Mission to Hubble

BEST 2005 Design Contest

Game Specific RULES

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BEST 2005: Mission To Hubble

Could it really happen? Could a powerful telescope actually be placed in a location only dreamed about by astronomers and scientists, a location where its view of the heavens would be free of the distorting effects of Earth's own atmosphere? Not since Galileo first used his simple optics to peer into the heavens has a telescope promised to so dramatically change our view of the universe. On April 25, 1990 the dream became reality as NASA, using the space shuttle Discovery, deployed the Hubble Space Telescope.

But as the first views were received the engineers and scientists knew something was wrong; its vision was blurred. A massive and exhausting analysis traced the problem to a tiny flaw in the process used to make and test the mirror at the heart of the Hubble space telescope. Even as the problem was being identified, engineers began thinking about how it could be repaired, and a plan evolved. In December of 1993 NASA flew the Space Shuttle and its crew on a mission to add ingenious instruments that would correct the flaw. It was an amazing success and Hubble was able to open the window to discoveries beyond anyone's imagination.

Over the years as the Hubble continued its mission, onboard systems aged and some even failed. But the Hubble is a unique spacecraft; from the beginning it was designed such that astronauts could repair it while it orbited the earth. On three additional shuttle flights the Hubble was repaired and updated by teams of skilled astronauts.

In February 2003, the world was harshly reminded of just how difficult it is to fly into space and return to the Earth. Shuttle Columbia and its crew of explorers were lost on reentry.

As engineers worked to discover what had gone wrong and to design ways to prevent it from happening again, the shuttles did not fly. Although the Hubble was not being serviced, it carried on with its task. But as the Hubble worked, it also continued to age and its batteries and gyroscopes continued to deteriorate and fail. And with no shuttle missions to boost it higher into orbit, the relentless action of earth's gravity and the ever so slight friction of the atmosphere, evident even in orbit, together conspired to pull the Hubble toward an uncontrolled reentry, possibly over populated areas. Despite these concerns, it was necessary for NASA to make the difficult decision to never again send manned missions to service the Hubble. But all was not lost for the Space telescope.

In June of 2004 NASA made the remarkable announcement that it would seek proposals to send a robot to service the Hubble. Had the state of the art in robotic development reached the point where robots could do tasks designed for human hands? NASA believed it had, and the call went out to the robot experts of the world for a robot that could service the Hubble. In September of 2005, BEST Robotics Incorporated answers that call.

Students will be given the task of designing a robot capable of replacing the Hubble's aging batteries and gyroscopes. Additionally, that robot must be able to attach De-orbit rocket engines to the Hubble to allow for a controlled reentry when its mission is finally concluded.

Students will not only design the robot, they will be required to control the robots during the mission itself. Only the BEST robots and only the BEST teams will succeed.

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Mission to Hubble: MISSION BRIEFING

Mission summary: On this complex task, 4 robots will work together to repair the Hubble space telescope. New gyro/battery units and a de-orbit rocket engine have been launched and are waiting in orbit on 4 specially designed Space Tugs. Orbital rendezvous between the BEST servicing robot, the Space Tug and the Hubble can only be maintained for 3 minutes. Robots that complete the mission the quickest will be awarded all future servicing contracts. In the event none of the robots can complete the mission before the rendezvous time expires, robots completing the most mission critical tasks will be considered for future contracts.

Mission objective for each robot: A specific panel on the Hubble will be assigned to each robot. Located on that panel are a power switch, 8 depleted gyro/battery units, and a location for the de-orbit rocket engine.

Mission parameters and restrictions:

Hubble Electrical system restrictions: Robots must first power off their assigned panel before attaching the new gyro/battery units. Failure to do so is known as "hot switching" and will render the affected gyro/battery attachment point useless. Once all the gyro/battery units have been replaced, the main power switch must be returned to the on position. Even if only some of the gyro/batteries were replaced, the switch should still be activated before the 3-minute rendezvous window is over to enable the units that were replaced.

Payload size restriction: To reach orbit the robot must fit into a rocket's payload compartment. This requires the robot to fit, self constrained, into a 24 X 24 X 24 inch cube. During the orbital rendezvous time the robot may unfold into a larger flight configuration.

Payload weight restriction: At launch the robot must weigh less than 24 pounds.

Control of orbital debris: To keep Hubble repair components from becoming potentially unsafe orbital debris, all depleted gyro/battery units must be returned to specially designed locations on the space tug. Any components dropped from the robots will be considered to have drifted away and to be beyond the robot's reach.

On orbit maneuvering restrictions: Once in orbit, Robots will carry out all operations while attached to a maneuvering arm. One mission specialist will control the movement of the arm and another will control the operation of the robot.

Mission Change Notice: It has been confirmed that the de-orbit rocket engines, which are specifically designed for each individual panel, were loaded on the wrong Space Tugs. BEST servicing robots must perform an in-orbit exchange of the rocket engines with the other servicing robots to obtain the proper engine for their assigned panel.

Objective

The objective is to design and build a remotely controlled device to replace the defective gyros/batteries from the Hubble Space Telescope and attach a boost motor, all within the 3-minute time limit. Two Mission Specialists from each team control these robots. The Arm Operator controls the arm on which the robot is mounted, positioning the robot in space. The Robot Driver controls the operation of the various mechanisms on the robot.

1.0 Field Description

The field is approximately 24-feet square. The surface of the field is covered with carpet and the interior of the field contains the Hubble Space Telescope. Four rotating maneuvering arms onto which the robots are attached are spaced evenly around the Hubble. Four Space Tugs, containing replacement gyros/batteries, are placed between the maneuvering arms. A general layout of the field is shown in Figure 1.

Robot drivers will stand in the drivers' boxes, just off the carpet near their Space Tug. Arm operators must keep both hands on their arm's handle, with one hand on each side of the attachment point of the handle to the arm. Removing a hand for a few seconds to take care of something like an itchy nose is permitted; removing a hand in order to lean over for a better view is not permitted and will incur a 20 second "time out" penalty per BEST Generic Rules section 4.3, item 1. During this penalty time, the robot must maintain its position relative to the Hubble.

Detailed dimensions, component specifications, and the locations of the field elements can be found in the separate field drawing document.

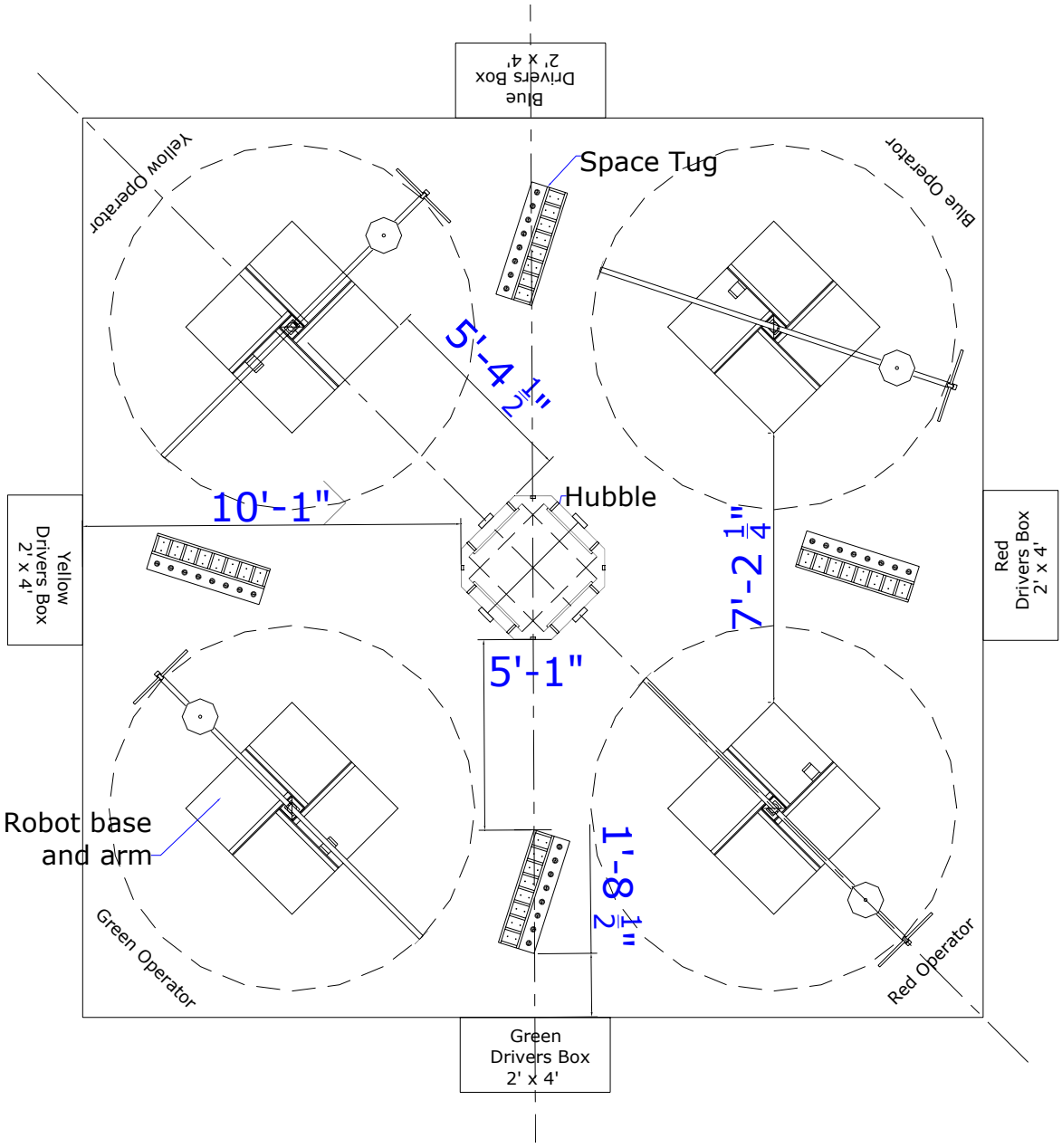

Figure 1 – Field Layout

1.1 The Hubble Space Telescope

The Hubble consists of three parts. The lower half holds the equipment bays and is where all robot activity takes place. The upper half and the solar panels have no scoring opportunities.

The lower half is roughly cylindrical, 4' high, 4' diameter, and octagonal in cross section. Four of the eight panels each contain 8 gyro/batteries, a panel power switch, and a boost motor receptacle. The other four panels each contain an array of LED indicator lights for the 8 gyro/battery sockets, arranged similarly to the gyro/battery sockets.

The upper half is a cylinder, 4’ high and 3’ diameter. The solar panels protrude over the short panels, between two teams.

1.2 The Space Tug

The Space Tug is 37.75” x 12”. At the beginning of each match it will contain 8 new gyro/batteries and 1 boost motor. As old gyro/batteries are removed from the Hubble, they will be placed in 8 stowage spaces located adjacent to the fresh gyro/batteries. The new gyro/batteries will be “upright” (knob on top), on their flat ends, held in place by a magnet. The boost motor will initially be placed in the storage compartment nearest the center of the field. When properly placed in the Space Tug by the robot, the old gyro/batteries will lie on their sides in the compartments, resting on 2 bolts.

1.3 The Maneuvering Arm

The maneuvering arm consists of a stable base, 4’ x 4’ x 2’ tall, onto which is mounted a 10’ beam. The beam is attached at its center. It is free to pivot up and down and it is free to swing left and right. As a result, the robots will move over the partial surface of a sphere. The end of the beam nearest the Hubble has a 6” x 6” x ¼” plate onto which the robots are mounted. The other end of the beam has a control handle and a counterweight. The control handle is wrapped in colored electrical tape. The counterweight is fixed in place and will balance a specific weight robot (it is up to the team to determine this weight). This means when a robot of that weight is mounted to the arm, the control handle will have mass and inertia but no apparent weight.

At one extreme of the arm’s permitted travel is a docking station. The arm end with the handle will be securely fastened here for attaching and detaching the robot. The restraint will be removed and the robot will begin the match from the docking station. The docking station also determines the other extreme of the robot’s travel, when the end with the robot is at the docking station.

1.4 Field Restrictions

1. It is illegal to intentionally tip over or move any portion of the field. A team that intentionally violates this rule will be disqualified from the match per BEST Generic Rules section 4.3, item 5.
2. A referee will untangle machines that become entangled with part of the field or another robot for more than 10 seconds or that appear to be damaging the field because of the entanglement. If the two tangled machines were attempting to transfer a boost motor, the referee will put the boost motor back on the machine which originally had it.
3. Game pieces that are released and touch the carpet are considered to have drifted away in space and are out of play. (This is not desirable because it adds to the amount of debris in orbit.)
4. Since, strictly speaking, there is no floor in this game because the Hubble is drifting in space, interaction with the floor is not permitted. Robots may “bump” the floor in the process of moving about, but actions such as resting on the floor or using the carpet as an anchor against which to pull while deploying an arm are not permitted and will result in disqualification from the match in which they occur.

2.0 Game Pieces

The gyro/batteries and boost motors are empty 1 quart metal paint cans. The cans are approximately 4.25" in diameter and 5" tall.

There is a knob on the top (can lid) end of each gyro/battery. The center of the knob is attached 1" in from the edge of the can. The rotation angle of the cans in the Hubble and on the Tug is arbitrary – that is, on the Hubble the knobs may be toward the top, the bottom, or anywhere in between; on the Tug the knobs may be closer or farther from the robot. Also note that the Hubble socket openings are larger than the diameter of the gyro/batteries, so the gyro/batteries are not necessarily centered in the openings.

The boost motors do not have lids or knobs.

(To enable electronic scoring, the old gyro/batteries are non-conductive on their ends, the new gyro/batteries are non-conductive on their sides, and the boost motors are non-conductive on various parts of their sides. This has no bearing on the game mechanics and is used to electronically determine which cans are where.)

3.0 Scoring

Each team has two scoring locations.

The main scoring location is the Hubble. It is here that the old gyro/batteries are removed, the new gyro/batteries are inserted, and the boost motors are attached.

The secondary scoring location is the Space Tug. It is here that the old gyro/batteries are stowed for return to Earth, failure analysis, and recycling.

Robots must not be in contact with their gyro/batteries at match end or the gyro/batteries will not count toward the score. Robot contact with other teams' gyro/batteries does not cancel the other team's points.

3.1 Gyro/batteries on the Hubble

Replacing the gyro/batteries is complicated by the requirement that "hot switching" is not allowed. The power to your equipment bay must be turned off (switch handle down, green light over switch is on) prior to inserting any new gyro/batteries in that bay. 2 points will be scored the first time the power is turned off. If the power is on, inserting a new gyro/battery will cause a power surge that blows the socket (but not the gyro/battery; it is still usable in another socket); no points can be scored in a socket once it has been blown. Points may still be scored in the other sockets, though, provided the power is turned off when inserting gyro/batteries into them. Of course, after the new gyro/batteries have been placed into their sockets the power should be turned back on (switch handle up, green light off) before the match ends!

"Hot removal", pulling out an old gyro/battery while the power is on, is permitted.

New gyro/batteries must be inserted with their handle end toward the outside of the Hubble (the same orientation as the old gyro/batteries had except that the knob location may be different) and

be in full contact with the magnet inside the socket, i.e. the lid of the gyro/battery must be parallel to the face of the Hubble panel in order to score.

The status of the power switch at the end of the match determines the point value for each gyro/battery properly inserted in the Hubble. Each properly inserted gyro/battery scores 2 points if the power remains off or 8 points if the power is on.

The Hubble power switch may be turned on and off as many times as desired.

As an aid for the Robot Driver, the gyro/battery bays in most fields are monitored and their status displayed on an indicator panel facing the Driver. (This is an optional part of the field and not all hubs have the resources to include it.) There is one LED per socket and the socket status is shown using the following code:

- LED off: The power is on and a new gyro/battery should not be inserted!
- Short LED blinks (1/8 duty cycle): Power is off and socket is ready to receive a new gyro/battery. (The old gyro/battery may still be in the way, though.)
- Long LED blinks (½ duty cycle): Power is off and a new gyro/battery is present. Turn on the power to quadruple the score for this socket!
- LED is on continuously: Power is on and a new gyro/battery is present – maximum score for this socket!

3.2 Boost Motors on the Hubble

Because of the mix-up loading the Space Tugs, the boost motor in each team's tug will not work in the motor attachment point on their panel. It will, though, work on either of the adjacent panels. Therefore two teams will need to cooperate in order to attach the boost motors. One team will have to give their motor to a neighboring team who will then attach it to the Hubble. Successfully completing this task will earn 24 points for each of the two teams involved with the effort (the other two teams will not get these points). Note that each team has *two* opportunities to get these points (for a maximum of 48 points) – one by providing their boost motor to a neighbor and another by receiving a boost motor from a neighbor and attaching it to their equipment bay panel. A team may trade boost motors with one of their neighbors or they may give their boost motor to one neighbor and receive a boost motor from their other neighbor.

Whether the Hubble power is on or off is not important when attaching boost motors.

Since teams are not allowed access to other teams' Space Tugs (see "scoring penalties"), boost motor transfers must be done while in flight!

3.3 Gyro/batteries on the Space Tug

Placing the old gyro/batteries that have been removed from the Hubble into their storage receptacles on the Space Tug earns 4 points for each old gyro/battery properly stored. "Properly stored" means that the gyro/battery is horizontal, nestled in one of the partitions on the space tug, and resting on the bolts protruding from the bottom of the partition.

New gyro/batteries placed into the storage spaces for the old gyro/batteries will not score any points.

3.4 Tie Breaker

The order in which the power switches are first turned off is used to resolve ties as described in the competition protocol section of this document. The power switches are electronically monitored to determine both their switching order and their on/off status.

3.5 Scoring Penalties

Intentionally damaging game pieces is not an acceptable strategy. The referee may disqualify from the match a machine that he or she feels is intentionally damaging game pieces.

Only the team owning a Space Tug or Hubble panel may remove anything from it or place anything onto it; stealing gyro/batteries or boost motors from another teams' space tug or panel on the Hubble is not permitted. Blocking another teams' access to their space tug or their equipment bay on the Hubble is not permitted. If the referee determines that interference has occurred the offending team will be disqualified from the match and any blocking device will be removed.

Attacking another team's Space Tug in an attempt to knock their gyro/batteries or boost motor off the Tug into space is not permitted and the offending team will be disqualified from the match.

A disqualified team automatically receives zero points for the match.

3.6 Scoring Summary

Table 1 summarizes the scoring opportunities and their point values.

Table 1 – Point values at match end

Socket contents	Power switch off	Power switch on
Hubble socket with old gyro/battery or empty	0	0
Hubble socket with new gyro/battery, properly inserted while power off	2	8
Hubble socket with new gyro/battery, improperly inserted while power on	0	0
Each old gyro/battery properly stowed on Tug	4	4
Your boost motor in partner's attach point	24	24
Partner's boost motor in your attach point	24	24
Hubble power turned off at least once	2	2

4.0 Match Protocol

Each match is 3 minutes long and is played with up to 4 teams. If necessary, matches may also be played with fewer than 4 teams. The scoring software will assign teams to a match and will determine teams' starting locations. No scoring changes will be made for matches having fewer than 4 teams.

4.1 Starting Locations

At the start of each match, Robot Drivers and Arm Operators must be in their respective areas and the arm must be positioned inside the docking area. Refer to Figure 1 for an overview of these locations.

It is the responsibility of the Robot Driver to remove the docking pin from the arm holder prior to the start of the match. Forgetful Robot Drivers may remove the pin after the start of the match but will be assessed a 20 second "time out" penalty. The robot will remain in the docking bracket during the penalty time.

At the start of each match, each space tug contains 8 fresh gyro/batteries and one boost motor. The Hubble equipment bays each contain 8 defective gyro/batteries and their power is "on".

4.2 Robot Driver & Arm Operator Rotation

There will be one rotation list for each team (see generic rules for guidelines of how many are needed on the list). Both the Robot Driver and the Arm Operator will be required to rotate. The Arm Operator for each match will be the name next on the list after the Robot Driver. In other words, the Arm Operator in a match will be the Robot Driver in the next match. See BEST Generic Rules section 4.2 for guidelines.

The rotation sequence will be followed all day and continued into the semi-finals and finals.

5.0 Competition Protocol

There will be three phases to the competition: a seeding competition, a semi-final competition, and a final competition.

During the seeding competition, each team will play up to eight matches against randomly selected opponents. Less than eight matches per team may be played when time limitations exist, but all teams must play the same number of matches. The team ranking for the seeding competition will be based on the average of the points scored during the seeding matches excluding the team's lowest scoring match.

The top seven teams from the seeding competition will advance to the semi-final competition. The eighth team for the semi-final competition will be selected from the other teams by a single "wild card" game between the four teams with the highest BEST notebook scores. Regional competitions will include wild card slots in the semi-finals.

During the semi-final competition, each team will play a total of three matches based on the rotation shown in the table below. The team ranking for the semi-finals will be based on the

total points the team accumulates during the three semi-final matches (i.e. no scores are dropped, and the results of the seeding matches are not included.)

Table 2 – Semi-final match rotation

Semi-Final Match	Starting Position			
	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

Competitions with a team count greater than 32 may choose to advance more teams to the semi-final. In this case there will be 16 teams in the semi-final. The top 14 teams from the seeding will advance plus two wild card teams selected from the other teams by a pair of games by the eight teams with the highest BEST notebook scores (each team plays in one of the games). The two teams with the highest scores will get the wild card slots; note that these two teams may come from the same game. Details on the semi-final matches in this case will be provided by the hub or regional.

The four top ranked teams from the semi-final will advance to the final competition where they will play three additional matches in the field starting positions shown in the following table. The final team ranking will be based on the total points scored during the three final matches.

Table 3 – Final match rotation

Final Match	Starting Position			
	Yellow	Blue	Red	Green
1	Semi 1	Semi 2	Semi 3	Semi 4
2	Semi 4	Semi 3	Semi 2	Semi 1
3	Semi 3	Semi 1	Semi 2	Semi 4

5.1 Tiebreaker

The average tiebreaker position will be included in the team position calculation for each phase of the competition. The tiebreaker position is determined by the order in which the Hubble power switches are initially turned off. The tiebreaker position includes only those matches played during a particular phase of the competition. For the seeding matches, the tiebreaker position of a team's lowest scoring match will be dropped (along with the score). If the average tiebreaker

position does not resolve a tie, the tiebreaker positions of the tied teams will be compared starting with the most recent match and proceeding to earlier matches (within a competition phase) until a difference is found. The team that turns off the Hubble power switch first will place before the other team(s).

6.0 Industry Standards

Imagine a world where every piece of electrical equipment you buy has a different power plug… Imagine if every automobile had a different position and order for its foot pedals… Thanks to industry standards we don't live in such worlds. Well, OK, maybe we do, as you'll learn when you go to other countries…

Note that the transfer of the boost motor from one robot to another entails a lot of cooperation between teams. If I am handing you a boost motor sticking up from the top of my robot and your robot is built to receive a boost motor that is hanging down from the bottom of a robot, we've got a problem.

We propose the following as an "industry standard": Boost motors will be presented to the receiving robot with the open end nearest the center of the Earth. The details of how best to hold the motors when giving and when receiving are left to each team to develop.

*** END OF DOCUMENT ***