Mission to Mars

MCHE 201: Introduction to Engineering Design
Spring 2017 – Final Project

1 Introduction

Humans have long looked to Mars as the place our species will first expand beyond Earth. After several failed attempts by the Soviet Union in the early 1970s, NASA has led the exploration of Mars, beginning with the first successful landing on Mars by Viking 1 in 1976. More recently, a series of rovers, Spirit, Opportunity, and Curiosity, have completed successful exploratory missions. The latter two are still in operation. The next major exploration planned is the Mars 2020 mission, currently under development for launch in 2020. SpaceX and Elon Musk have an even more ambitious goal, to start sending private spacecraft and then human explorers to Mars beginning in 2018. However, getting to Mars is hard. Luckily, *MCHE 201* students can help.

MCHE 201 students will design and build devices that *Transport Astronauts to the Mars Base*, *Plant a flag in the Mars Landing Zone*, *Avoid and/or Mine Asteroids*, *Collect Pre-launched Fuel*, and *Safely Return to Earth*. The capabilities of these devices will be demonstrated on the representation of the Solar System shown in Figure 1. It consists of four zone-and-starting-zone pairs. Each triangular slice of the square, defined by the crossing diagonals minus the area of the circular center section, is considered a team zone. For each round of competition, the competing teams will each be assigned one zone.

The devices should:

1. **Transport Astronauts to the Mars Base:** Prior to the each competition round, each team will be given five Astronauts (LEGO Minifigures). For each Astronaut delivered to the Mars Landing Zone, the team will **earn 5 points**. For each one placed into the rotating Mars Base, the team will **earn 10 points**. In order to earn the points for the Mars Base, the Astronaut must be *completely* contained in the Base, including in the vertical dimension (*i.e.* Unlike other sections, the volume of air above the Mars Base is *not* considered part of it.). If an Astronaut is not completely contained in the Mars Base, but is still within the Mars Landing Zone, Mars Landing Zone points will be awarded as appropriate.

2. **Plant a Flag in the Mars Landing Zone:** Prior to each competition round, each team will be given a (small "desk" size) flag to plant in the Mars Landing Zone. If the flag is delivered to the Mars Landing Zone, the team will **earn 10 points**. In order to earn the points, the flag must be *completely* contained in the Mars Landing Zone.

3. **Avoid and/or Mine Asteroids:** In each zone, there are five asteroids (foil-wrapped table tennis balls). For each asteroid that remains in the team's zone at the end of the round, the team will be **penalized 5 points**. However, for each collected and placed *completely* in the team's Asteroid Processing zone, the team will **earn 5 points**.

4. **Collect Pre-launched Fuel:** There are two pieces of pre-launched fuel (plastic toy blocks) located at the edges between the team zones. For each of these collected *completely* into the team's zone, the team will **earn 10 points**.

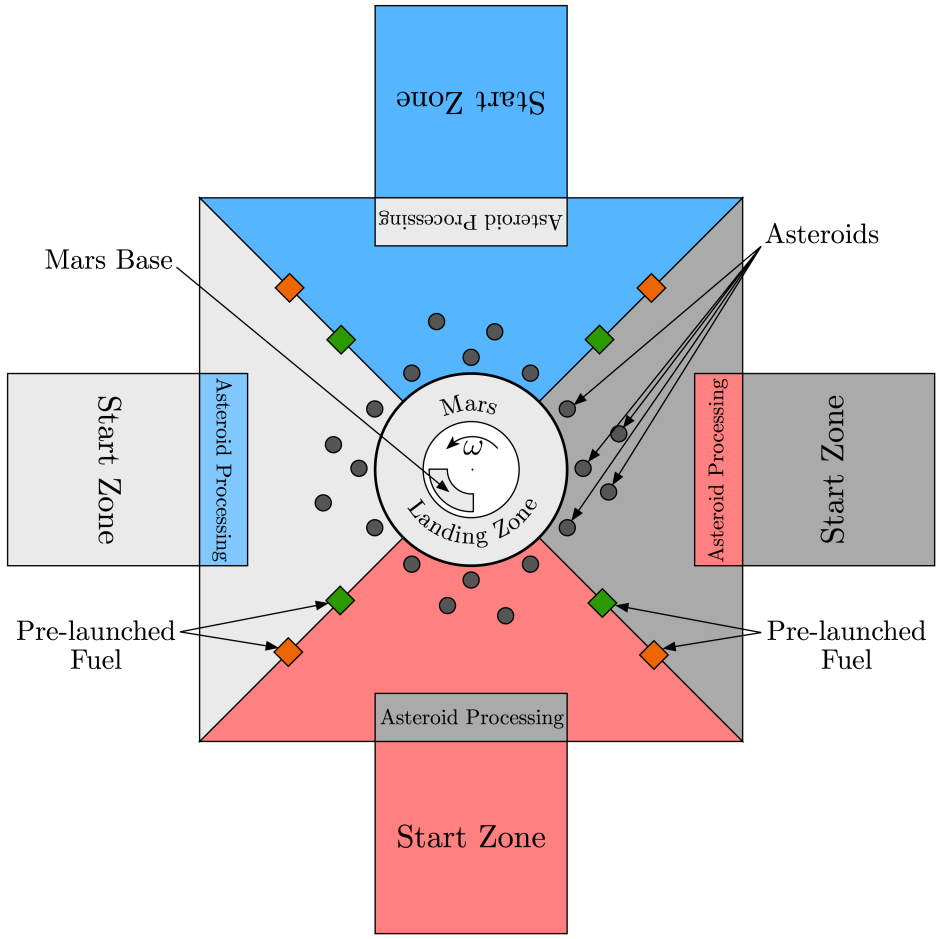


Figure 1: The *MCHE 201* Solar System

5. **Safely Return to Earth:** Once the mission is completed, the device must safely return to Earth. To return to Earth, the device must be *completely* outside the team's zone at the end of the round of competition. Doing so will **earn 20 points**. However, teams are *only* eligible for these points if they have also collected at least once piece of pre-launched fuel.

2 The Competitions

Teams will need to demonstrate the capabilities of their machine on four different occasions.

2.1 Individual Contest

Every student will build a device and compete in an Individual Contest, scheduled for March 14. Each machine should complete a simplified version *Transport Astronauts to the Mars Base* task. In this contest only, the Mars Base will not be rotating, and the entire surface area of the Mars Base Platform will count as placing the Astronauts in the base. The Mars Landing Zone is scored

normally.

This competition does not utilize any of the electronics available; it is a purely mechanical design. The machine will be manually triggered and cannot receive any significant energy from its student operator. That also means that it must start from a stable equilibrium condition.[1] Each device will be run at most 2 times in 3 minutes. **1 of the possible 15 total Robot Performance grade points will come from this competition.**

2.2 Preliminary Competition

On March 23, the machine must demonstrate that it is able to *Transport Astronauts to the Mars Base*, and *Avoid and/or Mine Asteroids*. The machine must be electronically triggered and operate autonomously. During this contest, the machines will be alone. Each team will have 5 minutes to run their machine at most 3 times. The score will be the sum of the three attempts. **3 of the possible 15 total Robot Performance grade points will come from this competition.**

2.3 Qualifying Round

On April 4, a qualifying round test will be held with all competition rules and scoring in effect. The results of this competition will be used to seed the final competition bracket, and the competition will continue until a clear ranking is evident or class time runs out. **3 of the possible 15 total Robot Performance grade points will come from this competition.**

2.4 Final Competition

On April 11, the Mission to Mars competition will be held. There will be two events in this contest.

Design Review: A panel of judges will perform a design review of the machines. Each team will need to clearly and concisely describe their machine to the judges. The judges will evaluate the teams on aesthetics, ingenuity, and presentation. **5 of the 55 possible total Final Project grade points will come from this design review.**

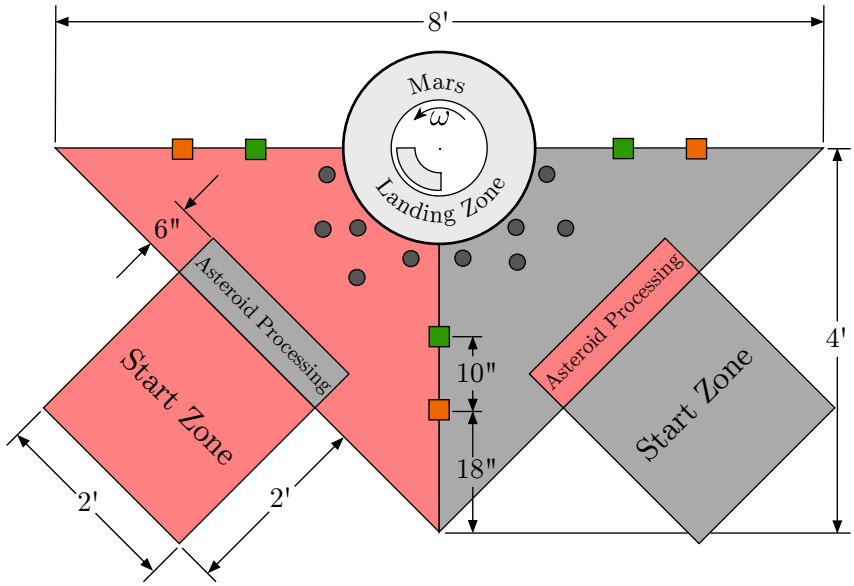
Mission to Mars Contest: The robots will compete in head-to-head competition. **8 of the possible 15 total Robot Performance grade points will come from this competition.**

3 Details

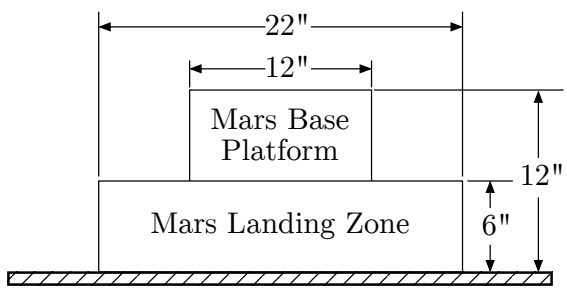
3.1 The Solar System

The approximate dimensions of the Solar System are shown in Figure 2(a). The dimensions of the center section, Mars Base and Mars Landing zone, are further detailed in Figure 2(b). Note that

[1] For example, the student builder/operator can not be holding the device, then release it to start a trial, as they'd be imparting significant energy to hold it away from an equilibrium condition.



(a) Approximate Dimensions of the Solar System



(b) Approximate Dimensions of the Mars Landing Zone

Figure 2: Approximate Dimensions

these dimensions are approximate and that robots should be robust to uncertainties in them.

3.2 Construction Materials

Each team is permitted to use one Arduino controller and the sensors and servomotors contained in three SparkFun Inventor's Kits. The components of the kit that each team has been given for the contest can also be used. The small DC motors from the SIK kits can *not* be used.

Each team is also allowed to purchase construction materials and additional sensors, but the total cost may not exceed $100. *No* additional actuators can be used. A bill of materials should be included in final report to document these costs. For devices nearing the $100 limit or suspected of exceeding it, receipts or other documentation of costs may be requested.

Table 1: Grading Summary

Maximum Available	Event
1	Individual Contest
3	Preliminary Contest
3	Qualifying Round
8	Final Contest
5	Design Review

3.3 Tie Breaker Procedure

In the event of a tied contest, the following tiebreakers will be used in order until a winner can be determined:

1. Points from *Safely Return to Earth*
2. Points from *Collect Pre-launched Fuel*
3. Points from *Transport Astronauts to Mars Base*
4. Points from *Avoid and/or Mine Asteroids*
5. Points from *Plant a Flag in the Mars Landing Zone*
6. Coin toss

3.4 Grading Summary

The performance of the robots will determine 15 of the 55 points available for the final project. Another 5 grade points will be determined by the Design Review. The division of these points is summarized in Table 1. Additional grade points from this project are determined by project reports and presentations. See the class syllabus for the division of those grade points.

3.4.1 Individual Contest

The maximum total score will receive 1 grade point, and the minimum score will receive 0.1 point. The grade for scores between the minimum and maximum will be linearly interpolated between these values. Failure to compete in this contest will result in a grade of 0 for this part of the robot performance grade.

3.4.2 Preliminary Contest

The maximum total score will receive 3 grade points, and the minimum score will receive 1 point. The grade points for scores between the minimum and maximum will be linearly interpolated between these values. Failure to compete in this contest will result in a grade of 0.

3.4.3 Qualifying Contest

The qualifying round is a full test; all contest rules apply. The score will reflect the team's ranking within the class. The highest ranked within each division team will receive 3 points, and the lowest ranked within each division will receive 1 point. The grade points for rankings between the highest and lowest will be linearly interpolated between these values. Failure to compete in this contest will result in 0 grade points. This round of competition also determines the initial seeding for the final contest.

3.4.4 Final Contest

The grade points for the final contest are based on the the final contest ranking of the robot. The winning team earns 8 grade points. Teams with zero wins get 2 grade points. Other teams' grade points are scaled linearly between these values according to their final contest ranking. Failure to compete in this contest earns 0 grade points.

3.4.5 Design Review

The judges' scores will be summed and divided by the number of judges that evaluate each robot. These resulting, average scores will be ranked across the class. The maximum score will earn 5 grade points, and the minimum score earns 1 grade point. All other scores will be scaled linearly between these two.

3.5 Contest Rule Details

1. If a team is disqualified for a rules violation, then they lose the current match in which they are competing. If the team can eliminate the violating offense, then they are eligible for future matches.

2. For the each round of contest, the devices will be assigned to a 7-minute time block. All competing devices will be automatically activated at the 4-minute mark, and must be removed from the track by the 7-minute mark. There is a 4-minute block of time dedicated to device setup. The devices will compete for 30 seconds. The next 2.5 minutes will be used for scoring and cleaning up. By the end of the 7-minute period, teams must remove their device (and any bits and pieces), return any competition pieces, and clean up their zone of the competition track. Disqualification can be imposed for taking longer than the allotted time.

3. Devices that are not ready for competition 15 seconds prior to the start of a round will be disqualified. *Note:* This means that of the 4-minute block of time dedicated to device setup, only 3 minutes and 45 seconds is actually available.

4. The device must be launched from within the 2 $\times$ 2-foot starting zone. The devices may be placed in any configuration or orientation within the starting zone; however, it must be completely contained in the zone.

5. The robot must fit within a 1-foot × 2-foot footprint. It also must be less than 18 inches tall. It may be oriented any way that fits within the 2 × 2-foot starting zone. Your device will be measured with a go/no-go box during the 4-minute setup period. When the box is removed, your machine may not "bloom" out and occupy a larger volume. Doing so will require a re-boxing of the machine. If your machine has not been cleared to compete by 15 seconds before the start time of the round of competition, you will be disqualified for that round.

6. Once the device has been boxed to check its dimensions, teams can only reposition the device. Teams cannot set/reset triggers, adjust components, turn on the controller, etc. Doing so will result in the device having to be re-boxed. The device may be translated and/or rotated post boxing, but it must move as a rigid body. If the device changes size or "blooms" during final positioning, it will need to be re-boxed.

7. Once teams have exited the setup area following boxing, teams may not interact with the device or enter the competition area. Doing so during the allowed setup time will result in the device needing to be re-boxed. Doing so outside of the setup time and before an official had indicated it is time to clear out the machine will result in a disqualification.

8. It is each team's responsibility to be on time with a working machine. If a team is not present during their assigned time, they are disqualified for that match.

9. All zones are defined as the immediate area on the competition track as well as the volume above the zone, unless otherwise stated in the contest rules.

10. A three-foot perimeter around the competition area, marked by tape, will be off limits during the competition. Entering the zone during a competition round will result in disqualification.

11. The device must be safe. It must not injure bystanders or team members. It must not damage, stain, or permanently change the competition area, components, or its surroundings. It must not scratch the floor. The faculty will disqualify any device they deem unsafe.

12. Each team may not spend more than a total of $100 on the device. Teams should document the cost of the materials by submitting their receipts, as well as a table of materials and costs in the final report. Material may be prorated for costs. The cost of an object is defined to be that which Joe P. Citizen must incur in obtaining the object. For donated, recycled, or scrounged material, an equivalent price must be specified.

13. The cost of the SparkFun kits is *not* included in the $100.

14. The $100 is out of pocket expense; it will not be reimbursed.

15. The costs of any aesthetic materials (*e.g.*, paint) and fasteners (*e.g.* staples, tape, and glue) are not included in the $100 budget.

16. Any and all supplies provided (extra electronics, motors, etc.) must be returned in good working order.

17. The device shall not be permanently bonded in any manner to the competition track or its surroundings in any way.

18. The device must be activated by using the start plugs near the starting zone. The start plug circuits will be closed during the thirty-second competition and open otherwise. The control code must sense the closed circuit and activate its actions.

19. Power to the robots will be available from outlets near the starting zones. If the robot travels far out into the competition area, teams must supply their own extension cord.

20. The robots cannot have active (powered applied) components prior to triggering. (*i.e.* solenoids and motors must be powered off).

21. The device must shut down (*i.e.*, no electric motors, etc. operating) at the end of the thirty-second competition. Failure to do so will result in disqualification.

22. The only power sources that the robots can use are gravity and the electromechanical energy from the allowed kit components.

23. The device must operate autonomously. No remote control is allowed.

24. The device may touch or otherwise utilize any part of the arena or its surroundings. It may not utilize or interact with any living person or living object, such as trained alligators, during the competition.

25. False starts that disrupt the playing field such that it cannot be reset in time for the scheduled start will result in a disqualification of the offending device.

26. While machines may go outside of the playing field, there are no guarantees as to what will be located outside of the track, *e.g.*, a wall or motor or people may be located outside of the track area. However, no part of the machine may leave the three-foot perimeter, nor should the machine cause any object to leave the playing arena such that it crosses the three-foot perimeter (either a projectile or track component). Any violations will result in a disqualification due to safety considerations.

27. Teams will remain constant for the duration of the project. The faculty has the right to remove or otherwise penalize disruptive members of any team.

28. Wanton destruction of the opposing devices, the competition arena, or competition components is strictly prohibited.

29. Offensive language is prohibited. If heard, the offending team will be disqualified.

30. "If you don't play, you can't win." If a device does not make any noticeable movement, the device is disqualified from that round of competition.

31. The faculty's rulings on any clarification or dispute of these rules are binding and final.

Version History

- 02/22/17 – Initial posted version
- 03/09/17 – Corrected date for Qualifying Contest to match course schedule
- 03/17/17 – Corrected several typos