Boosting Engineering, Science & Technology™

PAY DIRT
BEST 2015 Design Contest
Game Specific Rules
Version 1.5
7 August 2015

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1.0 Introduction

The BEST Inc. Mining Division has purchased a mine that contains several valuable resources in record-shattering concentrations - but there's a problem: The mine is far too dangerous for humans. Consequently, the mine was decommissioned years ago and has since fallen into disrepair. Initial evaluations of the mine have revealed five lucrative materials at various depths beneath the surface: Coal, Iron, Aluminum, Copper, and Lithium.

BEST has released a request for proposal (RFP) to prototype a robotic system that can repair the mine and retrieve the valuable commodities below. Since the winning company will be awarded the contract of running the mine, BEST will be evaluating the companies themselves as well as the prototypes they create. Their project documentation (notebook), sales presentation (oral presentation), company exhibit (booth), as well as their company culture and business ethics (spirit and sportsmanship) will be considered.

Much like the real mining industry, success in the design competition will be determined by net profit and you will be in direct competition with your opponents. Also, the market values of the commodities will change over time, so you may have to adjust your priorities mid-contest. Good luck!

2.0 Objectives

Design and build a prototype robot to repair and operate an underground mine during a three minute match. A robot can score points by doing two things:

(a) Repairing the mine
(b) Extracting materials from the mine

2.1 Repairs

There are two repairs that can be completed. These include:

(a) Fixing the Filtration System
(b) Fixing the Broken Pipes

2.2 Mineable Materials

These are materials that can be extracted from the mine:

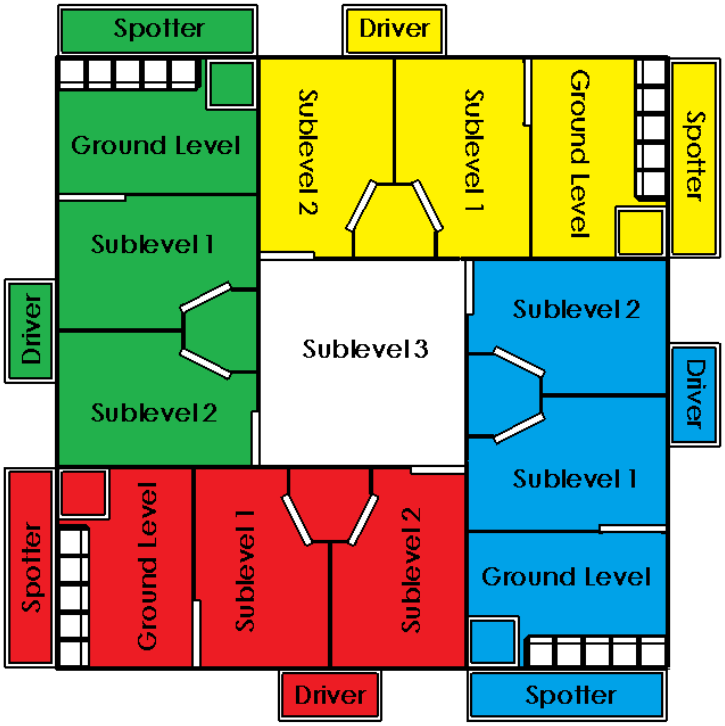
(a) Aggregate (limestone)
(b) Coal (coal)
(c) Magnetite (iron ore)
(d) Bauxite (aluminum ore)
(e) Chalcopyrite (copper ore)
(f) Spodumene (lithium crystals)
(g) Core samples

Items (b) through (f) are considered Commodities, and will be affected by the Market Shift (See Section 6.7).

3.0 Game Field Description

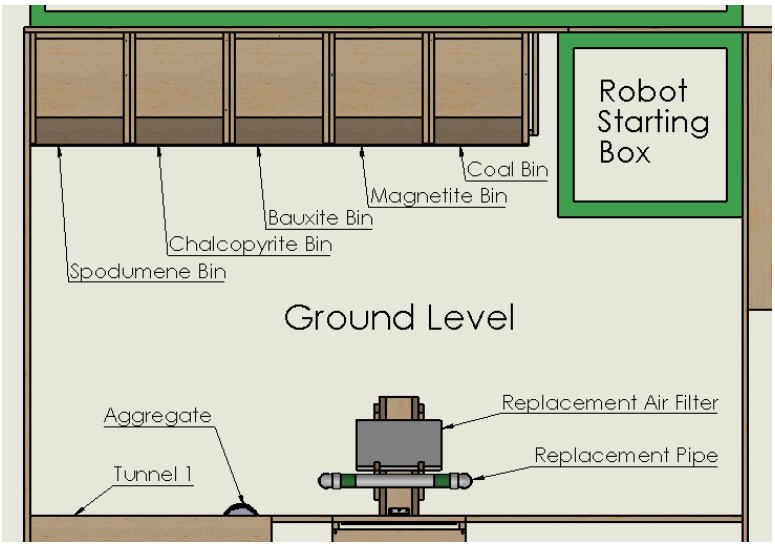
The field is made up of four quadrants called Shafts (red, green, yellow, blue) arranged in a square that is approximately 24'x24'. The Shafts are arranged radially, and are divided into four levels: the "Ground Level" and three "Sublevels."

Each team has their own Shaft, three Levels of which are off-limits to the other teams. Sublevel 3 is a part of all four Shafts, and all teams are allowed to access it. There are Tunnels between each of the Levels within a Shaft (See Section 3.5). The drivers and spotters will be outside the field in their respective areas.



3.1 Ground Level Details

Each Ground Level is located in the corner of the game field. The Ground Level is approximately 5'x8' and contains the following components:



3.1 a) Robot Starting Box

The Robot Starting Box is a 2'x2'x2' area marked on the ground by the outside edge of a tape border. Robots must be completely Contained in the RSB at the beginning of a match.

3.1 b) Commodity Scoring Bins

Five wooden bins are located next to each Robot Starting Box. Commodities must be Supported by *their respective bin* at the end of the match to count as scored. From the perspective of the Spotter Box, in order from left to right, the Scoring Bins are for Coal, Magnetite, Bauxite, Chalcopyrite, and Spodumene.

3.1 c) Spare Parts Rack

The Spare Parts Rack is an angled rack connected to the back of the Coal Chute (See Section 3.2) on the Ground Level. The SPR has two shelves; at the beginning of a match, the top shelf holds the Replacement Pipe and the bottom shelf holds the Replacement Air Filter.

3.1 d) Replacement Air Filter (RAF)

Whoa! The air in this mine is full of dust and hazardous vapors. The air filtration system on Sublevel 1 could really use a new filter.

At the start of a match, the RAF will be in its starting location on the Spare Parts Rack (See Diagram on previous page). The scoring location for the RAF is the Air Filtration System on Sublevel 1 (See section 3.2.c).

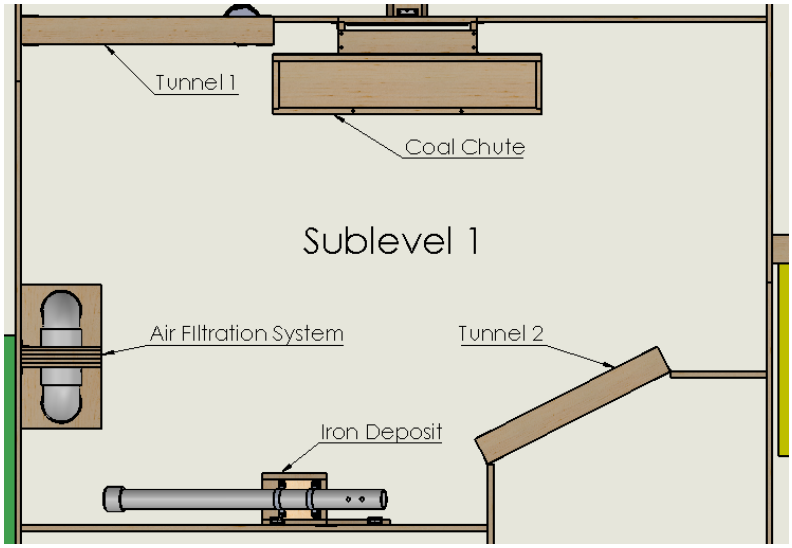
3.1 e) Replacement Pipe (RP)

It looks like the groundwater management system has sprung a leak - all the way down on Sublevel 2! The pipe should probably be fixed before the leak gets out of control.

At the start of a match, the RP will be in its starting location on the Spare Parts Rack (See Diagram on previous page) with the fittings facing down towards the floor. The scoring location for the RP is on top of the two pipes on the Broken Pipe Platform on Sublevel 2 (See section 3.3.c).

3.2 Sublevel 1 Details

Sublevel 1 is approximately 5'x8' and contains the following components:



3.2 a) Coal Chute

A large section of the roof is comprised mostly of coal, and it's ready to collapse; that one little support is the only thing holding it back. Hmm...

The Coal Chute holds 24 pieces of Coal at the beginning of a match. The Coal can be dispensed by rotating the Support Beam until the tray holding the game pieces drops down. Rotating the Support Beam also serves as the tiebreaker. Robots may not touch the Tray, or touch the Coal before the Tray drops.

3.2 b) Iron Deposit

There is a large deposit of loose Magnetite (iron ore) in the wall next to the Filtration System. If it were shifted just slightly, all that ore would spill out onto the ground.

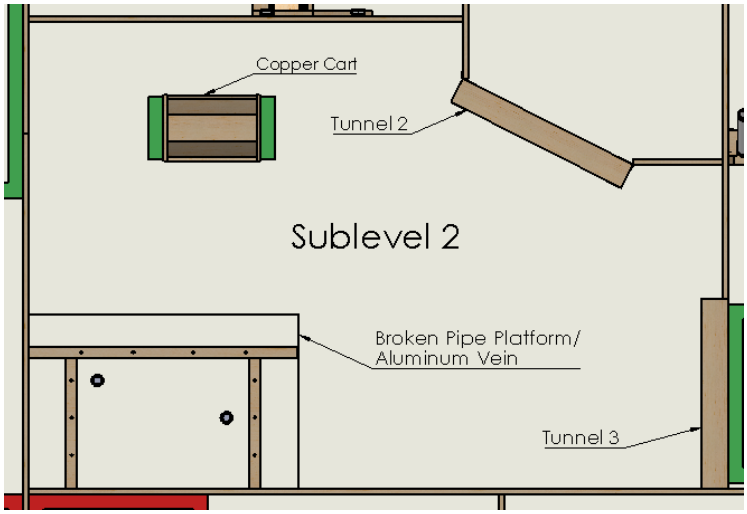
The Iron Deposit holds 20 pieces of Magnetite at the beginning of a match. The Magnetite is practically inaccessible unless the tube containing the game pieces is rotated, which will cause the Magnetite to spill out on its own.

3.2 c) Air Filtration System

This is the scoring location for the Replacement Air Filter. The RAF must be inserted into the 1.5" x 12" slot in the center of the Air Filtration System.

3.3 Sublevel 2 Details

Sublevel 2 is approximately 5’x8’ and contains the following components:



3.3 a) Aluminum Vein

Jackpot! There is a vein of Bauxite (aluminum ore) that runs along the ground near the broken pipes, but it looks like it may take a bit of digging to get it.

The Aluminum Vein is the area underneath the Broken Pipe Platform which contains 16 pieces of Bauxite at the beginning of a match. To be in proper starting position the Bauxite pieces must satisfy 3 conditions: They must (1) be completely underneath the platform, (2) be in contact with a 2x4 wall underneath the Platform, and (3) 6 of the 16 must be on the shorter side, while the other 10 are on the longer side.

3.3 b) Copper Cart

Well, that’s convenient. The last people down here had a mine cart packed full of Chalcopyrite (copper ore) and ready to go; too bad the wheels have completely rusted off.

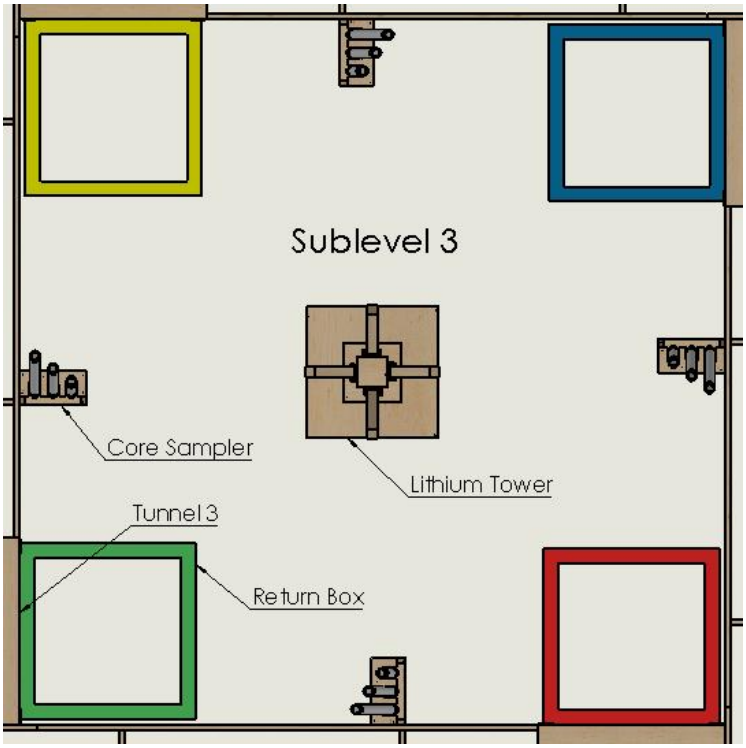
The Copper Cart is a wooden box which holds 12 pieces of Chalcopyrite at the beginning of a match. The Copper Cart will start inside the Copper Cart Box, which is marked by tape lines on Sublevel 2.

3.3 c) Broken Pipe Platform

This is the scoring location for the Replacement Pipe. The Broken Pipe Platform is a 2’x3’ platform with two vertical, 8” tall, 1” diameter PVC pipes upon which the Replacement Pipe can be installed. Each pipe has an electrical tape border on the top edge. This border must be completely covered for the Replacement Pipe to be scored.

3.4 Sublevel 3 Details

Sublevel 3 is an 8’ x 8’ square area, and is accessible by all teams. There are four entrances to Sublevel 3 - one from each team’s Sublevel 2. *Robots are only allowed to enter and exit Sublevel 3 from their own Tunnel.* Sublevel 3 contains the following components:



3.4 a) Lithium Tower

What is quite possibly the world’s largest Spodumene (lithium ore) crystal is right in the middle of Sublevel 3. It’s too big to get all at once, but the smaller pieces will break off.

The Lithium tower is the vertical structure located in the center of Sublevel 3, which has 8 pieces of Spodumene attached to its sides by re-closable fastener strips.

3.4 b) Core Sampler

We need to go deeper! In order to find out what other minerals might still be buried, a core sample can be brought back to the surface for analysis. The bigger the sample, the more valuable the information.

The Core Samples are the long pieces of 1” PVC located to the immediate left when entering Sublevel 3 from Tunnel 3. They are stored largest to smallest, right to left in the Core Sampler.

Note: Anything (besides Core Samples in their starting position) that is on Sublevel 3 and is not in a robot’s Possession is FAIR GAME for all teams - *including any commodities from other levels*.

3.4 c) Return Box

The Return Box is a 2’x2’ tape box on the Sublevel 3 side of each shaft’s Short Tunnel. It is marked by the outside edge of tape lines of the same color as the Shaft it is associated with. The purpose of the box is to reduce or eliminate situations where a robot is unable to return to its own shaft from Sublevel 3.

In the event that a Robot is partially or completely inside of a Return Box that is not its own color *and* that robot is ‘tagged’ (comes into contact with) the robot of the same color as the Return Box, the offending robot has 5 seconds to exit the Return Box or else must serve a 20 second penalty that begins after the offending robot has returned to its own Sublevel 2. (See section 5.1)

3.5 Tunnel Details

There are three Tunnels; one for each passage between Levels. Robots and game pieces are not allowed to move between Levels except by going *through* the tunnels.

3.5 a) Unstable Tunnel

Tunnel 1 (between the Ground Level and Sublevel 1) has a 24” tall and 24” wide opening. The entrance to the mine would be 30” wide, but it is made slightly narrower by a column (5 pieces) of very loose rock called Aggregate, located against the inner side of the Tunnel. The Aggregate is made of “Limestone” and can be scored for points (See Section 4.6).

3.5 b) Crooked Tunnel

Tunnel 2 (between Sublevels 1 and 2) has a 24” tall and 24” wide opening at its narrowest point - however - because of its shape, it will be difficult for a 24” wide robot to pass through.

3.5 c) Short Tunnel

Tunnel 3 (between Sublevels 2 and 3) has a 20” tall and 24” wide opening. Keep in mind that this constraint is shorter than the maximum robot starting height, and may significantly affect your design choices.

4.0 Game Pieces

There are five Commodities in the mine. They are (in order of starting point value): Coal, Magnetite, Bauxite, Chalcopyrite, and Spodumene. Coal and Magnetite are located on Sublevel 1, Bauxite and Chalcopyrite are located on Sublevel 2, and Spodumene is located on Sublevel 3. There is also Limestone Aggregate in Tunnel 1, and Core Samples on Sublevel 3. (See Appendix A for pictures)

4.1 Coal (Coal)

Coal is located on Sublevel 1 and there are 24 coal game pieces per shaft. The coal is represented by multi-faceted foam balls approximately 2.5” in diameter.

4.2 Magnetite \mag-nə-ˌtīt\ (Iron Ore)

Magnetite is located on Sublevel 1 and there are 20 pieces of Magnetite in each shaft. The Magnetite is represented by golf balls. Magnetite is the only game piece that is allowed to be painted.

4.3 Bauxite \bȯk-ˌsīt\ (Aluminum Ore)

Bauxite is located on Sublevel 2 and there are 16 pieces of Bauxite in each shaft. The Bauxite is represented by balls of aluminum foil greater than 2” and less than 3” in diameter.

The foil balls are all made of three square feet of aluminum foil and will be crumpled into a mostly spherical shape. Pieces will be legal if they meet two requirements: (1) They must be able to fit through a 3” hole in any orientation, and (2) they must *not* be able to

fit through a 2”x3” rectangular slot in any orientation. See the field drawings for more information on the game pieces. If Bauxite is damaged during a match to the point of not satisfying either of these conditions, it should be fixed or replaced.

4.4 Chalcopyrite \kal-kə-ˈpī-ˌrīt\ (Copper Ore)

Chalcopyrite is located on Sublevel 2 and there will be 12 pieces of Chalcopyrite in each shaft. The Chalcopyrite is represented by various combinations of PVC pipe fittings.

These game pieces may not all be the same. Each piece of ore is made of two ¾” fittings and a small length of pipe to connect them. The two fittings may be two elbows, two tees, or one of each. Additionally, there is no specification on which ends of the joints are connected, or the rotation of the fittings. Robots should be able to accommodate a large variety of shapes.

4.5 Spodumene \spä-jə-ˌmēn\ (Lithium Crystals)

Spodumene is located on Sublevel 3 in the very center of the field. There are 8 crystals for the whole game field. The Spodumene is represented by pieces of 2”x2”. Teams should remember that all four shafts have access to the Spodumene, so it may not be available for very long.

4.6 Limestone Aggregate

The loose rock on the side of the 1st tunnel (See Section 3.5.a) is made of “Limestone.” The Aggregate is represented by rolls of toilet paper wrapped in a layer of duct tape, and is stacked up against the vertical wall of Tunnel 1. There are 5 pieces of Limestone Aggregate per shaft.

4.7 Core Samples

Core Samples are represented by various lengths of 1” diameter PVC pipe, and are located in the Core Sampler in Sublevel 3. There are three Core Samples: Small (12” long), Medium (24” long), and Large (36” long). The ends of the Core Samples will be marked with tape of the color of the Shaft to which they belong. Teams may only score Core Samples of their own color. To interfere with another team’s Core Samples while they are in starting position is a 20-second penalty that begins *after* the offending robot has returned to its own Sublevel 2. This includes Core Samples that have been removed and put back in starting position by their own robot. The definition of starting position is that the Sample is touching the ground, the base of the Core Sampler, and the top of the Core Sampler.

4.8 Replacement Air Filter

In order to complete this repair, the robot must bring the Replacement Air Filter from the Ground Level and place it in the slot in the Filtration System on Sublevel 1. The Replacement Air Filter (RAF) is represented by an 8 ½”x11” piece of ¾” thick Styrofoam.

4.9 Replacement Pipe

In order to complete this repair, the robot must bring the Replacement Pipe from the Ground Level and place it on both Broken Pipes on Sublevel 2. The Replacement Pipe (RP) is represented by a 16 ¼" long piece of 1 ¼" PVC pipe with one 90 degree elbow on each end.

5.0 Definitions

5.1 Game Field Definitions

- **Game Field** - The area inside the 24' square formed by the outermost Walls, and all permanent structures within that area.
- **Shaft** - Consists of a Ground Level, Sublevel 1, and Sublevel 2 of the same color, and Sublevel 3.
- **Level** - A distinct section of the Game Field separated from the rest of the field by Walls or Tunnels.
- **Walls** - The 3 ½" tall wooden divisions between Levels. Walls are considered to be a barrier across which robots, sub-assemblies, and game pieces are not allowed to cross.
- **Ground Level (GL)** - The Level located in the corner of the game field.
- **Sublevel 1 (S1)** - The Level adjacent to the Ground Level, accessible through Tunnels 1 and 2.
- **Sublevel 2 (S2)** - The Level between Sublevels 1 and 3 - accessible through Tunnels 2 and 3.
- **Sublevel 3 (S3)** - The large Level in the center of the Game Field which can be accessed from all four Shafts through Tunnel 3.
- **Commodities** - Coal, Magnetite, Bauxite, Chalcopyrite and Spodumene.
- **Coal (Coal)** - Small, irregularly-shaped foam stress balls which start in the Coal Chute. There are 24 per Shaft and they are each worth 5 points during the seeding phase.
- **Magnetite (Iron Ore)** - Golf balls which start in the Iron Deposit. There are 20 per Shaft and they are each worth 7 points during the seeding phase.
- **Bauxite (Aluminum Ore)** - Balls of aluminum foil located in the Aluminum Vein. There are 16 per Shaft and they are each worth 10 points during the seeding phase.
- **Chalcopyrite (Copper Ore)** - Various combinations of PVC pipe fittings located in the Copper Cart. There are 12 per Shaft and they are each worth 15 points during the seeding phase.
- **Spodumene (Lithium Crystals)** - Pieces of 2"x2" which are slanted on one end and attached to the Lithium Tower. There are 8 per Game Field and they are each worth 25 points during the seeding phase.
- **Tunnel 1** - The Unstable Tunnel, between the Ground Level and Sublevel 1, which has an opening that is 30" by 24" and partially obstructed by Aggregate.
- **Tunnel 2** - The Crooked Tunnel, between Sublevels 1 and 2, which consists of two 24" by 24" openings that are not parallel to one another.
- **Tunnel 3** - The Short Tunnel, between Sublevels 2 and 3, which has an opening that is 20" tall and 24" wide.

- **Aggregate** - The “Limestone rocks” in the Unstable Tunnel, which are each worth 2 points each, but are not included in the Market Shift. Represented by rolls of toilet paper wrapped in a layer of duct tape.
- **Spare Parts Rack** - A wooden rack located on the Ground Level which serves as the starting location for the Replacement Air Filter and the Replacement Pipe. This is also the scoring location for a Core Sample.
- **Replacement Air Filter (RAF)** - The new filter for the Filtration System. The RAF is represented by an 8.5” x 11” piece of foam.
- **Filtration System** - The wooden structure on Sublevel 1 in which the RAF can be installed.
- **Replacement Pipe (RP)** - The new section of pipe to connect the Broken Pipes. The RP is represented by a PVC pipe with an elbow pipe fitting on each end.
- **Broken Pipes** - The two vertical, 8” tall, 1” diameter PVC pipes on Sublevel 2 upon which the Replacement Pipe can be installed.
- **Coal Chute** - The game field component that holds 24 pieces of Coal at the beginning of the match. The Coal can be released by rotating the Support Beam, which allows the Coal Tray to drop. Rotating the Beam is also the tiebreaker.
- **Support Beam** - The wooden beam that holds the Coal Chute Tray in the upright position.
- **Iron Deposit** - The game field component that holds 20 pieces of Magnetite at the beginning of a match.
- **Aluminum Vein** - The game field component that holds 16 pieces of Bauxite at the beginning of a match.
- **Copper Cart** - The game field component that holds 12 pieces of Chalcopyrite at the beginning of a match.
- **Lithium Tower** - The game field component that holds 8 pieces of Spodumene at the beginning of a match.
- **Core Samples** – PVC pipes of various lengths. There are 12 total - 3 per shaft. A team can only score one of the three per match. The largest, 2nd largest, and smallest Samples are worth 150, 100, and 50 points respectively.
- **Robot Starting Box (RSB)** - The area where the robot must be at the start of a match. It is marked by tape measuring 2’ by 2’ to the outside edge of the tape. The RSB is also a location that can be accessed by both the robot and the spotter (See Appendix D for examples).
- **Return Box** – A 2’x2’ tape box on the Sublevel 3 side of each shaft’s Short Tunnel. A robot is inside the Return Box if any part of the robot is within the outside edges of the tape, extending infinitely upwards. The tape will match the color of the shaft that the Return Box is associated with.

5.1 Scoring/Gameplay Definitions

- **Market Shift** - The adjustment to the point values of the Commodities that occurs before the semifinal phase and before the final phase.
- **Over-mining** - When an above average amount of a Commodity is collected.
- **Under-mining** - When a below average amount of a Commodity is collected.
- **Robot** - The machine controlled by a team's driver during a match. Anything in Possession of a robot is considered a part of that robot.
- **Possession** - A robot is in possession of a game piece if the game piece is fully supported by the Robot.
- **Sub-Assembly** - A non-electrically-powered portion of a robot that can be completely detached from the robot during a match.
- **Detached Sub-Assembly (DSA)** - A Sub-Assembly which is not in contact with its robot. A DSA is no longer considered part of the robot and is considered part of the field.
- **Contained** - An object (game piece, robot, DSA, etc.) is considered Contained by a field component when the object is completely within the infinite vertical planes created by the outermost edges of the field component.
- **Supported** - An object (game piece, robot, DSA, etc.) is considered Supported by a field component when all of the weight of the object rests on only that field component. Note: An object can be Supported by a field component, even if it is not Contained by that field component. An object is still considered supported if all of the object's weight rests on another Supported object. (See appendices C and D for examples)
- **Throwing** - An object is considered thrown if it is (1) travelling upwards when it leaves the Possession of the Robot or Spotter or (2) if it travels over one foot horizontally in the air before or after hitting another object (the ground, a field component, another game piece, etc.).
- **Blocking** - A robot (A) is considered to be blocking another robot (B) if robot (A) is inside the Return Box of robot (B), and remains in the Return Box for 5 or more seconds after being 'Tagged' by robot (B). The penalty for blocking is a 20-second penalty that begins *after* the offending robot (A) has returned to its own Sublevel 2.
- **Tagging** - A robot (B) may "Tag" another robot (A) to indicate that robot (A) is within the Return Box of robot (B) and that robot (B) wishes to return to its own Sublevel 2. The offending robot (A) will have 5 seconds to exit the Return Box before a Blocking penalty is applied.

  If the Tagging robot (B) interferes with the offending robot (A)'s ability to exit the Return Box, the referees may very well extend the 5 seconds as they see fit. This is to prevent robots from forcing other robots to incur penalties.

NOTE: Rules have been put in place to reduce the frequency of situations where a robot is unable to return to its Ground Level. However, it is entirely possible that a "loophole" or "fluke" situation will arise. It should be understood that there is an inherent risk in entering the Sublevels - especially Sublevel 3 - of a robot not being able to return to the Ground Level in time to score the game pieces in its possession.

6.0 Scoring

(* Ground Level = GL, Sublevels 1, 2, and 3 = S1, S2, S3)

Game Piece	Initial (Seeding) Value	Semifinals & Finals Value	Starting Location*	Scoring Location*	#Pieces per shaft
Aggregate	**2**	**2**	**Tunnel 1**	**Robot Starting Box (GL)**	**5**
Coal	**5**	**?**	**S1**	**Coal Bin (GL)**	**24**
Magnetite	**7**	**?**	**S1**	**Iron Bin (GL)**	**20**
Bauxite	**10**	**?**	**S2**	**Aluminum Bin (GL)**	**16**
Chalcopyrite	**15**	**?**	**S2**	**Copper Bin (GL)**	**12**
Spodumene	**25**	**?**	**S3**	**Lithium Bin (GL)**	**8 (for all 4 shafts)**
Core Samples	**50, 100, or 150**	**50, 100, or 150**	**S3**	**Spare Parts Rack (GL)**	**3 (1 can be scored)**
RAF	**100**	**100**	**GL**	**Filtration System (S1)**	**1**
RP	**100**	**100**	**GL**	**Broken Pipes (S2)**	**1**

6.1 General Scoring Requirements

a) Any mineable material is considered scored if it is supported by its scoring location at the end of the match.
b) Scoring positions are checked after the match when all game pieces have come to rest or 10 seconds after the match has ended, whichever comes first.
c) To count as scored, a game piece must not be in contact with the Robot or Spotter at the end of the match. Detached Sub-Assemblies are not considered part of the Robot, and may be in contact with scored game pieces at the end of the match.
d) If a Core Sample, RAF, or RP is not in a robot's Possesion and is crossing a Wall (is within more than one Level), it must be retrieved from the "deepest" Level. For example, if a red Core Sample falls onto the wall between Sublevel 3 and red Sublevel 1, the red robot may pick it up, but it must do so from Sublevel 3.

Non-Scoring Examples:

a) Commodities not completely supported by their Scoring Bin will not count.
b) If the RAF is supported by the Filtration System, but is not *all the way* inside the slot such that it cannot be seen from the side, it will not count as scored.

c) If the RP is Supported by the Broken Pipes, but the tape lines at the top ends of the Broken Pipes are not both completely covered by the RP, it will not count as scored.
d) If the Core Sample is resting partially on the Spare Parts Rack but also touching the floor it will not score.

6.2 Scoring Commodities

See Appendix C for pictures of properly and improperly scored game pieces.

6.2 a) Coal

Each piece of Coal is worth 5 points during seeding phase. This point value is subject to change following a Market Shift (See Section 6.7). In order to count as scored, the Coal must be Supported by the left-most Scoring Bin (when viewed from inside the spotter box) at the end of the match.

6.2 b) Magnetite (Iron Ore)

Each piece of Magnetite is worth 7 points during seeding phase. This point value is subject to change following a Market Shift. In order to count as scored, the Magnetite must be Supported by the Scoring Bin second from the left (when viewed from inside the spotter box) at the end of the match.

6.2 c) Bauxite (Aluminum Ore)

Each piece of Bauxite is worth 10 points during seeding phase. This point value is subject to change following a Market Shift. In order to count as scored, the Bauxite must be Supported by the middle Scoring Bin at the end of the match.

6.2 d) Chalcopyrite (Copper Ore)

Each piece of Chalcopyrite is worth 15 points during seeding phase. This point value is subject to change following a Market Shift. In order to count as scored, the Chalcopyrite must be Supported by the Scoring Bin second from the right (when viewed from inside the spotter box) at the end of the match.

6.2 e) Spodumene (Lithium Crystals)

Each piece of Spodumene is worth 25 points during seeding phase. This point value is subject to change following a Market Shift. In order to count as scored, the Spodumene must be Supported by the right-most Scoring Bin (when viewed from inside the spotter box) at the end of the match.

6.3 Scoring Aggregate

Each piece is scored for 2 points if it is Supported by the Robot Starting Box at the end of the match (See Appendix C). Since it is a very common material, Aggregate's point value is not affected by the Market Shift (See Section 6.7).

6.4 Scoring Core Samples

The largest (36 in.) Core Sample is worth 150 points, the second largest (24 in.) is worth 100 points, and the smallest (12 in.) is worth 50 points. The Core Sample must be supported by the Spare Parts Rack in place of either the RAF or the RP (RAF and/or RP must have been removed from the Spare Parts Rack. The Core Sample must be in contact with both sides of the shelf (top or bottom). See Appendix C). Since retrieving more than one Sample would be redundant, each team can only score *one* of *their shaft's* Core Samples per match. The Core Samples *must be scored by a robot*.

6.5 Scoring the Replacement Air Filter

In order to count as installed, the RAF must be completely inside the 1 ½" x12" slot in the Filtration System such that it does not break the vertical plane of the front of the Filtration System at the end of the match (See Appendix C). This repair is worth 100 points, but is not required. If a team decides to perform this repair, the RAF must be scored by a robot.

6.6 Scoring the Replacement Pipe

In order to count as scored, the RP must be Supported by the two vertical Broken Pipes and completely cover the line of electrical tape at the top of each of the Broken Pipes (see Appendix C). This repair is worth 100 points, but is not required. If a team decides to perform this repair, the Replacement Pipe must be scored by a robot.

6.7 Market Shift

Real world mining is an industry where a small fluctuation in the value of the commodities being mined has a huge impact. Mining requires a sizeable investment and in order to ensure that the return is profitable, companies have to pay extremely close attention to long-term market projections. If there is an overabundance of a certain commodity, the value will drop. Likewise, if a certain commodity is in short supply, it becomes more valuable.

The point value of each Commodity will start at the value specified in this document (e.g. coal is worth 5 points each), and will remain the same throughout all Seeding and Wildcard matches. It should be noted that Aggregate and Core Samples are not considered Commodities, and will not be affected by the Market Shift. The point value of the Commodities will be adjusted at the beginning of semi-finals, and the beginning of finals. The finals market shift is based on the semi-final matches only. These new values will be rounded to the nearest 1/100th of a point. The new values and the teams which are advancing to Semifinals and Finals will be announced at the same time. Teams that want more time to strategize for the semifinals or finals are encouraged to compute their own estimates of the Market Shift, or plan multiple contingencies.

The Market Shifts will be computed for each Commodity. "Over-mined" Commodities will drop in value *proportionally to how much they were Over-mined*. "Under-mined" Commodities will rise in value *proportionally to how much they were Under-mined*. A detailed explanation of the Market Shift calculation is on the next page.

6.7 a) Detailed Explanation of Market Shift

To calculate the Market Shift requires 2 pieces of information per commodity: The “Current Point Value”, and the “Ore Percentage.” The “Ore Percentage” can be calculated by dividing the total amount of one commodity scored by all teams in seeding matches (or semi’s), by the total amount that could have been scored. For example, if there was one seeding match and 4 teams, and all teams scored 3 Coal, the “Ore Percentage” for Coal would be 12/96 or 12.5%. (Note: these numbers will be much larger than in the above example since there will be much more than one match played.) “Ore Percentages” will range from 0% to 100%.

The first calculation is the “Average Percentage.” This is simply the result of adding the 5 “Ore Percentages” together and dividing by 5.

$$"Average\ Percentage" = \frac{\%\ Coal + \%\ Iron + \cdots + \%\ Lithium}{5}$$

The next calculation is to find the “Expanded Ore Percentages.” In order to maximize the variation of point values, the highest “Ore Percentage” is increased to 100%. Likewise, the lowest “Ore Percentage” is reduced to 0%. The other three “Ore Percentages” must be placed proportionally within this range. To find the middle three “Ore Percentages,” the following formula can be used:

$$"Expanded\ Ore\ Percentage" = \frac{X - L}{H - L} * 100\%$$

(H = Highest “Ore Percentage”, L = Lowest “Ore Percentage”, X = The “Ore Percentage” of which we are trying to find the “Expanded Ore Percentage.”)

The next calculation is to find the “Expanded Average Percentage.” The formula above can be used if X is the original “Average Percentage.”

The next calculation is to find the “Shift Percentage” of each commodity. This is equal to the “Expanded Average Percent” minus the “Expanded Ore Percent.” Note that if the commodity was Over-mined, the “Expanded Average Percent” will be smaller than the “Expanded Ore Percent,” and the “Shift Percentage” for that ore will be negative. The negative “Shift Percentage” will reduce the value of the Over-mined commodity, as expected. The opposite is true for Under-mining.

The final calculation is to find the “New Point Value.” This is equal to the “Current Point Value” plus the product of the “Current Point Value” times the “Shift Percentage.” A positive “Shift Percentage” will result in an increase in the Point Value for the next phase.

An example of these calculations with example numbers is on the next page.

6.7 Example 1:
At this particular competition, during the seeding phase, all the teams together get 55% of the Coal, 20% of the Magnetite, 30% of the Bauxite, 80% of the Chalcopyrite, and 30% of the Spodumene.

Commodity	"Current Point Value"	"Ore Percentage" (Seeding)
Coal (Coal)	5	55.00%
Magnetite (Iron)	7	20.00%
Bauxite (Aluminum)	10	30.00%
Chalcopyrite (Copper)	15	80.00%
Spodumene (Lithium)	25	30.00%

$$\text{"Average Percentage"} = \frac{55\% + 20\% + 30\% + 80\% + 30\%}{5} = \mathbf{43}\%$$

$$\text{"Expanded Ore Percentage"}\ of\ Coal = \frac{55 - 20}{80 - 20} * 100\% = 58.33\%$$

$$\text{"Expanded Avg. Percentage"} = \frac{43 - 20}{80 - 20} * 100\% = 38.33\%$$

Commodity	"Expanded Ore Percentage"	"Shift Percentage"
Coal (Coal)	58.33%	38.33% - 58.33% = **-20%**
Magnetite (Iron)	0%	38.33% - 0% = **+38.33%**
Bauxite (Aluminum)	16.66%	38.33% - 16.66% = **+21.66%**
Chalcopyrite (Copper)	100%	38.33% - 100% = **-61.67%**
Spodumene (Lithium)	16.66%	38.33% - 16.66% = **+21.66%**

Commodity	"CPV" + ("Shift %" * "CPV")	"New Point Value"
Coal (Coal)	5 + (-20% * 5) =	4.00
Magnetite (Iron)	7 + (38.33% * 7) =	9.68
Bauxite (Aluminum)	10 + (21.66% * 10) =	12.16
Chalcopyrite (Copper)	15 + (-61.67% * 15) =	5.75
Spodumene (Lithium)	25 + (21.66% * 25) =	30.42

6.7 Example 2:

During the semi-finals, the teams completely ignore Coal and Chalcopyrite, and get 80% of the Bauxite, 70% of the Magnetite, and 100% of the Spodumene.

Commodity	"Current Point Value"	"Ore Percentage" (Semi's)
Coal (Coal)	4	0%
Magnetite (Iron)	9.68	70%
Bauxite (Aluminum)	12.16	80%
Chalcopyrite (Copper)	5.75	0%
Spodumene (Lithium)	30.42	100%

$$\text{"Average Percentage"} = \frac{0\% + 70\% + 80\% + 0\% + 100\%}{5} = \mathbf{50}\%$$

$$\text{"Expanded Ore Percentage"}\ of\ Bauxite = \frac{80 - 0}{100 - 0} * 100\% = 80\%$$

$$\text{"Expanded Avg. Percentage"} = \frac{50 - 0}{100 - 0} * 100\% = 50\%$$

Commodity	"Expanded Ore Percentage"	"Shift Percentage"
Coal (Coal)	0%	50% - 0% = **+50%**
Magnetite (Iron)	70%	50% - 70% = **-20%**
Bauxite (Aluminum)	80%	50% - 80% = **-30%**
Chalcopyrite (Copper)	0%	50% - 0% = **+50%**
Spodumene (Lithium)	100%	50% - 100% = **-50%**

Commodity	"CPV" + ("Shift %" * "CPV")	"New Point Value"
Coal (Coal)	4 + (+50% * 4) =	6
Magnetite (Iron)	9.68 + (-20% * 9.68) =	7.74
Bauxite (Aluminum)	12.16 + (-30% * 12.16) =	8.51
Chalcopyrite (Copper)	5.75 + (+50% * 5.75) =	8.63
Spodumene (Lithium)	30.42 + (-50% * 30.42) =	15.21

These "New Point Values" (6, 7.74, 8.51, 8.63, 15.21) will be used during Finals.

7.0 Game Operations

7.1 Spotter and Driver Allowed Activities

a) The spotter may move Commodities between the Robot Starting Box, the Spotter Box, and the Scoring Bins. The spotter may also move Commodities between different Scoring Bins (e.g. To relocate a misplaced game piece, etc.). Commodities that the Spotter is allowed to interact with must be Contained by the Robot Starting Box *and* not be in contact with the Robot.
b) Spotters are allowed to touch/pick up a Detached Sub-Assembly, if it is *Supported by* the Robot Starting Box, the Spotter Box, and/or one or more of the Scoring Bins.
c) Spotters and Drivers are allowed to dance during the match as long as they stay out of referees' way and inside their respective areas, and especially if the song that is currently playing is their "jam."

7.2 Spotter and Driver Non-Allowed Activities

a) The Driver and Spotter are not allowed to leave their respective areas during the match. (20 second penalty)
b) The Driver is not allowed to touch the game pieces, the game field, or Robots in any way during the match. (20 second penalty)
c) The Spotter is not allowed to touch the Replacement Air Filter, the Replacement Pipe, or the Core Samples. (20 second penalty)
d) The Spotter is not allowed to pick up any game piece that is not inside the Robot Starting Box, the Scoring Bins, or the Spotter's Box. (20 second penalty)
e) The Spotter is not allowed to Throw anything. (20 second penalty)
f) The Spotter is not allowed to move Scoring Bins. (20 second penalty)
g) Drivers and Spotters are not allowed to intentionally move game pieces across Walls. Game pieces must go through Tunnels to pass from one level to the next. (20 second penalty)

NOTE: Anything the Spotter is touching is considered part of the spotter, i.e. touching is still considered touching even if the spotter is actually making contact via another game piece, gloves, etc.

7.3 Robot Allowed Activities

a) Robots are allowed to interact with the game field as defined in the generic rules.

7.4 Robot Non-Allowed Activities

a) Robots are not allowed to cross the Walls that define each Level of the field. These Walls represent solid rock walls. For ease of refereeing, incidental crossing of walls (i.e. a robot accidentally crossing with arm) is permitted, but intentionally moving game pieces across a wall is not.
b) Robots are not allowed to cause a game piece or DSA to cross the Walls.
c) Robots are not allowed to 'Block' other robots from returning to that robot's Sublevel 2 from Sublevel 3. See the definition of Blocking in Section 5.2. The penalty for Blocking is a 20-second penalty that begins *after the offending robot has returned to its own Sublevel 2.*

d) Robots are not allowed to detach Subassemblies in Sublevel 3 or move an already detached Subassembly into Sublevel 3.

8.0 Competition Protocol

8.1 Seeding Phase

The team ranking during this phase will be based on the total points scored during the seeding matches, not the average.

8.2 Wildcard Phase

Game pieces scored during wildcard matches *do not affect the Market Shift*.

8.3 Semi-Finals Phase

All advancing teams' scores will reset to zero. The team ranking during this phase will be based on the total points scored during the Semi-Final matches, not the average.

Before the Semi-finals phase begins, the first Market Shift will take place, and the point values of the five Commodities (Coal, Magnetite, Bauxite, Chalcopyrite, Spodumene) will change. The new point values will be announced at the same time as the announcement of the advancing teams (See Section 6.7). All advancing teams' scores will reset to zero.

8.4 Finals Phase

All advancing teams' scores will reset to zero. The team ranking during this phase will be based on the total points scored during the Final matches, not the average.

Before the Finals phase begins, the second and final Market Shift will take place. This Market Shift will be based on the "market" information gathered during the matches in the Semi-Finals phase only (not combined with the seeding matches). The new point values of the five Commodities will be announced at the same time as the announcement of the advancing teams (See Section 6.7). All advancing teams' scores will reset to zero.

Appendix A – Game Pieces

Limestone

Bauxite

Replacement Air Filter

Coal

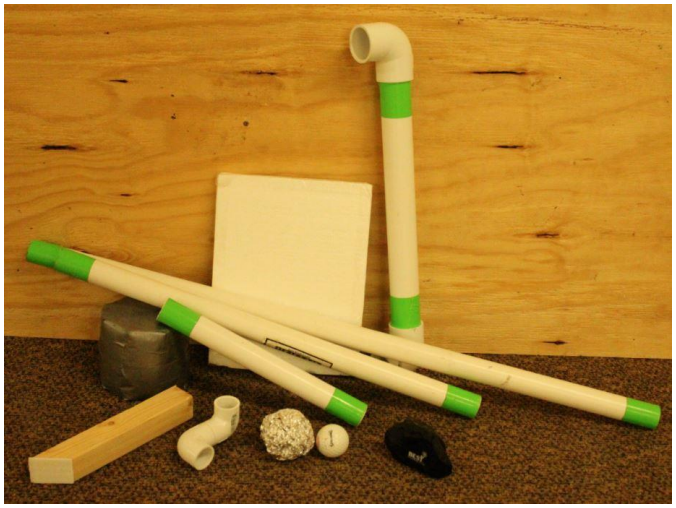
Chalcopyrite

Replacement Pipe

Magnetite

Spodumene

Core Sample (Small)



Note: As stated in the Field Drawings, the Chalcopyrite may exist in many configurations.

Note: As stated in the Field Drawings, the Bauxite shape and size may vary.

Appendix B – Starting Positions

Limestone Aggregate

Aggregate should not restrict opening more than 6".

Coal

Coal: BEST logo should face forward and be upright.

Magnetite

Viewing Holes: If 1 ball is visible, the pipe should be full (contains 20 balls).

Appendix B – Starting Positions

Bauxite

Figure 1 – Correct, all pieces are in contact with a 2x4, and underneath platform.

Figure 2 - Also correct, pieces do not have to be spread out.

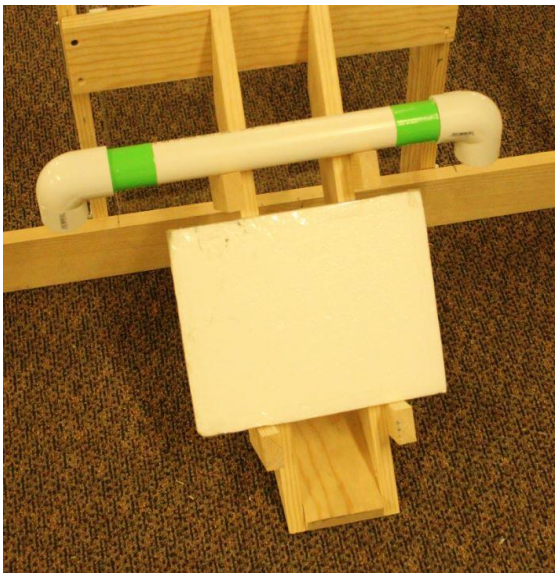
Figure 3 – Incorrect, must be 10 Bauxite on long side, 6 on short side.

Appendix B – Starting Positions

Chalcopyrite

Spodumene

Spare Parts



Core Samples

Appendix C – Scoring Positions

Correct 1: All commodities are Supported by their Bin.

Incorrect 1: The Bauxite and Magnetite are swapped, those game pieces will NOT be scored. The Coal, Chalcopyrite, and Spodumene will be scored.

Appendix C – Scoring Positions

Correct 2: Commodities are Supported by Bins.

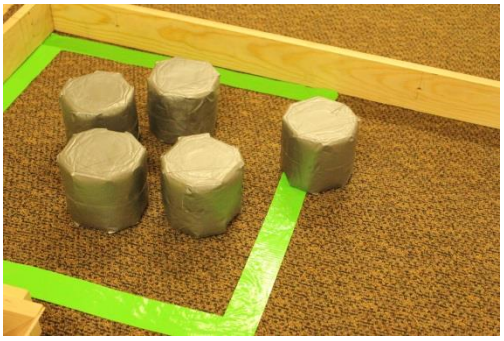
Incorrect 2: The one Spodumene and the one Chacopyrite are not fully Supported by their bins. The Commodities that are Supported by their bins in this picture will still be scored.

Correct 3: Coal is Supported by its own Scoring Bin.

Incorrect 3: Coal is not fully Supported by its own Bin.

Appendix C – Scoring Positions

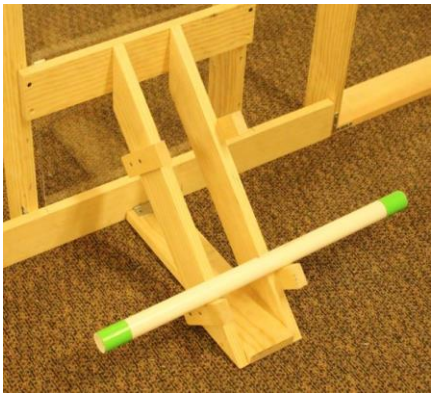
Correct 4: Aggregate is Supported by RSB.



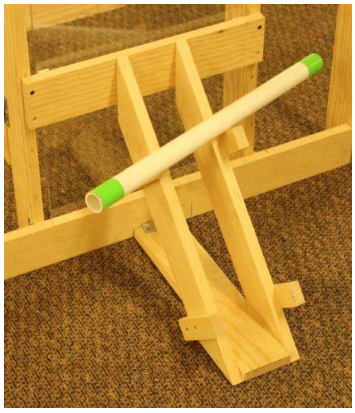
Incorrect 4: Four of these Aggregate score, the one that is not Supported by the RSB does not.

Correct 5: Aggregate is Supported by an Aggregate that is Supported by the Robot Starting Box.

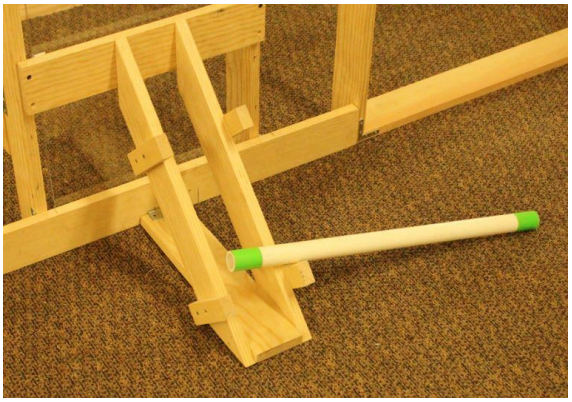
Appendix C – Scoring Positions



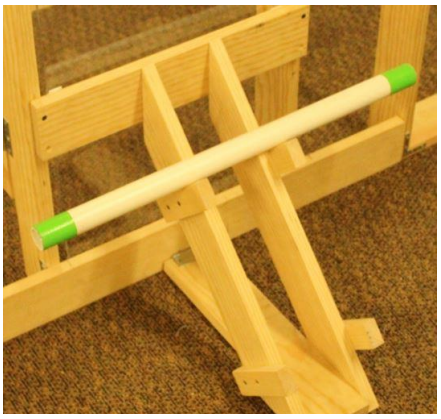
Correct 6: Core Sample is completely Supported by both sides of the lower shelf. (Incidental contact with the slanted sides is allowed)



Correct 7: Core Sample is completely Supported by both sides of the upper shelf. (Incidental contact with the slanted sides is allowed)



Incorrect 5: Core Sample is NOT completely Supported by both sides of the lower shelf.



Correct 8: Core Sample is completely Supported by both sides of the upper shelf. (Incidental contact with the slanted sides is allowed)

Incorrect 6: A Core Sample cannot be scored on both shelves simultaneously.

Correct 9: All three Samples are scored properly. The largest properly scored Core Sample will be scored, any others will not. There is no reason to score multiple Core Samples.

Appendix C – Scoring Positions

Correct 10: RAF is not visible.

Incorrect 7: RAF is visible.

Incorrect 8: RAF is visible.

Incorrect 9: RAF is visible.

Correct 11: RAF is not visible.

Appendix C – Scoring Positions

Incorrect 10: RP only covering one tape line.

Incorrect 11: RP Supported by both pipes, but not covering the tape lines.

Correct 12: RP Supported by two pipes and covering the tape lines.

Appendix D – Spotter Allowed Activities and Sub-Assemblies

Correct 13: The Copper Cart is like a Sub-Assembly; since it is supported by the RSB the Spotter may touch its contents.

Incorrect 12: The Copper Cart is like a Sub-Assembly; since it is NOT supported by the RSB the Spotter may NOT touch its contents.

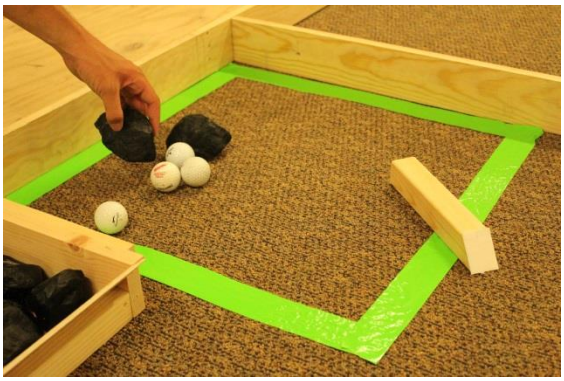
Correct 14: The Copper Cart is like a Sub-Assembly; since it is supported by the RSB the Spotter may touch it, e.g. to dump the contents into their bin.

Incorrect 13: The Copper Cart is like a Sub-Assembly; since it is NOT supported by the RSB, the spotter may NOT touch it.

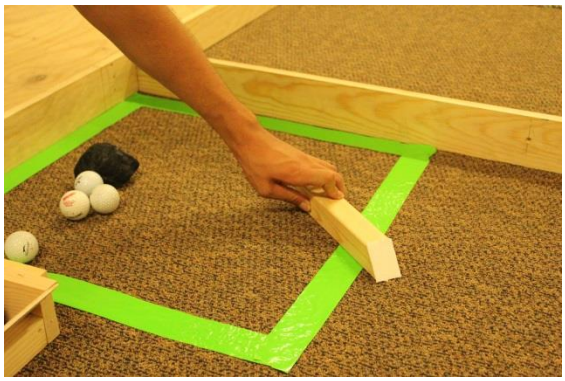
Correct 15: The Copper Cart is like a Sub-Assembly; it is Supported by the Chalcopyrite Bin, so its contents are Supported by the Chalcopyrite Bin and will be scored.

Incorrect 14: The Copper Cart is like a Sub-Assembly; it is NOT Supported by the Chalcopyrite Bin, so its contents are NOT Supported by the Chalcopyrite Bin and will NOT be scored.

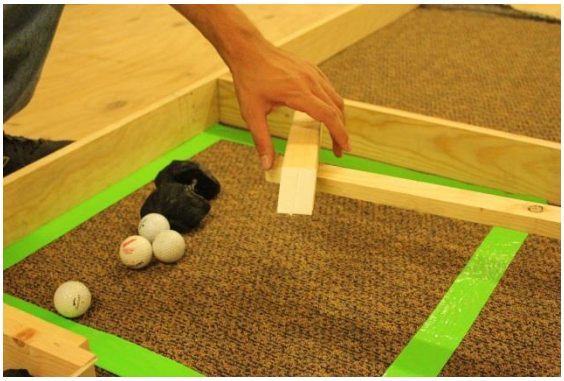
Appendix D – Spotter Allowed Activities and Sub-Assemblies



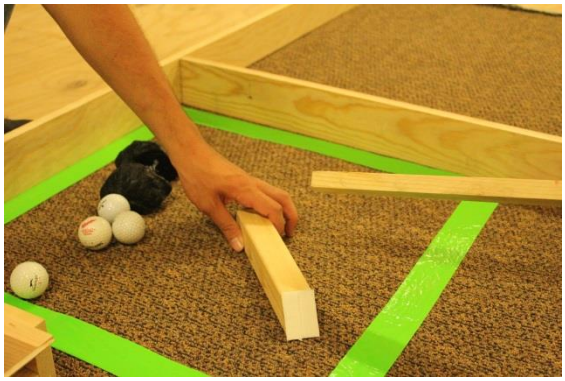
Correct 16: The Coal is Supported by the RSB; the spotter may touch it.



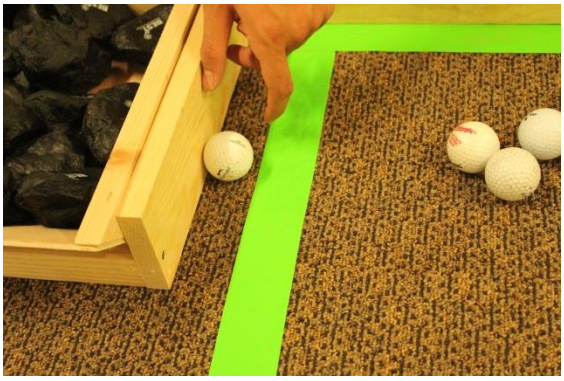
Incorrect 15: The Spodumene is NOT Supported by the RSB; the spotter may not touch it.



Incorrect 16: The robot is still in contact with the Spodumene; the spotter may NOT touch it.



Correct 17: The robot is NOT in contact with the Spodumene; the spotter may touch it.



Incorrect 17: There is a gap between the RSB and the Scoring Bin Brace. This Magnetite is not supported by the RSB, so the Spotter may NOT touch it.