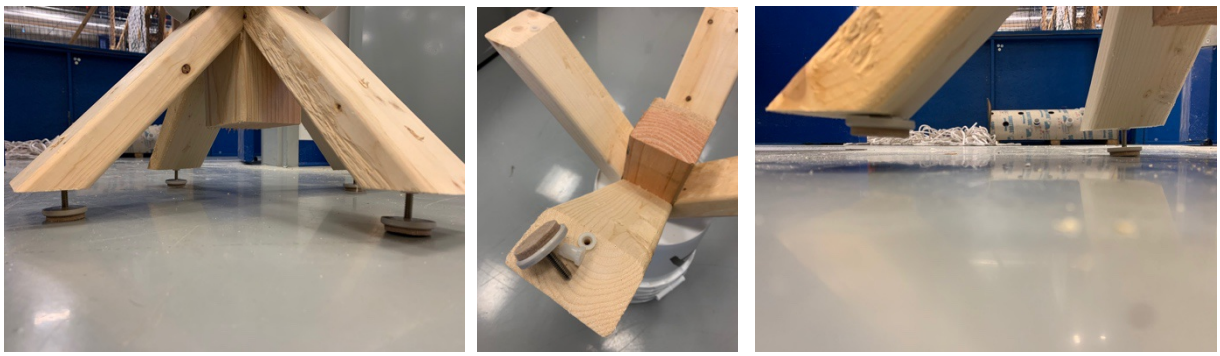
MDF 8in round disk x 1/2in thick
Amazon, Counter Culture DIY, Item# B07L3ZT93K
1 per, $3
Need 10 total for randomization, 20 stickers covering both sides, per scenario.
https://www.amazon.com/Unfinished-Cutout-Surface-DIY-Projects/dp/B07L3ZT93K

Aluminum 8in round disk
American Metalcraft, Item#18908
24 pack, $2.30 each, 6lbs total
Need 10 total for randomization, 20 stickers covering both sides, per scenario.
https://www.amnow.com/product-category/pizza-supplies/separators/round-separators/
https://www.amnow.com/product/18908/

OTHER MATERIALS
Wood, Plastic, Galvanized Steel, Other
Craftcuts
8in round disk x (CHOOSABLE THICKNESS), $variable
Need 10 total for randomization, 20 stickers covering both sides.
https://www.craftcuts.com/circle-craft.html?material=Baltic%20Birch%20Plywood&longest_dimension=8%20Inch&shape_thickness=3%2F8%20inch&item_image=0%2F517%2F173517%2Fshapesbasiccircle.jpg&price_start=6.30&matchtype=&network=u&device=c&keyword=&gclid=EAIaIQobChMI38rb9MjM6AIVooVaBR3rwg5GEAQYASABEgKJG_D_BwE#slide-0

Leveling Feet

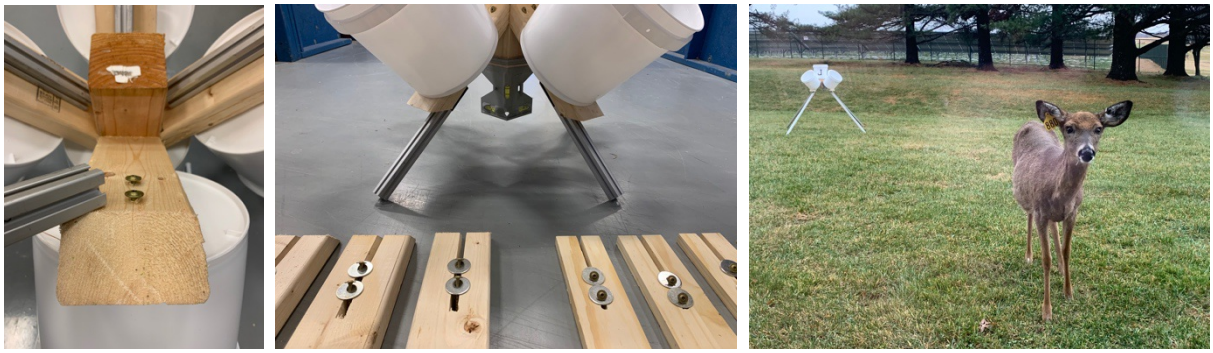
Leveling feet are the quickest and easiest way to deal with relatively level but uneven flooring, paved driveways/roads, and ball fields. These are good where overall terrain is flat but the four legs don't all touch the ground. They also protect indoor floors, basketball/tennis courts, etc. The lenth of the thread provides a decent amount of correction for uneven terrains.



LEFT) Leveling feet inserts ($5) can go a long way toward protecting floors (like basketball or tennis courts for example). Or when placed on the roof of a rental car scenario. CENTER) They are inserted into the leg tips closest to the inside edge. RIGHT) They also provide a fair bit of leveling capability, maybe 5 degrees.

Leg Extensions

The omni bucket stands only work if they are deployed vertically at their designated locations, so the angled 45-degree buckets all point to the location directly over the next omni stand. So leg extensions are necessary to level the stands when the terrain is undulating, sloped, or just uneven. Any wood extension can be affixed to the underside of the three legs that do not reach the ground when the stand is tipped to vertical. The uphill leg can always be touching the ground in any case. Use a POST LEVEL affixed under the center post to guide level in two orientations.



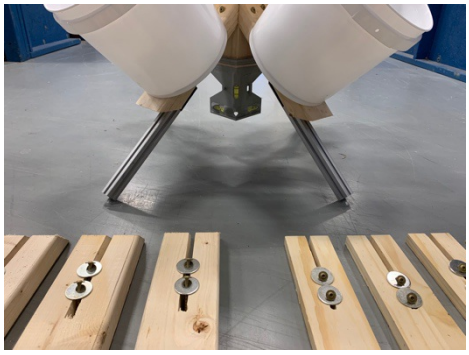
The four leg extensions bind against each other once the stand is leveled on uneven ground. The wood extensions can use the wingnut for locking in place. The aluminum extensions can't be easily locked in place. RIGHT) Any length wood or aluminum leg extensions can be used to level the stands in hilly terrain. This helps get all the stands onto a level plane. Or double act as a deer feeder too!

Screwed Version
Add (3) 2.5x10x30cm (1x4x12in) wood leg extensions UNDERNEATH the legs with the angled buckets attached. Mark each extension before flipping the stand to screw the extension into the underside of the leg. Or better yet, pre-draw lines on the extensions every 2.5cm (1in) with numbers as a measure of the exposed extension needed to touch the ground. This will make the extensions easily adjustable for DIFFERENT setting each time you deploy them in the field.

Slotted Wood Version
Use the same wood extensions described above with an added SLOT down the center to provide an easy and continuous adjustment when leveling. Use (2) hanger bolts for the slot to slide along and wing nuts to tighten in place when the stand is vertical. This is worth the effort if the stands are to be deployed on uneven terrain often and quick and easy set-up is needed.

Slotted leg extensions made from 1x4x12in wood can be fabricated rather easily. LEFT) The objective is a slot thicker than the screw shank and thinner than the washer head. CENTER) Clamp the wood to bench. Draw a center line from one end to the midpoint with a thick marker line. Drill a hole the size of the marker line at the midpoint at the end of the line. RIGHT) Saw straight along both sides of the marker line from one end.

Aluminum Extrusion Version
Aluminum extrusions 2.5x2.5x30cm (1x1x12in) can be purchased for $15 per stand for four legs. In this case, two washer head screws partially sunk into the underside of the legs about 5cm (2in) apart provides the slide mechanism inside the aluminum slot. They all slide very easily during adjustment, and then bind from the weight of the stand and opposing forces. Short aluminum leg video Long aluminum leg video for tall grass or steep hills



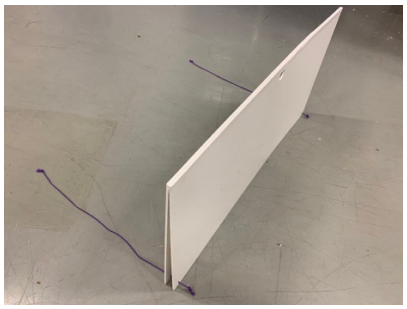
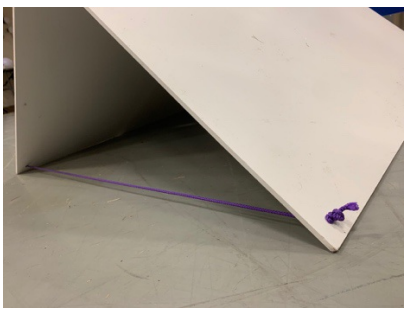
LEFT) The aluminum extensions slide very smoothly, then bind against each other once the stand is leveled on uneven ground. But they can't be easily locked in place. CENTER) The slotted wood extensions use the wingnut for locking in place. RIGHT) Any length wood or aluminum leg extensions can be used to level the stands in hilly terrain. This helps get all the stands onto a level plane. Or they make for nice deer feeders too!

Sensor Panels

These folding panels make for easy setup, carry, and stow. The ropes can thread through the thumb holes to act as a handle to carry several at a time.

A-frames provide targets at various distances in the lane to evaluate visual acuity along with all the more operationally significant targets. This helps people understand how many Concentric C rings relate to their mission needs from known hover distances. These are 1/4in x 24in x 48in PVC panels purchased as shown from stores (about $16 each). Laminated wood panels or other materials could also be used. The key is that the taped hinge on top is taped on BOTH SIDES of the seam to act like a hinge. The top row of lettered acuity targets with mulit-colored rings. The letters lead the pilot to look sequentially at the four different sensor target panels in order, so the targets are every 4th letter in the alphabet. The lower row shows various other targets to help correlate how many visual acuity rings are necessary to see operational features. The lower targets are (left to right): Rotating letter also names the board generally), hazmat labels, partial license plates or gauges to read, operational or random pictures, and a thermal acuity target using drilled holes with a hand warmer behind the panel (as shown, the holes are not yet drilled). It folds by pulling up the rope on the back side and stays closed by threading through the hole on top. All the panels in the lane can be attached and carried together to stow using the rope through all the aligned top holes.

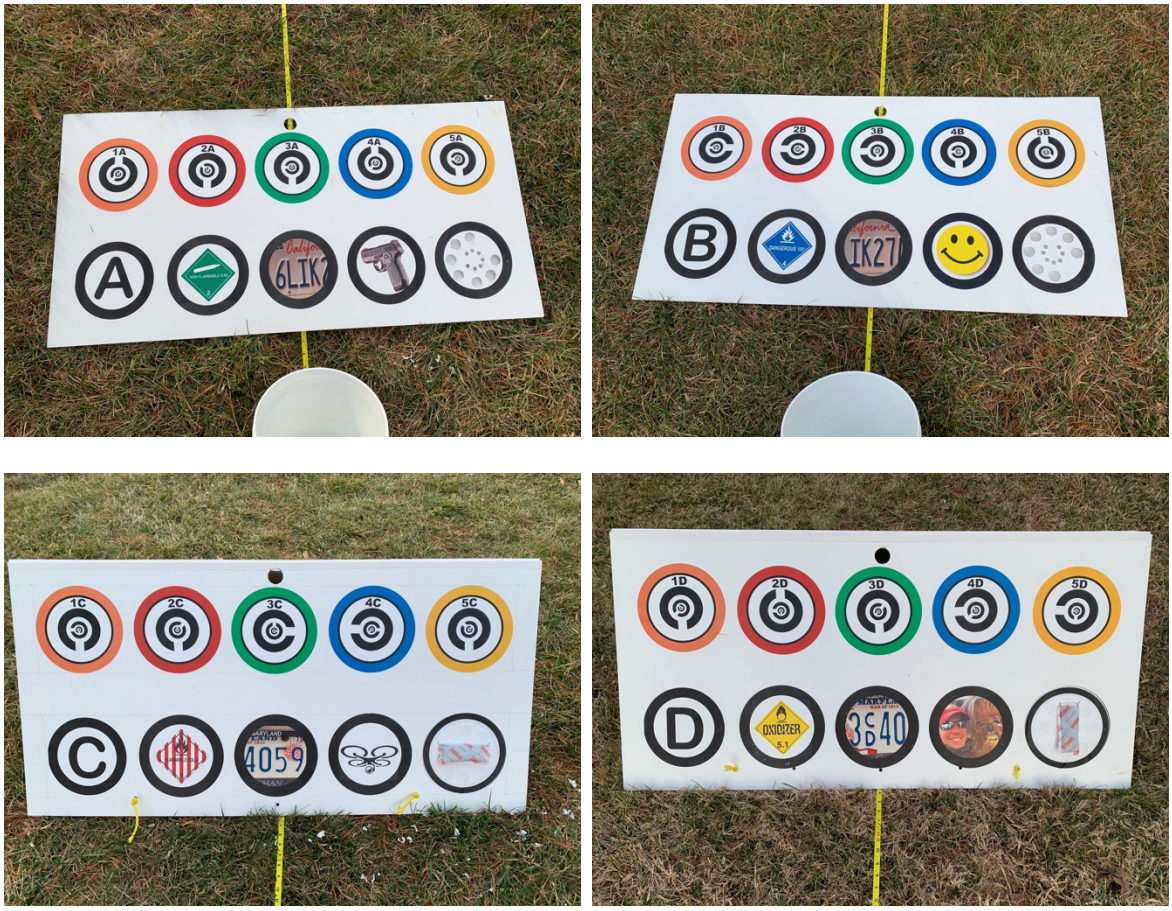
SEE VIDEO OF ASSEMBLY PROCESS
https://vimeo.com/405091028

LEFT) Start with the two panels flat on the floor and perfectly abutted to each other. Tape the underneath seam as it sits. Use your weight to ensure the two panels don't move relative to one another. Then fold to upright and tape the top seam also. Cut off excess tape on both ends. CENTER) The two panels should fold perfectly flat with the seam taped on both sides. While folded, drill through both panels at the same time. Drill (2) holes just a bit larger than whatever rope you have in from each corner near the bottom. Be certain not to interfere with where

the stickers targets will go. The holes in both panels will line up perfectly for stowage. Do so in both corners as shown or at 12-16in in from each corner to be slightly stiffer when deployed. Add an oversized thumb hole at the top center to string the ropes through to carry multiple panels simultaneously. RIGHT) Tie knots on the OUTSIDE of both panels as you string the rope around the assembly. Do so while the A-frame is on its side and open to about 90 degrees. You should have 4 knots when you're done. The rope can be ONE continuous rope with four knots, making the excess between two sides a carry handle. Cut off excess from the last knot when complete.

Example test method to validate individually as the SPEED test without the SPIRAL or as combined RECON evaluation an object of interest downrange:



[8] PVC SHEETS FOR SENSOR PANELS, A-FRAMES, and LAUNCH/LANDING PLATFORMS
These can be found in many lumber stores and metal stores as well. Thin wood laminates can be used as well although they might not look as good and last as long.

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

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

[1] ROLL WHITE 7.5CM (3IN) WIDE DUCT TAPE FOR HINGES ON FOLDING SENSOR PANELS A-FRAMES AND LAUNCH/LAND PLATFORMS
https://www.amazon.com/Gorilla-6025302-White-Tough-Wide/dp/B07LFZF9KN/ref=sr_1_6?dchild=1&keywords=white+3in+duct+tape&qid=1585934432&sr=8-6

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

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

[1] SCISSOR TO CUT EXCESS POLY ROPE AND EXCESS DUCT TAPE
https://www.amazon.com/Stanley-All-Purpose-Ergonomic-Scissor-SCI8EST-YLW/dp/B00LSWNOJ8/ref=sr_1_1_sspa?dchild=1&keywords=scissors+dewalt&qid=1585934945&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzNkEwUEpFWktHNDkwJmVuY3J5cHRlZElkPUEwMDE0ODkyTUZYVVBEMVFRRUM1JmVuY3J5cHRlZEFkSWQ9QTA0OTYyODgyMU9FOTBYNE1VVlJCJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==

[1] 7.5CM (1-1/2 IN) PADDLE BIT FOR CARRY THUMB HOLES ON TOP
https://www.amazon.com/DEWALT-DW1586-2-Inch-6-Inch-Spade/dp/B0001LQYIU/ref=sr_1_5?dchild=1&keywords=paddle+bit+large&qid=1585935081&sr=8-5

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

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

Washer Head Torx/Star Screws

WASHER HEAD CONSTRUCTION LAG SCREWS (TORX/STAR BIT)

LIGHT DUTY – SHORT OMNI-STAND FABRICATION

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

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

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

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

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

(100) **1/4in x 2-1/2in** screws (T25 BIT) with WASHER HEADS – FOR ASSEMBLY OF LEGS TO POSTS
http://www.screwsolutions.com/CCTX- 14250-14-x-2-12-Bronze-Star-ACQ- Compatible-Star-Drive-Exterior- Construction-Lag-Screws--100-count_p_367.html

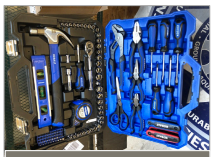
(100) **1/4in x 4in** screws (T25 BIT) with WASHER HEADS – FOR ALL HINGE JOINTS IN STOWABLE APPARATUSES
http://www.screwsolutions.com/CCTX- 14400100-14-x-4-Bronze-Star-ACQ- Compatible-Star-Drive-Exterior- Construction-Lag-Screws--100-count_p_372.html

Helpful Tools

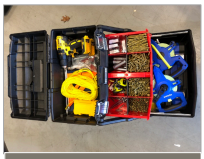
If you're building multiple lanes, it is worth spending the first 10 minutes building this miter saw jig. It as measured blocks at key component distances: 30cm (12in), 60cm (24in), 120cm (48in). Just feel each piece is at the right length and skip the measurement. The key is that ALL THE LEGS ARE THE SAME DIMENSION. So note you can cut two legs at a time.

Also, be sure to MARK THE MITER SAW at the location to remove the 45-degree ends of the legs. Your goal is to cut bluntly in mass amounts. Then trim ends necessary to be coincident with the length already cut. So mark that location on the saw itself, and repeat for a thousand 45 degree cuts and they'll all turn out the same.

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


MISC TOOL CASE

MISC TOOL CASE


ROLLER BOX

SQUARE

8-10 INCH BIT EXTENDER

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

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