

Final Design Project: Toy Story

A. Overview and Theme

The goal of this project is to use a structured design process to design, construct, build and test an automated system that will compete in a head-to-head competition. The theme of this competition is Toy Story. You and your team must rescue Woody and Buzz from the destructive Sid and return them to Andy before they get lost during the big move! In this competition, your team must rescue Buzz from the Aliens, help Buzz shoot the rocket to infinity and beyond and return RC cars to Andy's minivan. These tasks are described in the following text and pertain to the competition track depicted in Figure 1.

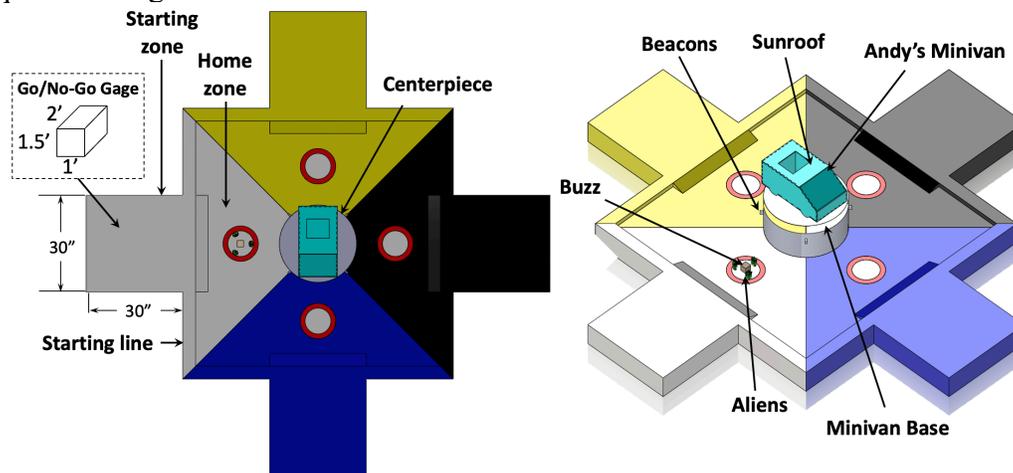


Figure 1. The competition arena.

B. Primary Competition Parameters

All tasks will be executed in the competition arena during a 40-second time period. The arena is square-shaped with sides 7 feet in length and constructed by 2-inch x 4-inch lumber over $\frac{1}{2}$ -inch plywood, as shown in Figure 2. These 2-inch x 4-inch boards are oriented such that their height is 2 inches (actually, 1.5 inches) around the perimeter of the competition arena. They are stacked on top of the $\frac{1}{2}$ -inch plywood zone base. The arena has 4 home zones which are separated by physical barriers and each home zone has a starting zone. Beside each starting zone, the arena provides two 120V AC outlets and a set of female connectors which receive the banana plugs provided in the mechatronics kit. At the beginning of the round, the circuit will be closed between the two connectors, which must be used as the signal to activate your system. At the end of the round, the circuit will be opened again. In the center of the arena is a cylindrical body 24 inches in diameter and 25 inches tall, shown in Figure 1. The cylindrical body has 4 cutouts assigned to each of the zones by color. These cutouts are marked by beacons whose vertical position is as marked in Figure 2. These beacons are 1 inch x 1 inch x 0.5 inches in size. Atop the cylindrical body is a car that is 10 inches tall with an open 6-inch x 7-inch sunroof, as shown in Figure 2. The centerpiece rotates at approximately 6 rotations per minute. This rotation is automatically stopped at the end of the match period.

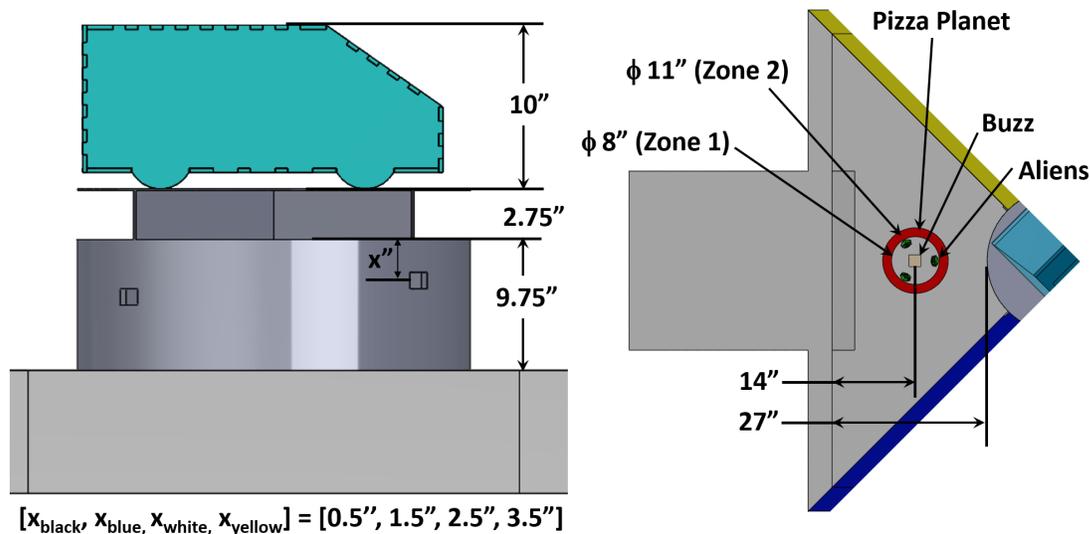


Figure 2. The arena centerpiece (left) and competition item layout (right).

C. Competition Tasks and Competition Points

The goal of the competition is to maximize the points scored for successfully completing these various tasks. Judging of these tasks will take place at the end of each round, so any points scored and subsequently de-scored before the end of the 40-second time period will not be counted. The design problem is inherently constrained by limits on volume, energy, cost and time. **Your system must be deactivated and static before the start and at the end of the 40-second round; failure to do so will result in disqualification.** Deactivated and static is a state of your machine, defined as a system which neither supplies power to electrical components, nor has the ability to suddenly release potential energy via springs, rubber bands, or otherwise. The following describes the primary tasks and the points associated with each task are summarized in Table 1.

1. Launch the System

The system must start, fully at rest, behind the marked starting line in Figure 1. Upon activation of the track, the system must deploy and complete the competition tasks. Your team will earn points for successful deployment of the system. Successful deployment is determined by a successful trigger of your system and abiding by the rules specified at the end of this document, specifically that your system must have a perceptible motion from an actuator after button start to score. Teams can load competition items and position the system in the starting zone before start.

2. Rescue Buzz Light Year with the Claw

The goal of this task is to rescue Buzz while avoiding Aliens. Buzz will start in the home zone and on the Pizza Planet shown in Figure 1. Buzz is a wooden cube 2 inches in size. Buzz will be surrounded by 3 Aliens positioned as shown in Figure 1. The Aliens are 3-D printed objects that are 2.4 inches tall x 1.7 inches wide x 1 inch deep. Your team will earn points for rescuing Buzz from the Pizza Planet and will lose points for moving Aliens from the Pizza Planet. Maximum points are associated with rescuing Buzz back to your starting zone and not disturbing any of the Aliens. Some points are given for a partial rescue of Buzz from the Pizza Planet as well as partial movement of the Aliens, as shown in Table 1.

Table 1: Scoring Detail.

Task	Task	Competition Point Value
1	Launch	5 points for successful deployment
2	Rescue Buzz with the Claw	36 points for Buzz in fully/partially in team's starting zone 18 points for Buzz fully outside zone 2 12 points for Buzz partially outside zone 2 3 points for each Alien fully inside zone 1 1 point for each Alien partially inside zone 2 0 points for each Alien fully outside zone 2
3	Launch Rocket To Infinity and Beyond	20 points for rocket clearing 42 inches above competition floor 10 points for rocket clearing 36 inches above competition floor 5 points for rocket clearing 24 inches above competition floor +30 points for highest rocket in round* +10 points for second-highest rocket in round*
4	Return RC Cars to the Minivan	15 points per RC in the top of the Minivan Sunroof 7 points per RC in team's marked quadrant in Minivan Base
5	Egress	2x points T4 score for full egress (from center and start)

* All rockets reaching 100 inches will receive $20+30 = 50$ points.

3. Launch Rocket to Infinity and Beyond

The goal of this task is to launch the Rocket to Infinity and Beyond by raising the rocket as high as possible. Your team will be provided with a rocket before the start of the competition. The rocket is a wooden cylinder with a conical nosecone and 3 fins at the cylinder base. The rocket is approximately 6-inches tall x 2-inches diameter in the mid-section and 4 inches in effective diameter at its base due to the fins. Your team will receive points if the rocket is held at least 42 inches above the arena floor. Additional points are available if your team is able to hold the rocket at the highest position or second highest position compared to other teams in a particular round, as detailed in Table 1. If a rocket reaches 100 inches above the competition floor it will receive the maximum points for this task.

4. Return RC to the Minivan

The goal of this task is to return the RC Cars to the Minivan by depositing the RC Cars in the centerpiece shown in Figure 1. Your team will be provided with 3 RC Cars before the start of the competition. These RC Cars are plastic spheres 1.57 inches in diameter and approximately 0.095 ounces in weight. Each sphere is to be placed in the centerpiece quadrants corresponding to your team's zone color in the Minivan Base or in Andy's Minivan Sunroof. You may not modify the spheres and/or deposit other objects in the centerpiece. If you violate this rule, your team will be disqualified. Your team will receive points for each RC Car in your quadrant or in the Minivan, as noted in Table 1. This means that other teams' RC Cars will count towards your score if they are mistakenly placed in your quadrant. There is no explicit restriction on removing or displacing RC Cars from other teams' quadrants, but mechanisms should never enter another team's protected zone.

5. Egress from Centerpiece and Start Zone

The goal of this task is to egress from the starting zone. Egress is considered successful if no part of your system is within the starting zone or in vertical interference with the starting line. Points associated with egress are detailed in Table 1.

D. Design Constraints

The design problem is inherently constrained by limits on volume, energy, cost and time. **Your system must be deactivated and static before the start and at the end of the 40-second round; failure to do so will result in no points for that round.** Deactivated and static is a state of your machine, defined as a system which neither supplies power to electrical components, nor the ability to suddenly release potential energy stored in the system via springs, rubber bands, or otherwise before application of an external electrical input. You are permitted to use energy only from the electricity supplied from your controllers, 5 mousetraps (Victor Brand, M154 or equivalent), any mechatronics kit components, 5 #64 rubber bands and gravity. Your team will be provided with a set of pneumatic and electrical actuators. Your controllers may only power the actuators supplied to you. The controller also powers the sensors supplied to you. You may also purchase additional sensors if your budget remains under \$100. All sensors purchased must be approved by the Head TAs in writing and submitted purchasing information will be published on the class website. Please see the rules at the end of this document for details on the budget specifications.

E. Competitions and Grading

You will design and construct devices in 2 sprints. During each design sprint, your design may evolve due to revisions that are needed as your team experientially learns more during fabrication and testing. To accomplish this, your team will utilize the IDEA Laboratory during: (1) time available for dedicated studio hours and (2) open studio hours. To record machine performance, your team will run your system during your dedicated studio timing or as determined by your instructor if your studio does not meet at the specified times below.

Design Sprint 1: During weeks 5-8 (Sep. 20 – Oct. 15), all tasks are in play and your system should demonstrate design feasibility and control system design to achieve the minimum functionalities associated with:

- Task 1: launching the system (5 points)
- Task 2: partial Buzz rescue (12 points)
- Task 3: launch rocket 24 inches above competition floor (5 points)
- Task 4: 1 RC Cars in team's marked quadrant (7 points)

The score for the above minimum functionalities is 29 points/trial, your system may score higher than this total as all tasks are in play, but the maximum per trial is 29 points. You will run 3 consecutive trials with no other teams running and the average number of points scored will determine your grade. The maximum grade for machine performance in this design sprint is out of 29 points. Total scores greater than or equal to this will all be considered a perfect score.

Design Sprint 2: During weeks 9-11 (Oct. 18 – Nov. 5), all tasks are in play and your system should demonstrate design feasibility and control system design to achieve the minimum functionalities associated with:

- Task 1: launching the system (5 points)
- Task 2: full zone 2 Buzz rescue and 1 Alien fully within zone 1 (21 points)
- Task 3: launch rocket 36 inches above competition floor (10 points)
- Task 4: 2 RC Cars in team’s marked quadrant (14 points)

The score for the above functionalities is 50 points/trial, your system may score higher than this total as all tasks are in play, but the maximum per trial is 50 points. You will run in at least 3 rounds in head-to-head format against 3 other teams and the average number of points scored will determine your grade. The maximum grade for machine performance in this design sprint is out of 50 points. Total scores greater than or equal to this will all be considered a perfect score. Your team’s raw score in this competition will determine seeding for the final competition.

Table 2: All System and Subsystem Competitions.

Competition (type)	Week	Date	% of Final Grade
Competition 1 (studio)	8	October 11-15	2%
Competition 2 (studio)	11	November 01 - 05	3%
Final (class-wide)	12	November 12	5%

Final Competition: The final competition will occur at 6PM on 12 November, your system should demonstrate design feasibility and control system design to achieve the minimum functionalities associated with:

- Task 1: launching the system (5 points)
- Task 2: full zone 2 Buzz rescue and 2 Aliens fully within zone 1 (24 points)
- Task 3: launch rocket 36 inches above competition floor (10 points)
- Task 4: 2 RC Cars in team’s marked quadrant (14 points)

The score for the above functionalities is 53 points/trial, your system may score higher than this total, but the maximum per trial for grading purposes is 53 points. You will run in at least 2 rounds in head-to-head format against 3 other teams and the average number of points scored will determine your grade. The maximum grade for machine performance in the final competition is out of 53 points. Total scores greater than or equal to this will all be considered a perfect score. Scoring and performance in round 3 and beyond will not impact your final grade and are solely to determine final competition winners. To compete in round 3, a machine must have been among the top two teams based on total score during their round 1 or round 2 trials. To advance in subsequent rounds, teams must be among the top two teams until four teams remain in the overall competition. These four teams will compete in a final round to determine the final competition winner. Any ties will be broken in order of the priority: total points for Task 3 and Task 4, final competition seeding.

F. Design Review Grade

The design review grade will be determined between 430 PM and 6 PM on the competition day before your system competes. **The design review grade is 5% of your overall grade.** This will operate in a typical science fair type mode. Judges will evaluate your team on the basis of three categories: (1) design ingenuity/innovation, (2) design aesthetics, (3) technical communication and presentation. The judges will rank your team in these categories. Each judge’s ratings will be normalized based on their assessment of a common design review example. Your grade will be an

average of the judges' ratings. A copy of the scoring sheet template will be available on the ME2110 website for review prior to the event. You will be required to upload a video of an example design review presentation prior to the design review event.

G. Reports and Presentations

There will be three sets of reports/presentations associated with this project. The deadlines for these items are given in Table 3. Information regarding content/formatting of each is provided on the ME2110 website. Unless otherwise specified by the studio instructor, reports and presentations are due at the start of studio and must be uploaded to Canvas.

Table 3: All Reports and Presentations.

Report/Presentation	Week	Date	% of Final Grade
Design	6	Sept. 28 – Oct. 1	10%
Alternatives	9	Oct. 19 – 22	10%
Final	13	Nov. 16 - 19	15%

H. General Information

1. You will have a minimum of 5 minutes to prepare for the next round in the final competition.
2. There may be some slight differences between the floor surfaces of the various tracks (*e.g.*, one track may be a bit rougher than another). Your device should be engineered to be robust to these differences.
3. The tops of the 2-inch x 4-inch lumber boundaries of the home zones are not considered part of the home zones. The ramp is considered part of the home zone.
4. The device must be activated by using the start plug on the right side of your respective starting zone. The start plug circuits will be closed during the 40-second competition and open otherwise.
5. While machines may go outside of the competition zone, there are no guarantees as to what will be located outside of the track (*e.g.*, a wall, pillar, trigger box or person may be located outside of the track area).
6. The faculty will assign the groups. The groups will remain constant for the duration of the project. The faculty has the right to remove or otherwise penalize disruptive members of any group.
7. The faculty's and TA rulings are binding and final.

I. General Rules

1. For the final competitions, your device will be assigned a 7-minute time block. All four devices will be automatically activated at the 4-minute mark, and must be removed from the track by the 7:00 minute mark. Your machine must be ready to run at the 3:00 minute mark, which includes satisfying the condition set by General Rule #7. Your machine will be disqualified if it is not ready at this time mark. Thus, you will have 3:00 minutes to set-up your device and 40 seconds for the robot to complete its tasks. By the end of the 7-minute period you must have removed your device (and any bits and pieces) and cleaned up the competition track. Your system will be disqualified for taking longer than your allotted time. It is your responsibility to be on time with a working machine. If you are not present during your assigned time, you forfeit the round.
2. If at the end of the round, your team leaves any liquids on the track surface and/or damages the track, this will result in a disqualification.

3. If your team leaves the competition arena with any competition objects or fails to return them to the track within the 7-minute time block, this will result in a disqualification.
4. The source of power in your device is limited to the five mousetraps provided to you, power provided to your system from a controller box, the mechatronics kit components, five #64 rubber bands, and gravity. No other devices that store energy are permitted. Air from the pneumatic tank may only be used to power pneumatic actuators, and may not be vented directly to the environment. Rubber bands that do not release energy (e.g., as treads on tires) do not count towards the total. Magnets cannot be used to generate power for competition tasks.
5. No actuators (e.g., valves, solenoids) can be pre-activated prior to the start of a round, or after the end of a round. Actuators must be in their resting state at the start and end of each round.
6. The only powered actuators that you are permitted are the ones that are supplied to you by the ME 2110 staff. You may purchase additional sensors as long as your budget remains under \$100, and as long as you are provided with written consent from the Head TA. Purchasing information must be submitted to the Head TAs ahead of time, and this purchasing information will subsequently be published on the course website once approved.
7. The device must fit within a 12-inch x 24-inch x 18-inch (length x width x height) box. Your device will be measured with a go-no-go gage immediately before each attempt. All parts of the device will be measured. The 18-inch dimension is the maximum starting height of your system. All measurements are to be made on the 30-inch x 30-inch starting zone. If you cannot clear the go-no-gage (as determined by a track judge) and have your device set within the starting zone behind the starting line within the allotted time, you will be disqualified.
8. The device must be launched from within the starting zone and behind the starting line. The outside of the lumber perimeter defines one of the sides of the starting zone. You may place your device in any configuration or orientation within the starting zone; however, the go/no-go box must be able to fit over the device immediately prior to its start with it ready to be triggered. You may reposition your device translationally or rotate it after it has been checked for size, but may not make any changes to the internal state of the machine (e.g., adjusting wires, pressurizing the tank, etc.) without having to again clear the go/no-go box. If your device triggers errantly (e.g., false start), you must again clear the go/no-go box prior to its start.
9. There will be a 3-foot area around the competition arena, marked off by tape on the floor that is off-limits during the competition.
10. The device must be safe. It must not damage, stain, or permanently change the competition track and competition items or its surroundings. No adhesives and no Velcro-type materials (e.g., hook and loop binding) may be used to interact with the track or the competition items. The device should not scratch the floor or paint on the track. It must not injure bystanders or you. The faculty will disqualify any device they deem unsafe, resulting in zero points for the competition.
11. Once it has been activated, you may not touch, or even appear to touch, the device until the staff member in charge of the competition arena indicates it is time to clear out the arena. If a team approaches the track before they are cleared to do so, their system will be disqualified from that round.
12. No device may throw any projectile such as a net or rope over the track centerpiece. Any such action will result in the disqualification of your system.

13. The device and your competition objects must not deliberately move outside of your quadrant (e.g., home zone, starting zone). For example, the team starting in the black quadrant may not move into the yellow quadrant. No part of their device may hover in another team's quadrant in the space above the centerpiece. Also, this means that the device must not move outside of the vertical bounds of the arena.
14. The device shall not be permanently bonded in any manner to the competition track or its surroundings in any way. The mechatronics components shall not be permanently bonded to the rest of the device (e.g., no glue or epoxy fastening components down).
15. The device must shut down/stop moving at the end of the 40 seconds when the start plug circuits are opened. Failure to do so will result in a disqualification.
16. The device must operate autonomously. No remote control is allowed.
17. The device may not utilize or interact with any living person or living object during the competition.
18. If your device fails to trigger or has made no perceptible motion after the round has started, this will result in disqualification.
19. Disqualification is defined as forfeiting the particular round in which the disqualification offense occurs.
20. Wanton destruction of opposing devices or competition arena is strictly prohibited.

J. Revision Notes

1. Revision 1 – Released on 12 September 2021.
2. Revision 2 – Released on 12 September 2021. Minor update to Table 1 egress task score to correct a typo.