

NASA's Third Annual Lunabotics Mining Competition

Rules & Rubrics, Revision 3

Kennedy Space Center Visitor Complex

Kennedy Space Center, Florida



Introduction

NASA's Lunabotics Mining Competition is designed to promote the development of interest in space activities and STEM (Science, Technology, Engineering, and Mathematics) fields. The competition uses excavation, a necessary first step towards extracting resources from the regolith and building bases on the moon. The unique physical properties of lunar regolith and the reduced 1/6th gravity, vacuum environment make excavation a difficult technical challenge. Advances in lunar regolith mining have the potential to significantly contribute to our nation's space vision and NASA space exploration operations.

The competition will be conducted by NASA at the Kennedy Space Center Visitor Complex. The teams that can use telerobotic or autonomous operation to excavate lunar regolith simulant, called Black Point-1 or BP-1, and score the most points wins the Joe Kosmo Award for Excellence. The team will receive the Joe Kosmo Award for Excellence trophy, KSC launch invitations, team certificates for each member, a \$5,000 team scholarship, and up to \$1,000 travel expenses for each team member and one faculty advisor to participate at one of NASA's remote research and technology tests. Awards for other categories include monetary team scholarships, a school trophy or plaque, team and individual certificates, and KSC launch invitations.

Undergraduate and graduate student teams enrolled in a U.S. or international college or university are eligible to enter NASA's Lunabotics Mining Competition. Design teams must include: at least one faculty with a college or university and at least two undergraduate or graduate students. NASA has not set an upper limit on team members. A team should have a sufficient number of members to successfully operate their Lunabot. Teams will compete in up to five major competition categories including: on-site mining, systems engineering paper, outreach project, slide presentation (optional), and team spirit (optional). Additionally, teams can earn bonus points for mined and deposited BP-1 in the competition attempts, having multidisciplinary teams, and collaborating between a majority institution and a U.S. minority serving institution. All documents must be submitted in English.

The Lunabotics Mining Competition is a student competition that will be conducted in a positive, professional way. This is a reminder to be courteous in all your correspondence and all interactions on-site at the competition. Unprofessional behavior or unsportsmanlike conduct will not be tolerated and will be grounds for disqualification. The frequently asked questions (FAQ) document is updated regularly and is considered part of this document. It is the responsibility of the teams to read, understand, and abide by all of NASA's Third Annual Lunabotics Mining Competition Rules and Rubrics, stay updated with new FAQs, communicate with NASA's representatives, and complete all surveys. These rules and rubrics are subject to future updates by NASA at its sole discretion.

For more information, visit NASA's Lunabotics Mining Competition on the Web at www.nasa.gov/Lunabotics; on Facebook at www.facebook.com/Lunabotics; on YouTube at <http://www.youtube.com/user/Lunabotics>; and follow Lunabotics on Twitter at <http://twitter.com/#!/Lunabotics>.

Lunabotics On-Site Mining Category

This year the scoring for the Mining Category will not be based primarily on the amount of material excavated in the allowed time but instead will require teams to consider a number of design and operation factors such as dust tolerance and projection, communications, vehicle mass, energy/power required, and level of autonomy. Each team must compete on-site at the Kennedy Space Center Visitor Complex, Florida in the United States of America on May 21-26, 2012. A minimum amount of 10 kg of BP-1 must be mined and deposited during each of two competition attempts according to the rules to qualify to win in this category. In the case of a tie, the teams will compete in a tie-breaking competition attempt. The judges' decisions are final in all disputes. The teams with the first, second, and third most LunaPoints averaged from both attempts will receive team plaques, individual team certificates, KSC launch invitations, \$3,000, \$2,000, and \$1,000 scholarships and 30, 25, and 20 points toward the Joe Kosmo Award for Excellence, respectively. Teams not winning first, second, or third place in the mining category can earn one bonus point for each kilogram of BP-1 mined and deposited up to a maximum average of ten points toward the Joe Kosmo Award for Excellence. The most innovative and lunar like design will receive the Judges' Innovation Award at the discretion of the mining judges.

- 1) Teams must arrive at the Lunabotics Mining Competition Check-In Tent in Parking Lot 4 of the Kennedy Space Center Visitor Complex no later than 12:00 p.m. (noon) on Tuesday, May 22, 2012.

Game Play Rules

- 2) Teams will be required to perform two official competition attempts using BP-1 in the LunArena provided by NASA. NASA will fill the LunArena with compacted BP-1 that matches as closely as possible to lunar regolith. NASA will randomly place three obstacles and create two craters on each side of the LunArena. Each competition attempt will occur with two teams competing at the same time, one on each side of the LunArena. After each competition attempt, the obstacles will be removed, the BP-1 will be returned to a compacted state, if necessary, and the obstacles and craters will be returned to the LunArena. The order of teams for the competition attempts will be chosen at NASA's discretion. See Diagrams 1 and 2.
- 3) In each of the two official competition attempts, the teams will score cumulative LunaPoints. See Table 1 for the Mining Category Scoring Example. The teams' ranking LunaPoints will be the average of their two competition attempts.
 - A) Each team will be awarded 1000 LunaPoints after passing the safety inspection and communications check.
 - B) During each competition attempt, the team will earn 2 LunaPoints for each kilogram in excess of 10 kg of BP-1 deposited in the LunaBin. (For example, 110 kg of BP-1 mined will earn 200 points.)
 - C) During each competition attempt, the team will lose 1 LunaPoint for each 50 kilobits/second (kb/sec) of average data used throughout each competition attempt. A minimum of 10 kg of BP-1 must be mined and deposited in the LunaBin during each competition attempt or the team will lose 100 LunaPoints, which is the maximum number of LunaPoints for this rule. (For example, 5000 kb/sec will lose 100 points.)
 - D) During each competition attempt, the team will lose 10 LunaPoints for each kilogram of total Lunabot mass. (For example, a Lunabot that weighs 80 kg will lose 800 LunaPoints.)
 - E) During each competition attempt, the team will earn 100 LunaPoints if the amount of energy consumed by the Lunabot during the competition attempt is reported to the judges after each attempt. The amount of energy consumed will not be used for scoring; a team must only provide a legitimate method of measuring the energy consumed and be able to explain the method to the judges.
 - F) During each competition attempt, the judges will award the team 0 to 200 LunaPoints for regolith dust tolerant design features on the Lunabot and regolith dust free operation. If the Lunabot has exposed mechanisms where dust could accumulate during a lunar mission and degrade the performance or lifetime of the mechanisms, then fewer points will be awarded in this category. If the Lunabot raises a substantial amount of airborne dust or projects it due to its operations, then fewer points will be awarded. Ideally, the Lunabot will operate in a clean manner without dust projection, and all mechanisms and moving parts will be protected from dust intrusion. The Lunabot will not be penalized for airborne dust

while dumping into the LunaBin. All decisions by the judges regarding dust tolerance and dust projection are final.

- G) During each competition attempt, the team will earn 250 LunaPoints if the Lunabot is able to drive autonomously (no teleoperation), through the obstacle area only. The Lunabot may be teleoperated in the mining area and LunaBin/starting area. A minimum of 10 kg of BP-1 must be mined and deposited in the LunaBin during each competition attempt to receive these LunaPoints. The points for autonomy through the obstacle area and full autonomy are mutually exclusive.
- H) During each competition attempt, the team will earn 500 LunaPoints if full autonomy is achieved and a minimum of 10 kg of BP-1 is mined and deposited in the LunaBin. No teleoperation is allowed to achieve full autonomy status. The points for autonomy through the obstacle area and full autonomy are mutually exclusive.

Mining Category Elements	Specific Points	Actual	Units	LunaPoints
Pass Inspections				1000
Regolith over 10 kg	+2/kg	110	kg	+200
Average Bandwidth	-1/50kb/sec	5000	kb/sec	-100
Lunabot Mass	-10/kg	80	kg	-800
Report Energy Consumed	+100	1	1= Achieved 0= Not Achieved	+100
Dust Tolerant Design & Dust Free Operation	0 to +200	150	Judges' Decision	+150
Autonomy through Obstacles	+250	0	1= Achieved 0= Not Achieved	0
Full Autonomy	+500	500	1= Achieved 0= Not Achieved	+500
Total				1050

Table 1: Mining Category Scoring Example

- 4) All excavated mass deposited in the LunaBin during each official competition attempt will be weighed after the completion of each competition attempt.
- 5) The Lunabot will be placed in the randomly selected starting positions. See Diagrams 1 and 2.
- 6) A team's Lunabot will only excavate BP-1 located in that team's respective mining area at the opposite end of the LunArena from the team's starting area. The team's starting direction will be randomly selected immediately before the competition attempt.
- 7) The Lunabot is required to move across the obstacle area to the mining area and then move back to the LunaBin to deposit the BP-1 into the LunaBin. See Diagrams 1 and 2.
- 8) Each team is responsible for placement and removal of their Lunabot onto the BP-1 surface. There must be one person per 23 kg of mass of the Lunabot, requiring four people to carry the maximum allowed mass. Assistance will be provided if needed.
- 9) Each team is allotted a maximum of 10 minutes to place the Lunabot in its designated starting position within the LunArena and 5 minutes to remove the Lunabot from the LunArena after the 10-minute competition attempt has concluded.
- 10) The Lunabot operates during the 10-minute time limit of each competition attempt. The competition attempts for both teams in the LunArena will begin and end at the same time.
- 11) The Lunabot will end operation immediately when the power-off command is sent, as instructed by the competition judges.

- 12) The Lunabot cannot be anchored to the BP-1 surface prior to the beginning of each competition attempt.
- 13) The Lunabot will be inspected during the practice days and right before each competition attempt. Teams will be permitted to repair or otherwise modify their Lunabots anytime the LunaPits are open.

Field Rules

- 14) At the start of each competition attempt, the Lunabot may not occupy any location outside the defined starting position.
- 15) The LunaBin top edge will be placed so that it is adjacent to the side walls of the LunArena without a gap and the height will be approximately 0.5 meter from the top of the BP-1 surface directly below it. The LunaBin top opening will be 1.65 meters long and .48 meters wide. See Diagrams 1 – 3. A target may be attached to the LunaBin for navigation purposes only. This navigational aid must be attached during the setup time and removed afterwards during the removal time period. The mass of the navigational aid is included in the maximum Lunabot mass limit of 80.0 kg and must be self-powered.
- 16) There will be three obstacles placed on top of the compressed BP-1 surface within the obstacle area before each competition attempt is made. The placement of the obstacles will be randomly selected before the start of the competition. Each obstacle will have a diameter of approximately 20 to 30 cm and an approximate mass of 7 to 10 kg. There will be two craters of varying depth and width, being no wider or deeper than 30 cm. No obstacles will be intentionally buried in the BP-1 by NASA, however, BP-1 includes naturally occurring rocks.
- 17) The Lunabot must operate within the LunArena: it is not permitted to pass beyond the confines of the outside wall of the LunArena and the LunaBin during each competition attempt. The BP-1 must be mined in the mining area and deposited in the LunaBin. A team that excavates any BP-1 from the starting or obstacle areas will be disqualified. The BP-1 must be carried from the mining area to the LunaBin by any means and be deposited in the LunaBin in its raw state. A secondary container like a bag or box may not be deposited inside the LunaBin. Depositing a container in the LunaBin will result in disqualification of the team. The Lunabot can separate intentionally, if desired, but all parts of the Lunabot must be under the team's control at all times. Any ramming of the wall may result in a safety disqualification at the discretion of the judges. Touching or having a switch sensor springwire that may brush on a wall as a collision avoidance sensor is allowed.
- 18) The Lunabot must not use the wall as support or push/scoop BP-1 up against the wall to accumulate BP-1. If the Lunabot exposes the LunArena bottom due to excavation, touching the bottom is permitted, but contact with the LunArena bottom or walls cannot be used at any time as a required support to the Lunabot. Teams should be prepared for airborne dust raised by either team during each competition attempt.

Technical Rules

- 19) During each competition attempt, the Lunabot is limited to autonomous and telerobotic operations only. No physical access to the Lunabot will be allowed during each competition attempt. In addition, telerobotic operators are only allowed to use data and video originating from the Lunabot and the NASA video monitors. Visual and auditory isolation of the telerobotic operators from the Lunabot in the Mission Control Center is required during each competition attempt. Telerobotic operators will be able to observe the LunArena through overhead cameras in the LunArena through monitors that will be provided by NASA in the Mission Control Center. These color monitors should be used for situational awareness only. No other outside communication via cell phones, radios, other team members, etc. is allowed in the Mission Control Center once each competition attempt begins.
- 20) The Lunabot mass is limited to a maximum of 80.0 kg. Subsystems on the Lunabot used to transmit commands/data and video to the telerobotic operators are counted toward the 80.0 kg mass limit. Equipment not on the Lunabot used to receive data from and send commands to the Lunabot for telerobotic operations is excluded from the 80.0 kg mass limit.
- 21) The Lunabot must provide its own onboard power. No facility power will be provided to the Lunabot. There are no power limitations except that the Lunabot must be self-powered and included in the maximum Lunabot mass limit of 80.0 kg.
- 22) The Lunabot must be equipped with an easily accessible red emergency stop button (kill switch) of minimum diameter five cm on the surface of the Lunabot requiring no steps to access. The emergency stop button must stop the Lunabot's motion and disable all power to the Lunabot with one push motion on the button. It must be

highly reliable and instantaneous. For these reasons an unmodified “Commercial Off-The-Shelf” (COTS) red button is required. A closed control signal to a mechanical relay is allowed as long as it stays open to disable the Lunabot. The reason for this rule is to completely safe the Lunabot in the event of a fire or other mishap. The button should disconnect the batteries from all controllers (high current, forklift type button) and it should isolate the batteries from the rest of the active sub-systems as well.

23) The communications rules used for telerobotic operations follow:

A. LUNABOT WIRELESS LINK

1. Each team will provide the wireless link (access point, bridge, or wireless device) to their Lunabot, which means that each team will bring the Wi-Fi equipment/router and set their own IP addresses.
 - a. NASA will provide an elevated network drop (Female RJ-45 Ethernet jack) in the LunArena that extends to the Mission Control Center, where NASA will provide a network switch for the teams to plug in their laptops.
 - i. The network drop in the LunArena will be elevated high enough above the edge of the regolith bed wall to provide adequate radiofrequency visibility of the LunArena.
 - ii. A shelf will be setup next to the network drop and located 4 to 6 feet off the ground and will be no more than 50 feet from the Lunabot. This shelf is where teams will place their Wireless Access Point (WAP) to communicate with their Lunabot. The distance from the LunArena to the Mission Control Center will be around 150 – 200 feet.
 - iii. The WAP shelves for side A and side B of the LunArena will be no closer than 25' from each other to prevent electromagnetic interference (EMI) between the units.
 - b. NASA will provide a standard 110VAC outlet by the network drop. Both will be no more than 2 feet from the shelf.
 - c. During setup time before the match starts the teams will be responsible for setting up their access point.
2. The teams must use the USA IEEE 802.11 b/g standard for their wireless connection (WAP and rover client). Teams cannot use multiple channels for data transmission. Encryption is not required but it is highly encouraged to prevent unexpected problems with team links.
 - a. During a match, one team will operate on channel 1 and the other team will operate on channel 11.
 - b. The channel assignments will be made upon team check-in with the LunaPit crew chief.
3. Each team will be assigned an SSID that they must use for their wireless equipment.
 - a. SSID will be “Team_##”
 - b. Teams will broadcast their SSID
4. Bandwidth constraints:
 - a. Teams will be awarded the Efficient Use of Communications Power Award for using the least amount of average bandwidth during the timed and NASA monitored portion of the competition. Teams must collect the minimum 10 kg of BP-1 to qualify for this award.
 - b. The communications link is required to have an average bandwidth of no more than 5 megabits per second. There will not be a peak bandwidth limit.

B. RF & COMMUNICATIONS APPROVAL

1. Each team must demonstrate to the communication judges that their Lunabot and access point is operating only on their assigned channel. Each team will have approximately 15 minutes at the communication judge’s station.
2. To successfully pass the communications judge’s station a team must be able to command their Lunabot (by driving a short distance) from their Lunabot driving/control laptop through their wireless access point. The judges will verify this and use the appropriate monitoring tools to verify that the teams are operating only on their assigned channel.
3. If a team cannot demonstrate the above tasks in the allotted time, the team will be disqualified from the competition.
4. Each team will receive an assigned time from the LunaPit crew chief, on a first come, first serve basis, on Monday, May 21, 2012 or Tuesday, May 22, 2012 to show the communication judges their compliance with the rules.
5. The NASA communications technical experts will be available to help teams make sure that they are ready for the communication judge’s station on Monday, May 21, 2012 or Tuesday, May 22, 2012.

6. Once the team arrives at the communication judge's station, the team can no longer receive assistance from the NASA communications technical experts.
7. If a team is on the wrong channel during their competition attempts, the team will be required to power down and be disqualified.

C. WIRELESS DEVICE OPERATION IN THE PITS

1. Teams will not be allowed to power up their transmitters on any frequency in the Lunapits during the practice matches or competition attempts. All teams must have a hard-wired connection for testing in the Lunapits.
 2. There will be designated times for teams to power up their transmitters when there are no practice matches underway.
- 24) The Lunabot must be contained within 1.5 m length x 0.75 m width x 0.75 m height. The Lunabot may deploy or expand beyond the 1.5 m x 0.75 m footprint after the start of each competition attempt, but may not exceed a 1.5 meter height. The Lunabot may not pass beyond the confines of the outside wall of the LunArena and the LunaBin during each competition attempt to avoid potential interference with the surrounding tent. The team must declare the orientation of length and width to the inspection judge. Because of actual lunar hardware requirements, no ramps of any kind will be provided or allowed. An arrow on the reference point must mark the forward direction of the Lunabot in the starting position configuration. The judges will use this reference point and arrow to orient the Lunabot in the randomly selected direction and position. A multiple robot system is allowed but the total mass and starting dimensions of the whole system must comply with the volumetric dimensions given in this rule.
- 25) To ensure that the Lunabot is usable for an actual lunar mission, the Lunabot cannot employ any fundamental physical processes (e.g., suction or water cooling in the open lunar environment), gases, fluids or consumables that would not work in the lunar environment. For example, any dust removal from a lens or sensor must employ a physical process that would be suitable for the lunar surface. Teams may use processes that require an Earth-like environment (e.g., oxygen, water) only if the system using the processes is designed to work in a lunar environment and if such resources used by the Lunabot are included in the mass of the Lunabot. Pneumatic mining systems are allowed only if the gas is supplied by the Lunabot itself.
- 26) Components (i.e. electronic and mechanical) are not required to be space qualified for the lunar vacuum, electromagnetic, and thermal environments. Since budgets are limited, the competition rules are intended to require Lunabots to show lunar plausible system functionality but the components do not have to be traceable to a space qualified component version. Examples of allowable components are: Sealed Lead-Acid (SLA) or Nickel Metal Hydride (NiMH) batteries; composite materials; rubber or plastic parts; actively fan cooled electronics; motors with brushes; and proximity detectors and/or Hall Effect sensors, but proceed at your own risk since the BP-1 is very dusty. Teams may use honeycomb structures as long as they are strong enough to be safe. Teams may not use rubber pneumatic tires; air/foam filled tires; ultra sonic proximity sensors; or hydraulics because NASA does not anticipate the use of these on a lunar mission.
- 27) The Lunabot may not use any process that causes the physical or chemical properties of the BP-1 to be changed or otherwise endangers the uniformity between competition attempts.
- 28) The Lunabot may not penetrate the BP-1 surface with more force than the weight of the Lunabot before the start of each competition attempt.
- 29) No ordnance, projectile, far-reaching mechanism (adhering to Rule 24), etc. may be used. The Lunabot must move on the BP-1 surface.
- 30) No team can intentionally harm another team's Lunabot. This includes radio jamming, denial of service to network, BP-1 manipulation, ramming, flipping, pinning, conveyance of current, or other forms of damage as decided upon by the judges. Immediate disqualification will result if judges deem any maneuvers by a team as being offensive in nature. Erratic behavior or loss of control of the Lunabot as determined by the judges will be cause for immediate disqualification. A judge may disable the Lunabot by pushing the red emergency stop button at any time.
- 31) Teams must electronically submit documentation containing a description of their Lunabot, its operation, potential safety hazards, a diagram, and basic parts list by April 30, 2012 at 12:00 p.m. (noon) eastern time in the United States.

- 32) Teams must electronically submit a **link** to their YouTube video documenting no less than 30 seconds but no more than 5 minutes of their Lunabot in operation for at least one full cycle of operation by April 30, 2012 at 12:00 p.m. (noon) eastern time in the United States via e-mail to Susan.G.Sawyer@nasa.gov. One full cycle of operations includes excavation and depositing material. This video documentation is solely for technical evaluation of the Lunabot.

Shipping

- 33) Teams may ship their Lunabots to arrive no earlier than May 14, 2012. The Lunabots will be held in a safe, unairconditioned area and be placed in each team's LunaPit by Monday, May 21, 2012. The **ship to** address is:

Transportation Officer, NASA
Central Supply, Bldg M6-744
Kennedy Space Center, FL 32899
M/F: KSC Visitor Complex, Lunabotics Mining Competition, M/C: DNPS

Note: Do not have the shipping company deliver the Lunabot directly to the Kennedy Space Center Visitor Complex. They do not have facilities to store them until the LunaPits are set up. The shipper will come to the Pass & ID facility right before the gate on State Road 405. Central Receiving will send an escort

- 34) Return shipping arrangements must be made prior to the competition. All Lunabots must be picked up from the Kennedy Space Center Visitor Complex **no later than 5:00 p.m. on Tuesday, May 29, 2012**. Any abandoned Lunabots will be discarded after this date. The **return** shipping address is from:

Kennedy Space Center Visitor Complex
Mail Code: DNPS
State Road 405
Kennedy Space Center, FL. 32899

LunArena Diagrams

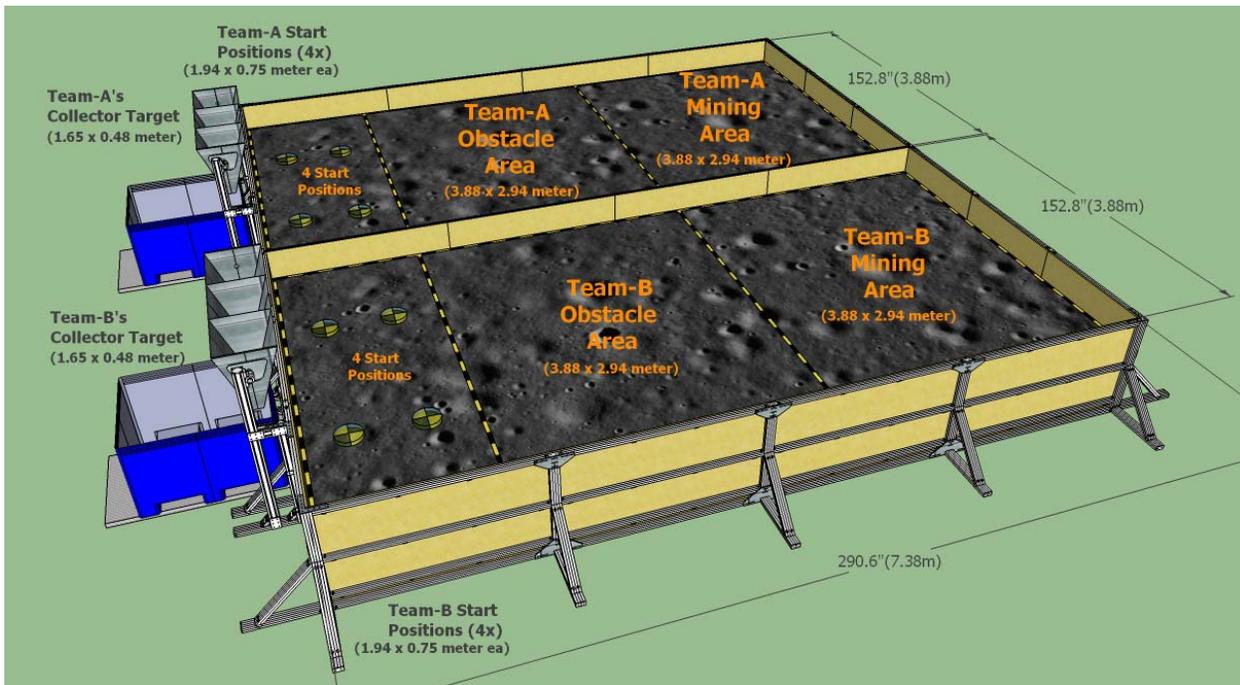


Diagram 1: LunArena (isometric view)

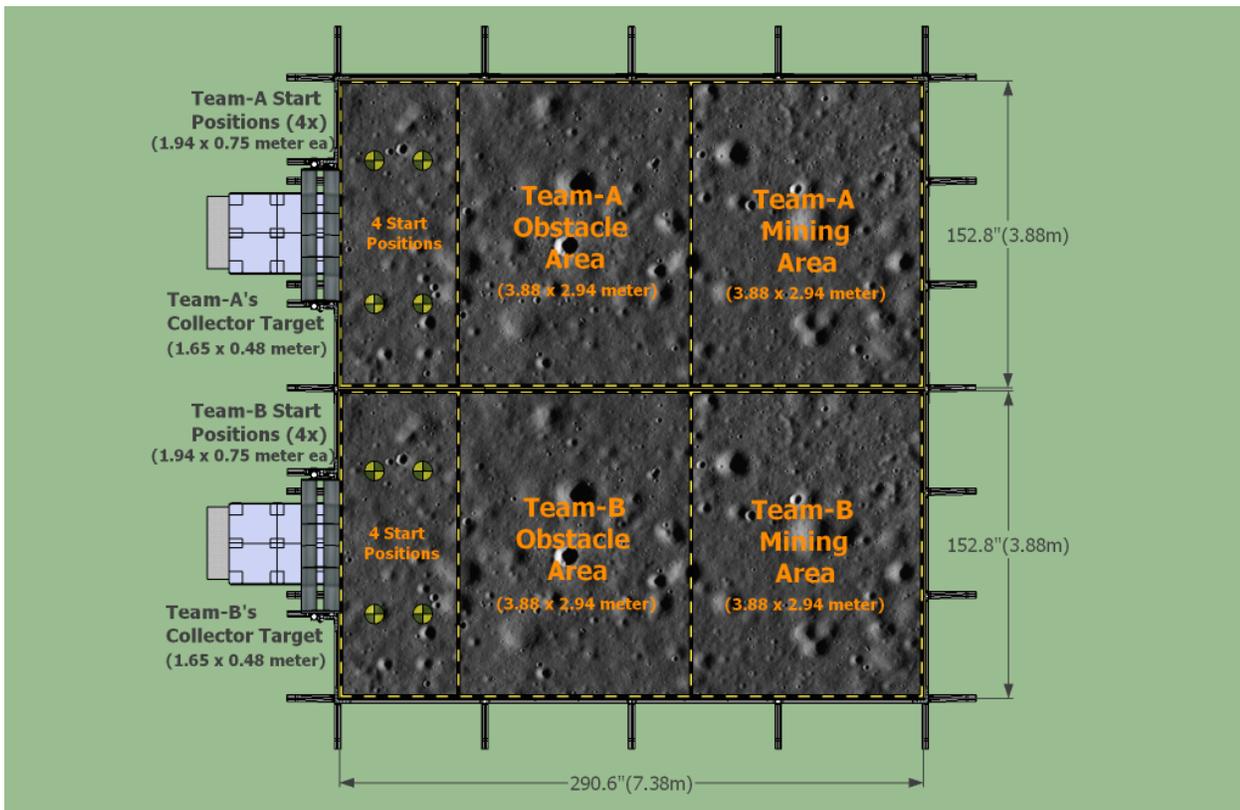


Diagram 2: LunArena (top view)

LunaBin Diagram

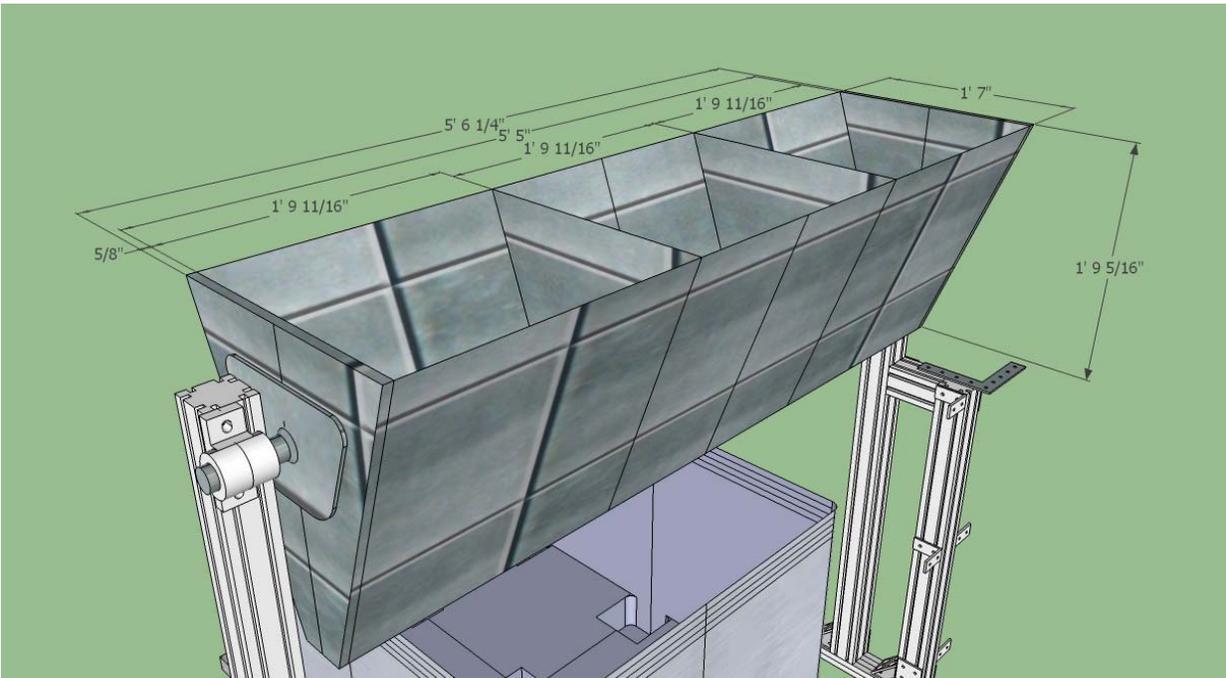


Diagram 3: LunaBin

Lunabotics Systems Engineering Paper

Each team must submit a Systems Engineering Paper electronically in PDF by April 23, 2012 at 12:00 p.m. (noon) eastern time in the United States. Cover page must include: team name, title of paper, full names of all team members, university name and faculty advisor's full name. **Appendices are not allowed.** All pertinent information required in the rubric must be in the body of the paper. A minimum score of 15 out of 20 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning Systems Engineering Paper. The judges' decision is final. The team with the winning Systems Engineering Paper will receive a team plaque, individual certificates, and a \$500 team scholarship. Second and third place winners will receive individual team certificates.

For reference, the NASA Systems Engineering Handbook is available at:

<http://education.ksc.nasa.gov/esmdspacegrant/LunarRegolithExcavatorCourse/Site%20Documents/NASA%20SP-2007-6105.pdf>.

Lunabotics Systems Engineering Paper Scoring Rubric					
Elements	4	3	2	1	0
Content: <ul style="list-style-type: none"> Formatted professionally, clearly organized, correct grammar and spelling, maximum of 20 pages not counting the <u>cover</u> and <u>source</u> pages only; 12 font size; single spaced. No appendices allowed. Cover page Introduction Purpose Sources 	All five elements are exceptionally demonstrated	Five elements are clearly demonstrated	Four elements are clearly demonstrated	Three or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Intrinsic Merit: <ul style="list-style-type: none"> Deliverables identified Budget Schedule Major reviews: system requirements, preliminary design and critical design Illustrations support the technical content 	All five elements are exceptionally demonstrated	Five elements are clearly demonstrated	Four elements are clearly demonstrated	Three or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Technical Merit: <ul style="list-style-type: none"> Concept of operations System Hierarchy Basis of design Interfaces defined Requirements definition Design margins Trade-off assessment Risk assessment Reliability Verification Requirement flow-down to validation and checkout Use of system life cycle 	One point for each element exceptionally demonstrated up to twelve points.				

Lunabotics Outreach Project Report

Each team must participate in an educational outreach project in their local community. Outreach examples include actively participating in school career days, science fairs, technology fairs, extracurricular science or robotic clubs, or setting up exhibits in local science museums or a local library. Other ideas include organizing a program with a Boys and Girls Club, Girl Scouts, Boy Scouts, etc. Teams are encouraged to have fun with the outreach project and share knowledge of science, robotics and engineering with the local community.

Each team must submit a report of the Lunabotics Outreach Project electronically in PDF by April 23, 2012 at 12:00 p.m. (noon) eastern time in the United States. Cover page must include: team name, title of paper, full names of all team members, university name and faculty advisor's full name. **Appendices are not allowed.** All pertinent information required in the rubric must be in the body of the paper. A minimum score of 15 out of 20 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning outreach project. The judges' decision is final. The team with the winning outreach project will receive a team plaque, individual certificates, and a \$500 team scholarship. Second and third place winners will receive individual team certificates.

Lunabotics Outreach Project Scoring Rubric					
Elements	4	3	2	1	0
Content: <ul style="list-style-type: none"> • Introduction • Outreach recipient group identified • Purpose • Cover page 	All four elements are exceptionally demonstrated	Four elements are clearly demonstrated	Three elements are clearly demonstrated	Two elements are clearly demonstrated	Zero elements are clearly demonstrated
Educational Outreach: <ul style="list-style-type: none"> • Inspires others to learn about robotics, engineering or lunar activities • Quality of the outreach • Utilizes hands-on activities 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two elements are clearly demonstrated	One element is clearly demonstrated	Zero elements are clearly demonstrated
Creativity: <ul style="list-style-type: none"> • Inspirational • Engages others in robotics, engineering or lunar activities • Material corresponds to audience's level of understanding 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two elements are clearly demonstrated	One element is clearly demonstrated	Zero elements are clearly demonstrated
Illustrations and Media: <ul style="list-style-type: none"> • Appropriate • Demonstrates the outreach project • Pictures 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two elements are clearly demonstrated	One element is clearly demonstrated	Zero elements are clearly demonstrated
Formatting and Appearance: <ul style="list-style-type: none"> • Correct grammar and spelling • Five-page limit (cover page excluded in page count) • Clearly organized 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two elements are clearly demonstrated	One element is clearly demonstrated	Zero elements are clearly demonstrated

Lunabotics Slide Presentation and Demonstration

The Lunabotics Slide Presentation is an optional category in the overall competition. The presentation and demonstration must be no more than 20 minutes with an additional 5 minutes for questions and answers. It will be judged at the competition in front of an audience including NASA and private industry judges. The presentations must be submitted electronically in PDF by April 23, 2012 at 12:00 p.m. (noon) eastern time in the United States. A cover slide must contain the team name, title of presentation, full names of all team members, university name, and faculty advisor's full name. A minimum score of 18 out of 24 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning presentation. The judges' decision is final. The team with the winning presentation will receive a team plaque, individual team certificates, and a \$500 team scholarship. Second and third place winners will receive individual team certificates.

Lunabotics Slide Presentation Scoring Rubric					
Elements	4	3	2	1	0
Content: <ul style="list-style-type: none"> Cover slide Introduction Purpose Sources referenced 	All four elements are exceptionally demonstrated	Four elements are clearly demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Technical Merit: <ul style="list-style-type: none"> Final Lunabot design Design process Design decisions Lunabot functionality Safety features Special features 	All six elements are exceptionally demonstrated	Six elements are clearly demonstrated	Five elements are clearly demonstrated	Four or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Creativity: <ul style="list-style-type: none"> Innovative Inspirational Engaging Highlights what makes the Lunabot design unique infuses personality 	All five elements are exceptionally demonstrated	Five elements are clearly demonstrated	Four elements are clearly demonstrated	Three or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Illustrations and Media: <ul style="list-style-type: none"> Appropriate Supports the technical content Shows progression of project Clearly presents design of Lunabot 	All four elements are exceptionally demonstrated	Four elements are clearly demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Formatting and Appearance: <ul style="list-style-type: none"> Proper grammar Correct spelling Readable Aesthetically pleasing 	All four elements are exceptionally demonstrated	Four elements are clearly demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Presentation: <ul style="list-style-type: none"> Makes presentation at competition Demonstrates Lunabot under hardwire and pendent control during presentation Engages audience Answers questions 	All four elements are exceptionally demonstrated	Four elements are clearly demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated

Lunabotics Team Spirit

Lunabotics Team Spirit is an optional category in the overall competition. A minimum score of 12 out of 15 possible points must be achieved to qualify to win in this category. In the case of a tie, the judges will choose the winning team. The judges' decision is final. The team winning the Team Spirit Award at the Lunabotics Mining Competition will receive a team plaque, individual certificates, and a \$500 team scholarship. Second and third place winners will receive individual team certificates.

Lunabotics Team Spirit Competition Scoring Rubric				
Elements	3	2	1	0
Teamwork: <ul style="list-style-type: none"> Exhibits teamwork in and out of the LunArena Exhibits a strong sense of collaboration within the team Supports other teams with a healthy sense of competition 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Attitude: <ul style="list-style-type: none"> Exudes a positive attitude in all interactions, not limited to competition attempt Demonstrates an infectious energy Motivates and encourages team Keeps pit clean and tidy at all times 	All four elements are exceptionally demonstrated	Four elements are clearly demonstrated	Three or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Creativity: <ul style="list-style-type: none"> Demonstrates creativity Wears distinctive team shirts or hats Decorates team's LunaPit to reflect school/team spirit 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Engage: <ul style="list-style-type: none"> Engages audience in team spirit activities Engages other teams in team spirit activities Makes acquaintances with members of other teams 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated
Originality: <ul style="list-style-type: none"> Demonstrates originality in team activities Displays originality in the team name Displays originality in the team logo 	All three elements are exceptionally demonstrated	Three elements are clearly demonstrated	Two or less elements are clearly demonstrated	Zero elements are clearly demonstrated

Categories for Bonus Points

Collaboration between a majority school with a designated United States Minority Serving Institution

Collaboration between a majority school and a designated U.S. minority serving institution (MSI) must be identified by November 30, 2011. MSI student team members must submit their student participant forms and transcripts and be indicated on the team roster by January 31, 2012 at 12:00 p.m. (noon) eastern time in the United States to receive the 10 bonus points. A list of U.S. minority serving institutions may be found at: <http://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html>.

Multidisciplinary Engineering Teams

Team members from each different science, technology, engineering or mathematics (STEM) discipline* will count for one bonus point up to a maximum of ten. Disciplines will be indicated on the student participant form by January 31, 2012 at 12:00 p.m. (noon) eastern time in the United States. No bonus points will be given in this category if a team has only one discipline represented. If a member of the team is in a STEM discipline that is not on this list, the team lead or faculty advisor may e-mail Susan.G.Sawyer@nasa.gov to request approval of that discipline for the competition.

Aeronautical Engineering	Geography
Aerospace Engineering	Geological Engineering
Astrobiology	Geosciences
Astronautical Engineering	Health Engineering
Astronomy	Industrial/Manufacturing Engineering
Astrophysics	Information Technology
Atmospheric Sciences	Instrumentation Engineering
Bacteriology	Materials/Metallurgical Engineering
Biochemistry	Mathematics
Biology	Mechanical Engineering
Biophysics	Microbiology
Chemical Engineering	Mining Engineering
Chemistry	Natural Resource Management
Civil Engineering	Nuclear Engineering
Computer Engineering	Oceanography
Computer Science	Optics
Electrical Engineering	Physics
Engineering Management	Software Engineering
Environmental Engineering	Systems Engineering

*Team members may be from other disciplines, but only STEM disciplines are awarded bonus points.

Mined and Deposited BP-1

Teams not winning first, second, or third place in the mining category can earn one bonus point toward the Joe Kosmo Award for Excellence for each kilogram of BP-1 mined and deposited up to a maximum of ten points during their competition attempts.

Categories & Awards

In addition to the awards listed below, school plaques and/or individual team certificates will be awarded for exemplary performance in the following categories:

Category	Required/ Optional	Due Dates	Award	Maximum Points toward Joe Kosmo Award for Excellence
On-site Mining in the LunArena	Required	May 23-26, 2012	First place \$3,000 team scholarship and Kennedy launch invitations Second place \$2,000 team scholarship and Kennedy launch invitations Third place \$1,000 team scholarship and Kennedy launch invitations Teams not placing 1 st , 2 nd , or 3 rd will receive one point per kilogram mined and deposited up to 10 points	30 25 20 Up to 10
Systems Engineering Paper	Required	April 23, 2012	\$500 team scholarship	Up to 20
Outreach Project Report	Required	April 23, 2012	\$500 team scholarship	Up to 20
Slide Presentation and Demonstration	Optional	April 23, 2012 and On-Site on May 23-26, 2012	\$500 team scholarship	Up to 24
Team Spirit Competition	Optional	All Year	\$500 team scholarship	Up to 15
Collaboration With a Minority Serving Institution	Optional	Nov. 30, 2011		10 bonus points
Multidisciplinary Team	Optional	Jan. 31, 2012		Up to 10 bonus points
Joe Kosmo Award for Excellence	Grand Prize for Most Points	All Year	A school trophy, \$5,000 team scholarship, KSC launch invitations, and up to \$1,000 travel expenses for each team member and one faculty advisor to attend one of NASA's remote research and technology tests	Total of above points, maximum of 129 points possible
Judges' Innovation Award	Optional	May 23-26, 2012	A school trophy	
Efficient Use of Communications Power Award	Optional	May 23-26, 2012	A school trophy	

Lunabotics Checklist

Required Competition Elements

If required elements are not received by the due dates, then the team is not eligible to compete in any part of the competition (NO EXCEPTIONS).

- | | |
|--|---------------------------|
| <input type="checkbox"/> Registration Application* | November 30, 2011 |
| <input type="checkbox"/> Systems Engineering Paper | April 23, 2012 |
| <input type="checkbox"/> Outreach Project Report | April 23, 2012 |
| <input type="checkbox"/> On-site Mining | May 21-26, 2012 |
| <input type="checkbox"/> Team Check-in, Unload/Uncrate Lunabot | May 21 & 22, 2012 by noon |
| <input type="checkbox"/> Practice Days | May 21-23, 2012 |
| <input type="checkbox"/> Competition Days | May 23-26, 2012 |
| <input type="checkbox"/> Awards Ceremony | May 26, 2012 (evening) |

Optional Competition Elements

- | | |
|--|----------------|
| <input type="checkbox"/> Presentation File | April 23, 2012 |
| <input type="checkbox"/> Team Spirit | All year |

Required Documentation

- | | |
|---|-------------------|
| <input type="checkbox"/> Registration Application | November 30, 2011 |
| <input type="checkbox"/> Letter of Support from lead university's Dean of Engineering | November 30, 2011 |
| <input type="checkbox"/> Letter of Support from lead university's Faculty Advisor | November 30, 2011 |
| <input type="checkbox"/> MSI Collaboration Notification | November 30, 2011 |
| <input type="checkbox"/> Team Roster with MSI students indicated | January 31, 2012 |
| <input type="checkbox"/> Student Participant Form | January 31, 2012 |
| <input type="checkbox"/> Faculty Form | January 31, 2012 |
| <input type="checkbox"/> Transcripts (unofficial copy is acceptable)** | January 31, 2012 |
| <input type="checkbox"/> Signed Media Release Form | January 31, 2012 |
| <input type="checkbox"/> Request for Team Invitation Letter for International Teams*** | February 24, 2012 |
| <input type="checkbox"/> Team Photo including faculty (high resolution .jpg format preferred) | March 30, 2012 |
| <input type="checkbox"/> Team Biography (200 words maximum) | March 30, 2012 |
| <input type="checkbox"/> Head Count Form | March 30, 2012 |
| <input type="checkbox"/> Revised Team Roster (no changes accepted after this date) | March 30, 2012 |
| <input type="checkbox"/> Rule 31 documentation | April 30, 2012 |
| <input type="checkbox"/> Rule 32 video | April 30, 2012 |

Optional Documentation

- | | |
|--|------------------|
| <input type="checkbox"/> Student Resume (optional) | January 31, 2012 |
|--|------------------|

*Registration is limited to the first 60 approved teams. Registration is limited to one team per university campus. Internationally, registration is limited to 10 teams per country. Registration will end when NASA approves 60 applications or on November 30, 2011, whichever occurs first.

**Each student's Transcript or Statement of Marks must be from the university and show:

- name of university
- name of student
- major course of study
- current student status within the 2011-2012 academic year
- coursework taken and grades

***International team's invitation letters for visa request purposes will be mailed during the week of February 27, 2012 with only the names of faculty advisors and student team members on the team roster who have completed their participant forms and submitted their transcripts or statement of marks. NASA will not provide individual letters.

**All documents are due by 12:00 p.m. (noon)
eastern time in the United States.**

Definitions

Autonomous – The operation of a team’s Lunabot with no human interaction.

Black Point-1 (BP-1) – A crushed lava aggregate with a natural particle size distribution similar to that of lunar soil. The aggregate will have a particle size and distribution similar to the lunar regolith as stated in the Lunar Sourcebook: A User's Guide to the Moon, edited by G. H. Heiken, D. T. Vaniman, and B. M. French, copyright 1991, Cambridge University Press. Teams are encouraged to develop or procure simulants based on lunar type of minerals and lunar regolith particle size, shape, and distribution.

Competition attempt – The operation of a team’s Lunabot intended to meet all the requirements for winning the mining category by performing the functional task. The duration of each competition attempt is 10-minutes.

Excavated mass – Mass of the excavated BP-1 deposited to the LunaBin by the team’s Lunabot during each competition attempt, measured in kilograms (kg) with official result recorded to the nearest one tenth of a kilogram (0.1 kg).

Functional task – The excavation of BP-1 from the LunArena by the Lunabot and deposit of BP-1 from the Lunabot into the LunaBin.

Minimum excavation requirement – 10.0 kg is the minimum excavated mass which must be met in order to qualify to win the competition.

Practice time – Teams will be allowed to practice with their Lunabots in the LunArena. NASA technical experts will offer feedback on real-time networking performance during practice attempt. Only one practice attempt is required and guaranteed.

Reference point – A fixed location signified by an arrow showing the forward direction on the Lunabot that will serve to verify the starting orientation of the Lunabot within the LunArena.

LunaBin – A collector bin in NASA’s Lunabotics Mining Competition provided by NASA for each competition attempt into which each team will deposit excavated BP-1. The LunaBin will be large enough to accommodate each team’s excavated BP-1. The LunaBin will be stationary and located adjacent to the LunArena. See Diagram 3.

Lunabot – A teleoperated or autonomous robotic excavator in NASA’s Lunabotics Mining Competition including mechanical and electrical equipment, batteries, gases, fluids and consumables delivered by a team to compete in the competition.

LunaPoints – Points earned from the two competition attempts in NASA’s Lunabotics Mining Competition will be averaged to determine ranking in the on-site mining category.

LunArena – An open-topped container (i.e., a box with a bottom and 4 side walls only), containing BP-1, within which the Lunabot will perform each competition attempt. The inside dimensions of the each side of the LunArena will be 7.38 meters long and 3.88 meters wide, and 1 meter in depth. The BP-1 aggregate will be less than one meter in depth. A dividing wall will be in the center of the LunArena. The LunArena for the practice days and official competition will be provided by NASA. The LunArena will be outside in an enclosed tent. The LunArena lighting will consist of artificial lamps inside a tent structure. Assume daylight conditions. The atmosphere will be an air-conditioned tent without significant air currents and cooled to approximately 77 degrees Fahrenheit. See Diagrams 1 – 3.

Telerobotic – Communication with and control of the Lunabot during each competition attempt must be performed solely through the provided communications link which is required to have a total average bandwidth of no more than 5.0 megabits/second on all data and video sent to and received from the Lunabot.

Time Limit – 10 minutes to set up the Lunabot in the LunArena, 10 minutes for the Lunabot to perform the functional task, and 5 minutes to remove the Lunabot.