



Boosting Engineering, Science & Technology™

WARP XX
BEST 2012 Design Contest
Game Specific Rules
Version 1.02
21 Aug 2012

1.0 Introduction

The Space Elevator:

Hours before your Cargo Ship arrives at an equatorial island in the Pacific Ocean, you can see a thin, bright, vertical line bisecting the sky. As the ship draws closer, you see that the base of the line terminates at a large building that occupies much of the island. Your gaze follows the bright line from the building upward, but you cannot see its far end. The line is a ribbon of super-strong carbon nanotube grown around an unobtainium monocrystalline structure, and it stretches from this equatorial island up to the anchor asteroid in geosynchronous orbit 62,000 miles above you.

Often hailed as the eighth wonder of the modern world, the Space Elevator is the premiere low-cost solution for lifting cargo out of Earth's gravity well. It will expand lunar colonization, exobiological exploration, and asteroid mining. It has already spawned many new industries, and competition for SE contracts is fierce.

The first stop on the Space Elevator is Midway Station, located just above the atmosphere, but well below geosynchronous orbit. Midway Station is a cargo transfer depot, solar power station, and a home away from home for the Space Elevator supervising engineers. The Space Elevator program needs unmanned robotic vehicles for routine cargo delivery, as well as additional Station expansion and construction.

The Defense Advanced Research Projects Agency (DARPA) has published a request for proposal (RFP) for the production of efficient robotic lifting vehicles for the Space Elevator program. Your job is to respond to the DARPA RFP with a Technical Design development and process document (Engineering Notebook) and prototype Technical Demonstration system (Robot).

Your document and prototype system will compete with other purveyors' entries in a "fly-off" occurring six weeks from today to support a Milestone B decision. This event (Game day) will include a technical evaluation of the engineering designs and head-to-head testing on prototype tether systems.

At the Milestone B decision point, a team of judges will select a limited number of teams to pursue an accelerated Engineering Manufacturing and Development (EMD) phase. The EMD phase will last approximately three weeks, and will culminate in a follow-up evaluation and down-selection at Milestone C (regionals) where superior designs and top-performing prototypes will be awarded Limited Rate Initial Production (LRIP) contracts.

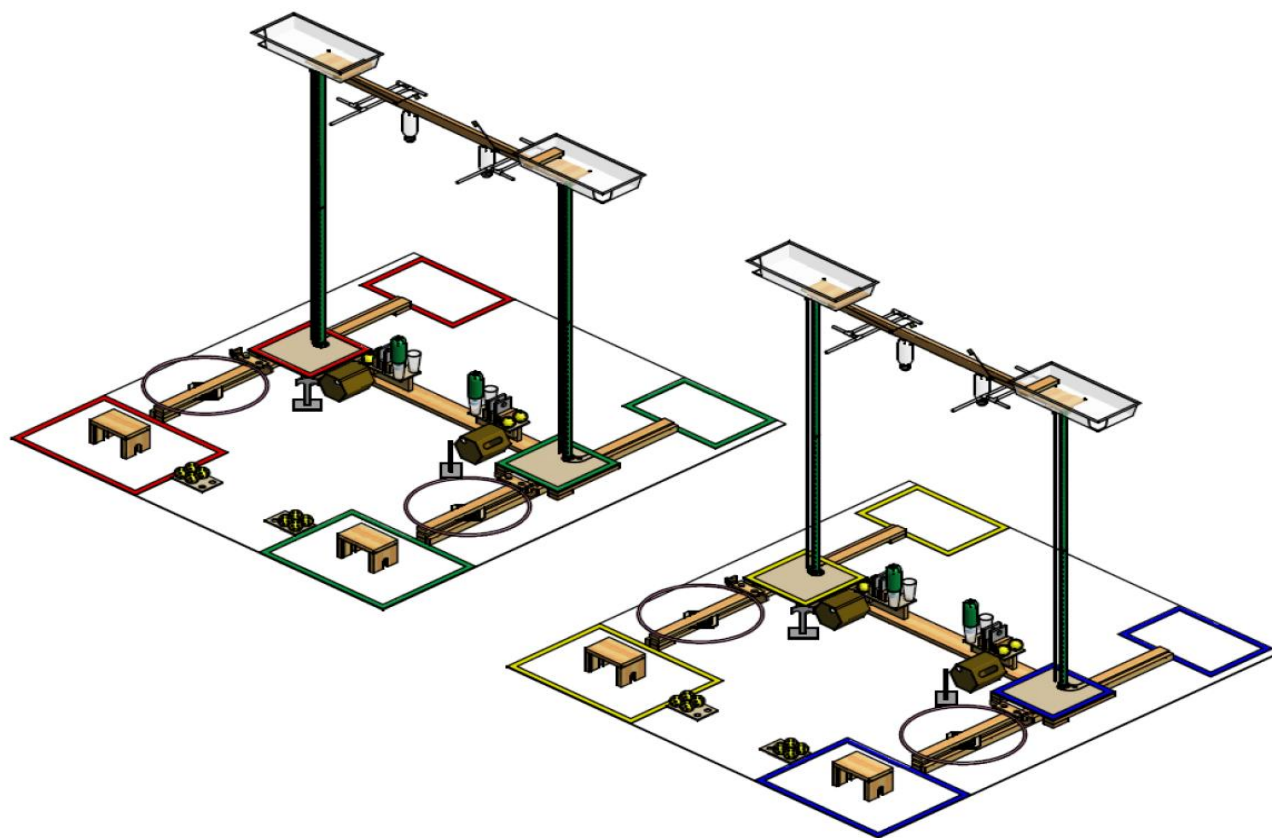
References:

Space elevator speculative fiction, such as "The Fountains of Paradise" Arthur C Clarke
<http://www.spaceward.org/elevator2010> space elevator design prize
http://en.wikipedia.org/wiki/Space_elevator

2.0 Objectives

Design and build a prototype robot to transport cargo and equipment on the space elevator tower during the three-minute match. There are a variety of tasks to do, to keep the station operational. These include:

- (a) Remove the Waste Cargo Balls from the base rack to trigger the tiebreaker switch.
- (b) Trigger the summit indicator flag by pressing upward on the linkage at the top of the tower.
- (c) Transport Light Cargo Balls from the cargo ship to the cargo bin on Midway Station.
- (d) Move the Waste Cargo Balls to the cargo ship.
- (e) Retrieve the Clear Fuel Bottle from Midway Station and store it on the base rack.
- (f) Refuel Midway Station with the Green Fuel Bottle from the base rack.
- (g) Install one or two Solar Panels from the base rack onto the mounting studs at Midway Station.
- (h) Install a large Habitation Module at Midway Station.
- (i) Install the T-structure in either the front or back slot at Midway Station.

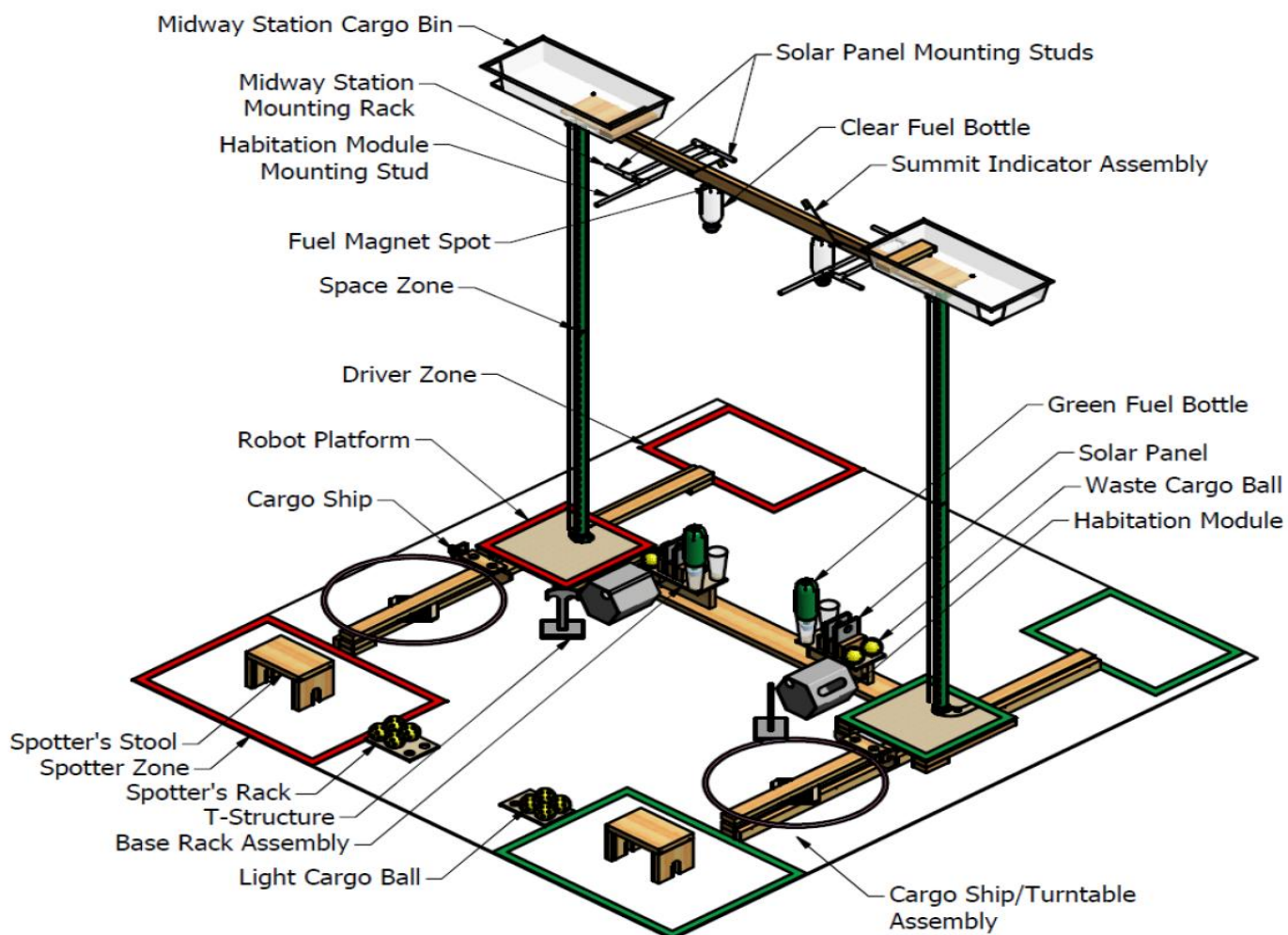


3.0 Warp XX -- Game Field Description

The WarpXX Game Field consists of four tower fields (red, green, yellow, and blue) arranged in a 28x13' rectangle, or a 26x26' square. Tower fields come in pairs, with the towers spaced 8' apart center to center. This paired layout creates right-handed and left-handed fields.

Note that red and yellow fields use the left tower, and game objects toward the center of the field are to the driver's left. Green and blue fields use the right tower, and center of the field is to the driver's right. This is a non-interaction game, so there is one team per tower field during a match.

See the field drawings for full dimensions. Tolerance is $\pm \frac{1}{4}$ " on purchased game pieces. Tolerance is $\pm \frac{1}{2}$ " on other field measurements.



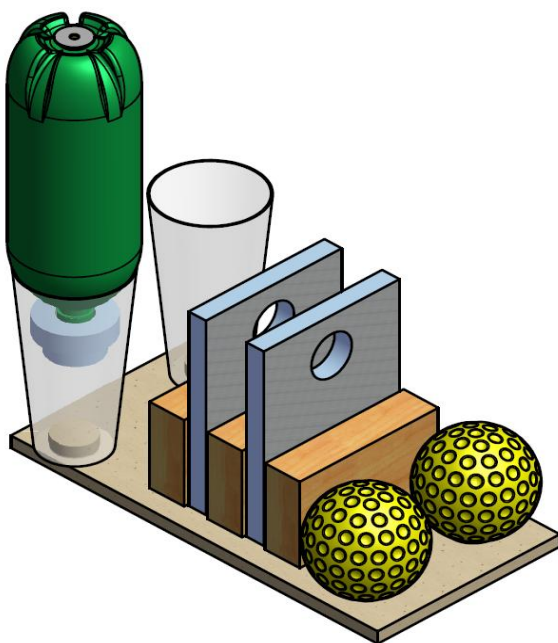
3.1 Tower Details

- (a) tower – a 1-5/8"x1-5/8"x10' metal C-channel 'uni-strut'
- (b) Midway Station beam – a 2x4" connecting the top of a pair of towers
- (c) Space Zone Plane– an infinite horizontal plane 5' above the start platform;
Robots must be completely above the Space Zone Plane when interacting with Midway Station.
Robots must be completely below the Space Zone Plane when interacting with the ground.
- (d) base beam – a 2x8" connecting the bottom of a pair of towers
- (e) start platform – a 24" plywood square at the base of the tower
- (f) crossbeam – a 2x4" & 2x3" support at base of each tower to keep the tower from tipping
The front portion also supports the turntable for the cargo ship
- (g) rope – a 5/32" diameter diamond braided nylon rope that hangs 2-1/2'" from the front of each tower; The rope has an overhand knot 4" (+/-1") above the start platform with a 1/2" tail after the knot. The rope hangs from an eyebolt that ties the top of the tower to the Midway Station beam.
- (h) front – the spotters side of the field

3.2 Base Rack Details

The base rack for each field is located between the towers, creating right-handed and left-handed layouts. The base rack sits on a 5.5" standoff on top of the base beam, and the near edge is 19" from the center of the tower.

- (a) Two Waste Cargo Balls rest in the 1-3/4" holes.
- (b) Removing the Waste Cargo Ball closest to the spotter triggers the tiebreaker switch.
- (c) Two Solar Panels start in the 1" slots between the 2x4s.
- (d) The Green Fuel Bottle starts in the 3.5" diameter cup closest to the spotter.

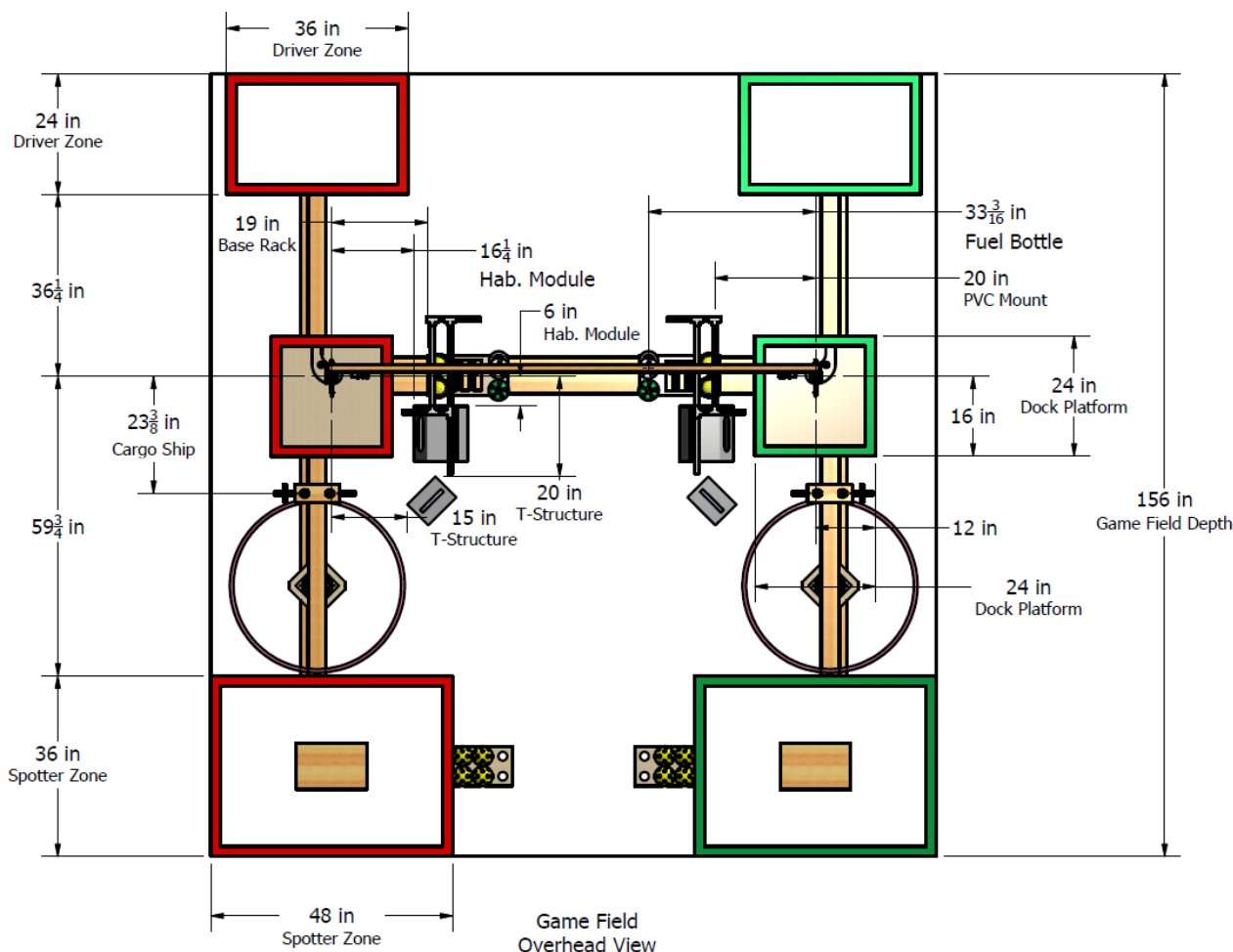


Base Rack starting configuration

3.3 Start Platform, Cargo Ship, and Spotter Area Details

General-purpose cargo bound for Midway Station is conveniently packaged into spherical Cargo Balls to provide uniform handling characteristics. The spotter may move Cargo Balls between the spotter rack and the Cargo Ship, and move the Cargo Ship with the circular handle.

- (a) Cargo Ship— holds up to two Cargo Balls at a time in two 1-3/4" holes on 5" centers, and rotates in a 35" diameter circle.
- (b) Cargo Ship handle – A circular handle the spotter uses to operate the Cargo Ship.
- (c) Spotter Rack – A 2x3 grid of holes to hold Cargo Balls or Waste Cargo Balls.
- (d) Spotter Stool – A 10" tall, 9x14" stool in the 3x4' Spotter Box. The Spotter may move the stool to any position in the Spotter's Box before the match starts. The Spotter must remain seated on this stool at all times during the match to provide the best view for the audience and judges.



Red and Yellow are on left side.
Base rack is to drivers left.

Blue and Green are on right side.
Base rack is to driver's right.

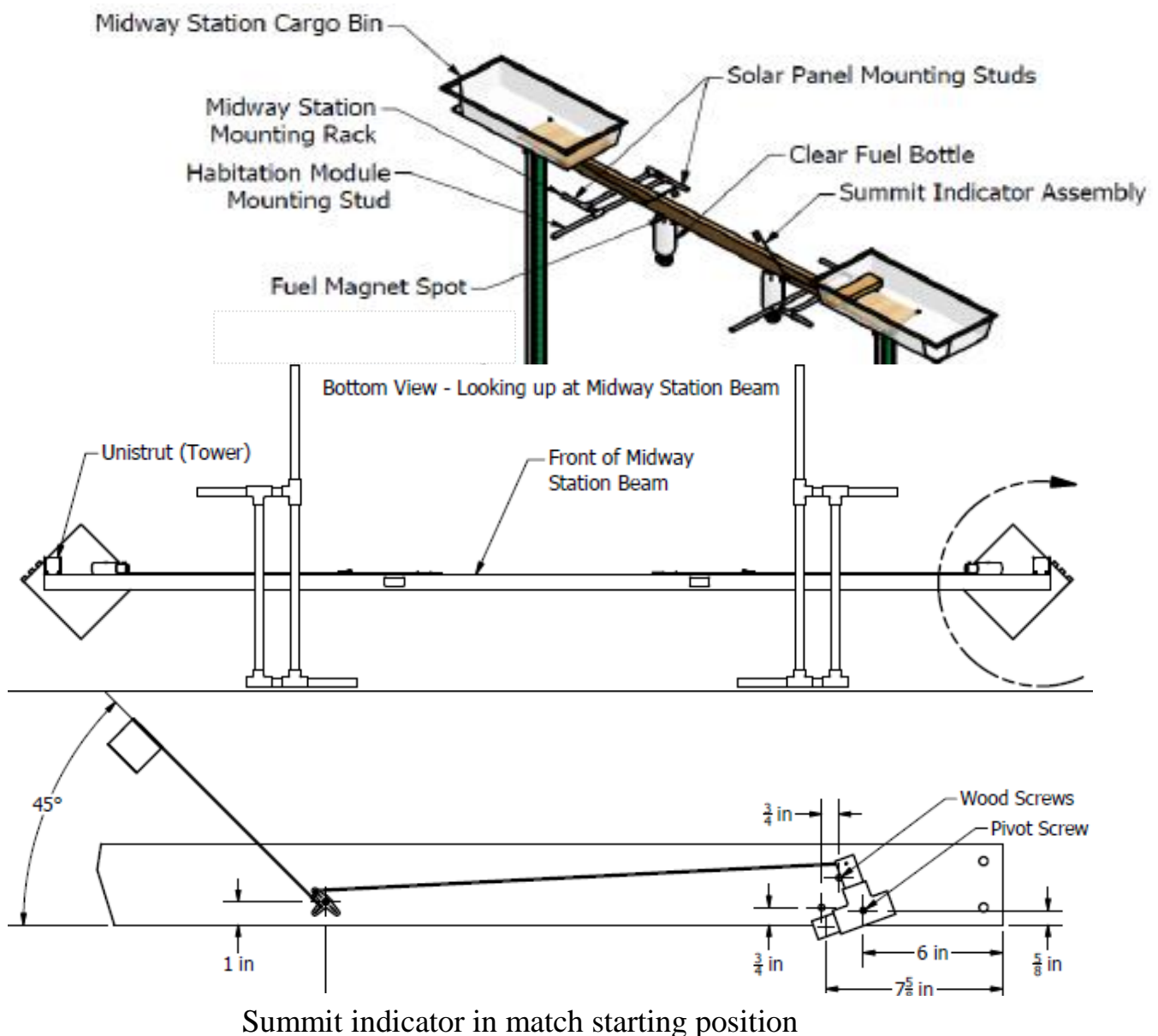
3.4 Midway Station

Midway Station is at the top of the Towers, a minority of the way to Earth orbit.

It has right- and left- handed layouts, similar to the Base rack.

Midway Station consists of the following components:

- (a) Beam: a 2"x4" connecting two Towers. It supports the remaining components.
- (b) Midway Cargo Bin: a translucent 16x34" bin located directly above the Tower;
- (c) Habitation Mounting Stud: a ½" PVC pipe stub pointing toward the spotter side
- (d) Solar Panel Mounting Studs: two ½" PVC pipe stubs
- (e) T-Structure Mounting Slots: a 3" x 8" gap between PVC pipes, one on each side of the Beam
- (f) Fuel Magnet: the Clear Fuel Bottle starts on this magnet which is attached to the bottom of the beam, 34" from the end of the Beam
- (g) Summit Indicator: provides evidence that the robot has reached to top of the Tower.
Operate the Indicator by pushing the protruding bottom edge of the PVC T assembly upward by ½".



4.0 Game Pieces

There is an independent set of game pieces for each tower. Carry only light-weight/low-density game pieces to Midway Station; leave the Waste Cargo Balls on the ground.

Cargo Balls have uniform handling characteristics due to their spherical shape.

The Green Fuel Bottle goes up to Midway Station.

The Clear Fuel Bottle comes down from Midway Station.

Upgrade Midway Station with Solar Panels and a new Habitation Module.

The T-structure is a test of complex robotic space assembly methods; insert T up through the slot and rotate it 90 degrees so that the arms of the T engage the edges of the slot.

4.1 Game Piece balls and bottles:

(a) Waste Cargo Ball : a softball pitching-machine practice ball; 4" dia.

(b) Light Cargo Ball : a softball whiffle ball; 4" dia.

(c) Clear Fuel Bottle : an empty clear 2-liter plastic bottle† with soft-hat and washer

(d) Green Fuel Bottle : an empty green 2-liter plastic bottle† with soft-hat and fender washer

† 2-liter bottles are "generic" 12" tall, 5-dimple-bottom bottles with a 5-1/4" long uniform cylindrical center section. They are slightly pressurized

See Appendix A: Game Piece Images for pictures of the game pieces.

4.2 Game Pieces from Foam Panel or Cardboard

Solar Panel and T-Structures consist of 3/4" thick 'R-MAX' aluminum covered foam insulation.

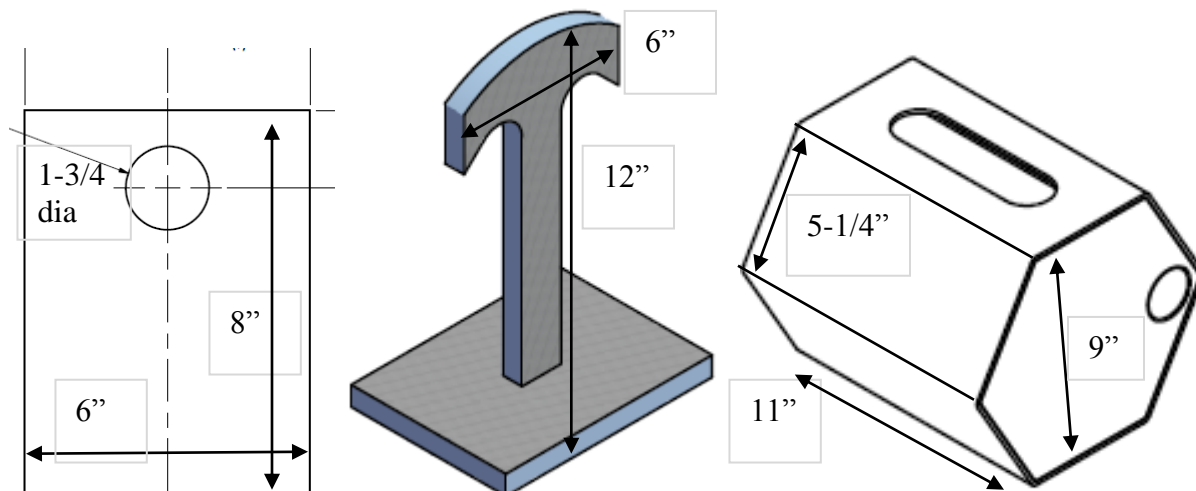
This foam is rigid, low density, and yet durable. It represents aerogel space station building material.

The aluminum skin helps prevent static charging from the solar wind, or the triboelectric effect.

(a) Solar Panel - 6x8" foam with a 1-3/4" mounting hole 3/4" from the center of the 6" top edge

(b) T-structure - a 12" tall x 6" wide T shape with 1" arm droop, on a 6x8" base

(c) Habitation Module - a hexagonal cardboard prism with six 11x5.25" faces, pierced by a 2" mounting tube, and a 2" handling slot.



5.0 Scoring: Table of Game Piece locations and point values

<u>Game Piece Name</u>	<u>Common Name</u>	<u>Diameter</u>	<u>Max Weight (Oz)</u>	<u>Point value (PV)</u>	<u>Starting Location</u>	<u>Scoring Location</u>	<u>#Pieces per Tower</u>
Waste Cargo Ball	practice softball	**4"	7	1	Base rack	Spotter Rack	2
Light Cargo Ball	softball whiffleball	**4"	2	3	Spotter Rack	Midway Cargo Bin	4
Green Fuel Bottle	2-liter bottle	5.25"	2	7	Base rack	Midway Magnetic Mount	1
Clear Fuel Bottle	2-liter bottle	5.25"	2	5	Midway Magnetic Mount	Base rack	1
T-Structure	Foamboard 8" x 12" Tee	1.5"x.75" Stem	2	8	Floor near base rack	Midway T Slot	1
Solar Panel	Foamboard 6x8"; 1-3/4" hole	0.75" thick	1	6 for each stud with a panel	Base rack	Midway Solar Panel Stud	2
Habitation Module	cardboard hex prism, 11" long	9" across flats	11	12	Floor near Base rack	Midway Module Habitation Stud	1

All game piece scores depend only on their final locations at the end of a match.

There is no intended interaction between game pieces in their scoring locations, so it is possible for all game pieces to be in their scoring locations at the same time.

5.1 Scoring Bonuses

<u>Bonus Type</u>	<u>Achieved by</u>	<u>Additional Points</u>
Fuel Tank Exchange Bonus	Placing clear fuel bottle from station into base rack holder and taking the green fuel bottle and attaching it to the mounting point on the station	4
Cargo Diversity Bonus	Scoring a lightweight cargo ball, a solar panel, and the T-structure	9
Rapid Turnaround Bonus	Scored if the entire robot is below the Space Zone at the end of the match	1
Summit Bonus	Toggling summit indicator at Midway Station	2

5.2 General Scoring Requirements

These requirements apply to all scoring objects.

Game pieces are usually either clearly in their right spot (e.g., hanging in the air), or clearly not.

- (a) Scoring positions are checked at the end of the match, after all pieces have come to rest.
- (b) To count as scored, a game piece must be fully supported by the designated holder.
- (c) To count as scored, a game piece must not be touched by anything but the field components; i.e. it may not be touching a robot, the spotter, or a detached mechanism of the robot.
- (d) Game pieces that fall from Space Zone or above are out of play

5.3 Specific Scoring requirements:

The term “solely supported” means the object may have incidental contact with other field component structures, but not be additionally supported by them.

- (a) A Solar Panel Stud scores when it pierces the mounting hole of, and solely supports a Solar Panel.
- (b) The Habitation Module scores when its mounting tube is pierced by, and solely supported by, the Habitation Mounting Stud.
- (c) The T-structure scores when it is solely supported by the arms of the Midway T slot, and pierces the slot. Both arms of the T must be through and above the slot.
- (d) Lightweight Cargo Balls are scored in the Midway Cargo Bin only.
- (e) Waste Cargo Balls are scored in the spotter's rack only.

5.4 Specific non-scoring examples:

- (a) A Solar Panel lying flat on the Midway T slot or on the Midway Beam does not score.
- (b) Waste Cargo Balls, Solar Panels, Habitation Modules, and T-structures do not score when placed in the Midway Cargo Bin.
- (c) A T-structure hanging by one arm on the outside of the Midway T slot does not score.
- (d) Any game piece touching the floor at the end of match does not score.

6.0 Game Operations

6.1 Match Protocol

The driver and spotter place their robot on the Start Platform on the field, and attach the safety cable around the Tower. They may also attach the robot to the Tower, and/or attach the rope to the robot. They may operate the robot controls if necessary to engage robot mechanisms to the rope or Tower. When all drivers and spotters are in their designated boxes, and signal ready, the head referee will start the match. During the match, the robots move the game pieces from their starting positions to their scoring positions.

6.2 Robot Starting Box and starting compliance requirements

- (a) Per Generic Rules 3.2.1, the robot starting configuration must be less than 24x24x24", however, for this year's game, none of the planes of the 24" constraining cube need to be parallel to the floor.
- (b) The robot must have a safety cable attaching it to the tower connecting to the two 1/4" eyebolts provided in the Consumable Kit. See figure 6.2
- (c) Attaching the robot to the tower is allowed, but must be quick, and safety cable is still required.
- (d) Robot must be touching the platform at the start of the match.

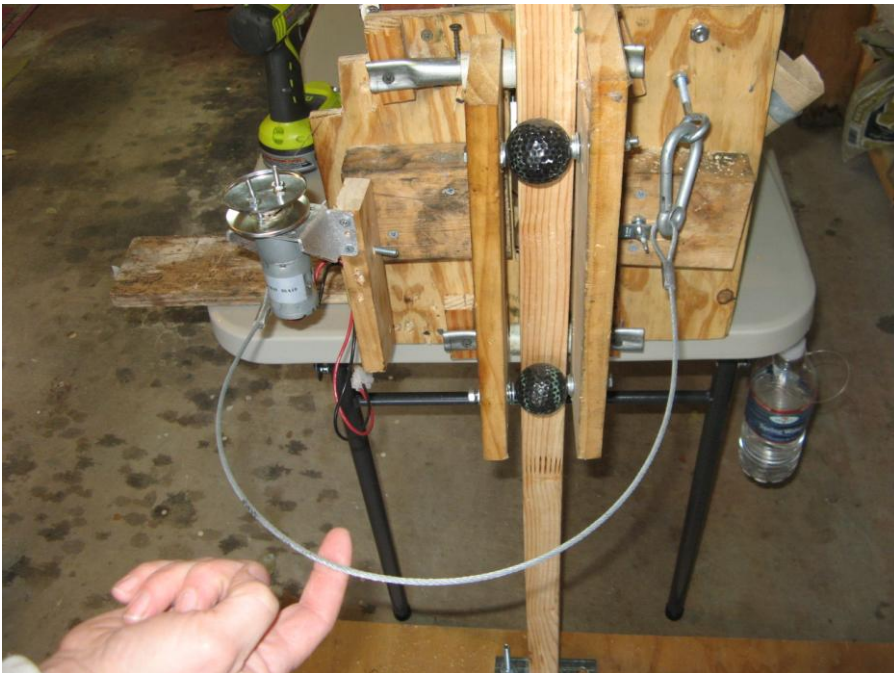


Figure 6.2 Example of safety cable on robot (note: robot is mounted to a wooden "test" pole)

6.3 Spotter/Driver allowed activities:

- (a) Spotter may move by hand Cargo Balls between cargo ship and spotter rack.
- (b) Spotter may rotate cargo ship with cargo ship handle, as needed.
- (c) The Spotter must sit on spotter stool during the entire round. Handicapped Spotters may use their own chair and use a team-provided reach extender to manipulate the field and game pieces as permitted by 6.3 (a) above.

6.4 Spotter/Driver Non-allowed activities:

Referee gives one warning, 20s penalty, and resets situation to correct state for the following infractions. Second infraction is DQ.

- (a) Spotter may not stand up.
Spotter must remain seated from start to finish of match.
- (b) Spotter/Driver may not pick up any items from the floor.
- (c) Spotter/Driver may not place any game pieces on the floor or on the robot.
- (d) Spotter/Driver may not touch detached Robot mechanisms

7.0 Additional Restrictions**7.1 Space Elevator theme restrictions**

The game theme requires transiting the space elevator Space Zone between interactions with the ground zone and interactions with Midway Station. The following rules are the practical enforcement of this restriction. Robot designs outside this theme are not allowed, and will be disqualified from every match.

- (a) The robot must be fully below the Space Zone Plane while interacting with the base rack or cargo ship.
- (b) The robot must be fully above the Space Zone Plane while interacting with Midway Station.
- (c) The robot may incidentally touch the floor, but not be supported by the floor.
(This is not the usual “driving game”!)

7.2 No Interference with other teams:

This is a no-interference game by design and intent. It should be impossible for one team to affect the outcome of another team. Due to field size restrictions, there are some unlikely situations where inadvertent interaction may occur. For example, if a bottle from Team 1 falls from sky and tips over a Team 2 T-structure, the Referee should remove the fallen object, and reset the disturbed piece to its previous position.

7.3 Other Rules:

- (a) Waste Cargo Balls may not be lifted above the Ground Zone (safety hazard).
- (b) Robots may not detach mechanisms while above the Ground Zone

8.0 Competition Protocol

There will be four phases to the head-to-head competition:

- a seeding phase,
- a wildcard phase,
- a semi-final phase, and
- a finals phase.

This protocol will be the same for both hub contests and regional contests.

8.1 Seeding Phase

During the seeding phase, each team will participate in up to eight matches against randomly selected opponents. Fewer than eight matches per team may be played when time limitations exist, but all teams will participate in the same number of matches.

The team ranking during this phase will be based on the average of the points scored during the seeding matches excluding the teams' lowest match score.

For competitions with 32 or fewer teams, the top 7 teams from the seeding phase will automatically advance to the semi-finals phase. The final team to advance into the semi-finals phase will be selected from the remaining teams using a single "wild card match" between the four teams with the highest BEST design notebook scores.

For competitions with greater than 32 teams, the top 14 teams from the seeding phase will automatically advance to the semi-finals phase. The final two teams to advance into the semi-finals phase will be selected from the remaining teams during the "wild card phase"

8.2 Wildcard Phase

For competitions with 32 or fewer teams, the wildcard phase will consist of a single match between the 4 teams with the highest BEST design notebook scores, which have not automatically advanced to the semi-final phase.

For competitions with greater than 32 teams, the wildcard phase will consist of two matches between the 8 teams with the highest BEST design notebook scores which have not automatically advanced to the semi-final phase. This phase will consist of 2 matches of 4 teams (as all matches are limited to 4 teams), which may be played in parallel.

The wildcard phase will be conducted according to the rules for the seeding phase. Each wildcard team will play in only one match during this phase. The team(s) that achieve the highest scores during the wildcard phase will advance to the semi-finals.

8.3 Semi-Finals Phase

During the semi-finals phase, each team will participate in three matches based on the rotation shown in Table 1 or 2. The team ranking at the end of the semi-finals will be based on the total points the team accumulated during their three matches. No scores are dropped and the results of the seeding and wildcard matches are not included. Only the top 4 ranked teams from the semi-finals phase will advance to the finals, regardless of the number of teams competing in the semi-finals.

Table 1. Field Position Assignments for 8-team Semi-Finals

Semi-Final Match	Field Assignment			
	Yellow	Blue	Red	Green
1	Seed 4	Seed 1	Seed 5	Seed 8
2	Seed 2	Seed 8	Seed 3	Seed 7
3	Seed 6	Seed 4	Seed 7	Seed 1
4	Seed 3	Seed 2	Seed 4	Seed 5
5	Seed 5	Seed 7	Seed 8	Seed 6
6	Seed 1	Seed 3	Seed 6	Seed 2

Table 2. Field Position Assignments for 16-team Semi-Finals

Semi-Final Match	Factory Assignment			
	Yellow	Blue	Red	Green
1	Seed 4	Seed 13	Seed 5	Seed 16
2	Seed 2	Seed 10	Seed 3	Seed 15
3	Seed 5	Seed 9	Seed 8	Seed 14
4	Seed 1	Seed 16	Seed 6	Seed 11
5	Seed 8	Seed 4	Seed 2	Seed 12
6	Seed 7	Seed 11	Seed 9	Seed 10
7	Seed 3	Seed 14	Seed 13	Seed 6
8	Seed 10	Seed 12	Seed 1	Seed 5
9	Seed 14	Seed 2	Seed 16	Seed 7
10	Seed 11	Seed 8	Seed 15	Seed 13
11	Seed 1	Seed 7	Seed 4	Seed 3
12	Seed 6	Seed 15	Seed 12	Seed 9

8.4 Finals Phase

The four top ranked teams will participate in 3 matches during the finals phase. Field assignments per match will rotate as shown in Table 3. Points from all previous phases will be disregarded. The final team ranking will be based on the total points accumulated by the team during these 3 finals matches.

Table 3. Field Position Assignments for Finals

Final Production Match	Field Assignment			
	Yellow	Blue	Red	Green
1	Semi-Final 1	Semi-Final 2	Semi-Final 3	Semi-Final 4
2	Semi-Final 4	Semi-Final 3	Semi-Final 2	Semi-Final 1
3	Semi-Final 3	Semi-Final 1	Semi-Final 4	Semi-Final 2

9.0 Appendix A: Game Piece Images



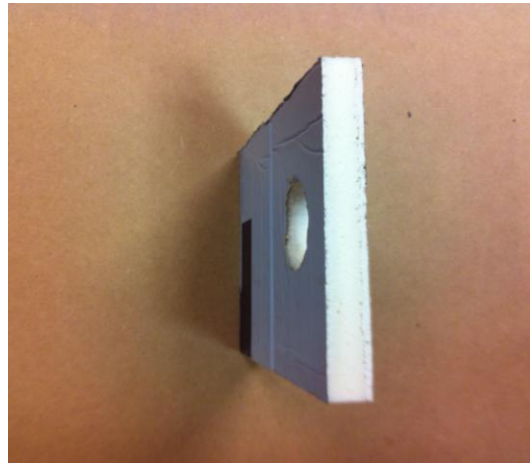
Waste Cargo Ball

Light Cargo Ball



Fuel Bottle with foam soft hat

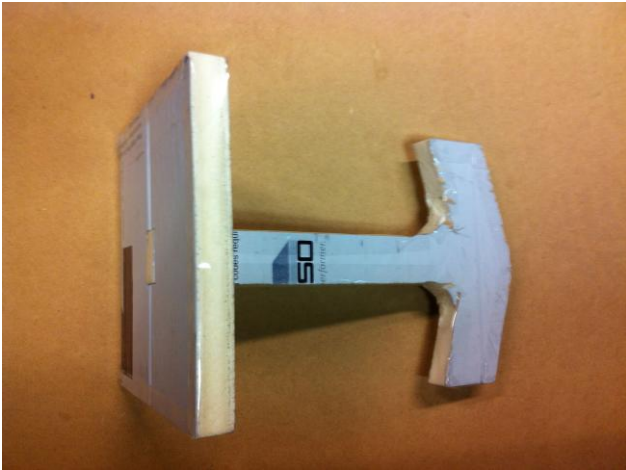
Fuel bottle preparation procedure: Freeze an empty uncapped bottle. While it is cold, tightly seal the bottle with the cap. At room temperature, the bottle will now be pressurized and more solid to grasp. Green Fuel Bottles have a $\frac{1}{4}$ " fender washer glued/taped to the bottom for a strong magnetic attraction. Clear Fuel Bottles have a $\frac{1}{4}$ " flat washer glued/taped to the bottom for a weaker magnetic attraction.



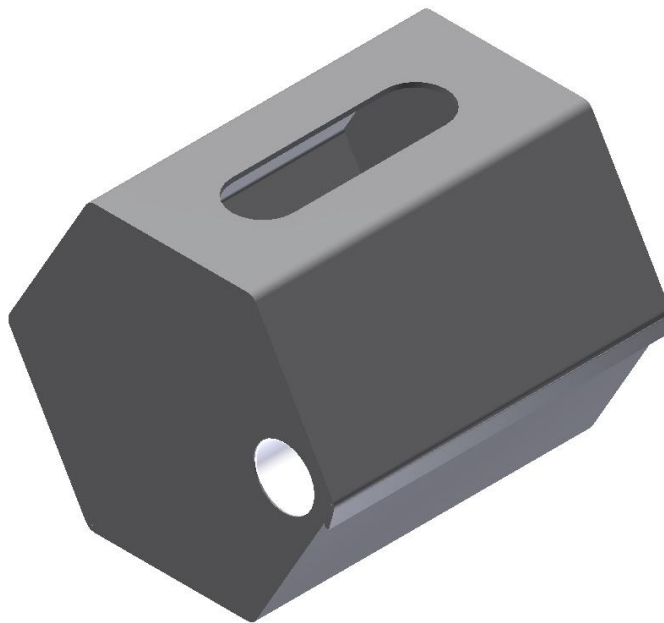
Solar Panel, color with markers/graphics as desired

Solar Panel prep: To protect the raw foam edges and prevent foil covering from peeling off, wrap edges of foam rectangle with 2" wide by 6+8+6+8" long clear packing tape.

T-structure prep: Wrap raw foam edges of T-structure similarly.



T: T-structure



HM: Habitation, color with markers/graphics as desired