Embedded Systems International

Project Requirements

This document provides an overview of the project requirements. Teams have developed mission goals for an autonomous vehicle (AV) application. All aspects of the design problem and requirements are represented in the Mars rover application, so that is used for the sake of illustration. For any AV application, including Mars rover, this document establishes a set of basic criteria to be met. Teams will be given a test field with boundaries, objects, and a destination. The objects represent obstacles and other objects specific to your application. You may define navigation goals specific to your application, in addition to reaching a destination. You will have a base station that communicates with the vehicle. Unique or innovative features of an application, e.g., in the system or test environment, may qualify for bonus points, whereas serious incidents may lead to deductions.

The project consists of four parts :

- Part I – Communication with the Autonomous Vehicle
- Part II – Movement and Navigation in a Test Field
- Part III – Positioning the AV at a Destination
- Part IV – Code and Other Deliverables: Statement of Work (Proposal), Team Contract, Code Review, Final Prototype, Peer Evaluation, and Project Reflection

The lab attendance policy stated in the syllabus remains in effect for the project. All students must attend the lab as usual until their project is demonstrated and submitted. Missing a lab without permission can result in a zero grade on the lab project. The lab project is 20% of the course grade.

Typically, all team members on the same team are given the same project score. Exceptions can occur if peer evaluations and/or lab instructor observations indicate that a team member is not contributing to the project and supporting a collaborative team environment. Team members are encouraged to handle issues promptly with other members and/or the lab TA in the best interests of project success.

Demonstrations of Parts I-III will be scored using an evaluation checklist (120 points). Part IV items will be graded separately based on corresponding Canvas assignment submissions (20 points for code, 20 points for SOW, 20 points for Final Prototype, and 20 points for other four items). Thus Parts I-IV consist of 200 points.

A sample test field is shown in this video of a Mars rover application project demonstration: https://www.youtube.com/watch?v=ulidN0rs1NA

Teams are required to demonstrate their project no later than dead week in their lab session. Five extra credit points will be given for final demonstrations before dead week. The demonstration time limit is 20 minutes; this may be extended to 30 minutes before dead week. A TA has full discretion to stop the demonstration at any time.

Parts I-III will be evaluated using five categories:

1) Functionality in relation to the AV application mission goals and user needs
2) Mapping of functional requirements to platform components and capabilities
3) Elements of the test field
4) Serious incident penalties
5) Feature bonuses

In category 1), the basic functionalities are:

a. Cybot communication
b. Cybot movement
c. Object detection
d. Object avoidance
e. Boundary adherence
f. Arrival at destination
g. User interface
h. Base station remote control

These functionalities must address the application mission goals and user needs.

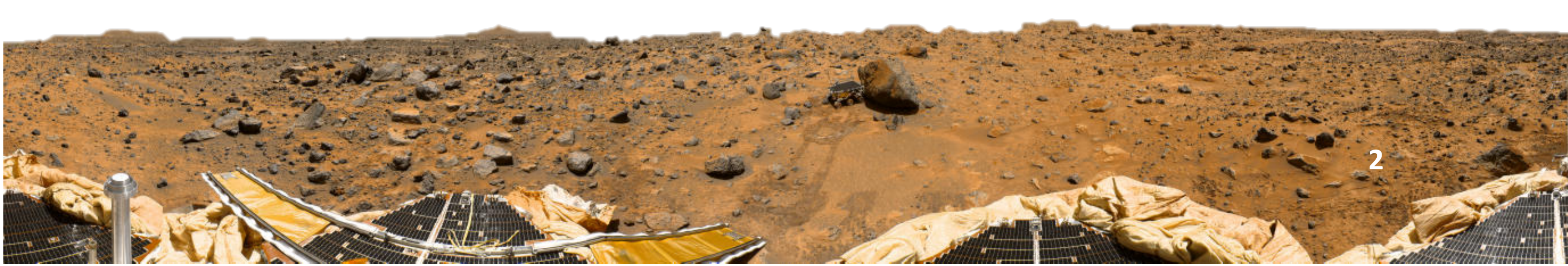
In category 2), the basic platform components and modes used are:

a. Open Interface and iRobot sensors
b. Interrupts
c. Analog to digital conversion
d. Input capture
e. Pulse width modulation
f. UART/WiFi

Any limitations in the use of these components must be justified or compensated for.

In category 3), the test field must include at least these elements:

a. Tall objects: These objects are detectable by the Ping and IR sensors and have a diameter of no less than 6 inches. The robot should not make any contact with these objects.
b. Short objects: These objects are not detectable by the IR sensor. They may or may not be detectable by the Ping sensor, depending on the distance from the sensor to the object. The robot can make slight contact with these objects but should move around them if detected through the bump sensors.
c. Boundaries: Boundaries, such as out of bounds, are marked with white tape.
d. Holes: Holes are created by pulling out the floor tiles. The robot must not fall into any holes. The cliff sensors and wheel drop sensors of the iRobot platform can detect a hole and be used to ensure the robot does not fall into it.



e. Pillars (destination zone): Four round pillars that are 3 inches in diameter mark a destination zone. Each pillar is detectable by the Ping and IR sensors. The robot should not make any contact with the pillars.

In category 4), examples of incidents and penalties are (points are deducted):

a. Leaving the test field or crossing a boundary (-5 points per incident, maximum -10 points)
b. Falling into a hole (-10, max -20)
c. Coming into contact with tall object (-5, max -30)
d. Repeatedly coming into contact with short object (-2, max -10)
e. Improper positioning or contact in the destination zone (-2, max -10)
f. Program crash (-5, max -10)
g. Exceeding time limit for demonstration (-1 for every minute over limit, max -5)
h. Other incidents specific to your application

In category 5), examples of features are (bonus points are given up to a maximum of 25):

a. Novel AV application and detailed mapping to the test field (up to 10 points)
b. Autonomous navigation of the test field (up to 10 points)
c. Graphical user interface (up to 5 points)
d. Use of sound (up to 2 points)
e. Additional functionality beyond basic requirements (varies)
f. Additional components beyond basic requirements (varies)
g. Demonstrating before dead week (5 points)
h. Other features specific to your application

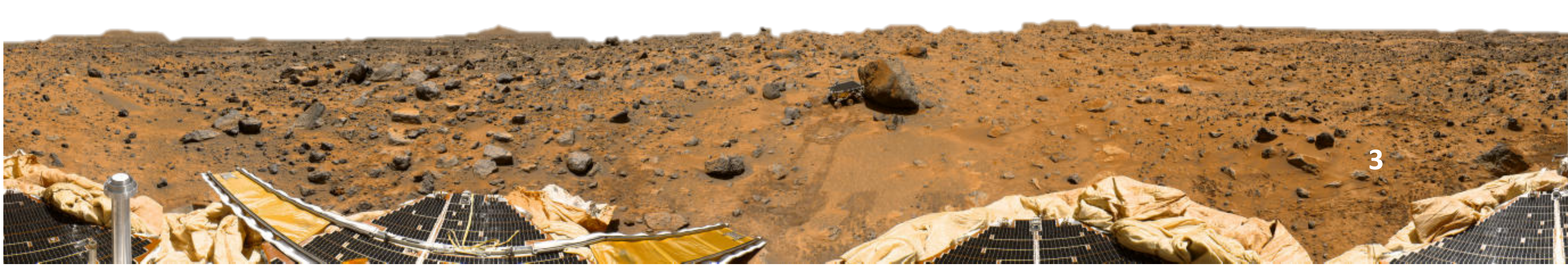
The base station and its operators must be able to process the information that the Cybot platform sends to it. You should format the information appropriately so that it can be understood by the operator. It is up to your team to decide what information the Cybot platform sends. Whatever information you choose to send should be enough to navigate the test field.

The base station must also be able to control the Cybot remotely. It is up to your team to decide the amount of control supported at the base station. Minimally, the base station operators should be able to:

- Send a signal to activate the Cybot at the start of the test.
- Send a signal to put the Cybot in standby when it has reached the destination zone.
- Send a signal to indicate that the destination zone has been found and prepare the Cybot for positioning in the zone.
- Control the basic movement of the robot.
- Control the sensors of the robot.

Any command sent from the base station must be handled as a high priority command. This means that it will be fully executed before the Cybot continues any of its normal tasks. However, note that some sensors may take higher priority.

In addition to base station remote control of the Cybot, you should provide some decision-making capability on the robot itself.

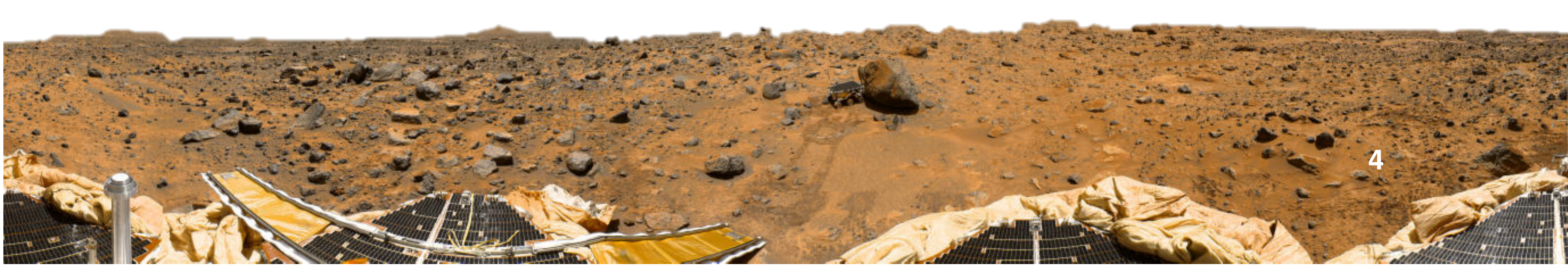


Example Functional Description for Mars Rover Application

The Mars rover will be landing in Martian terrain that is unknown to you and mission controllers. The only knowledge of the terrain is transmitted by the rover. The objective is for the rover to traverse the hazardous terrain for data retrieval at a predetermined rendezvous site. After the rover enters the retrieval zone, it should send signals to mission control indicating that data are ready for retrieval.

The rover will be placed at a random position in the test field and should navigate through several hazards to position itself within the retrieval zone. The rover will perform as follows:

1. find and stop in the zone where it can transmit the data it has collected
2. detect surface objects, such as boulders and stalagmites, so that it can avoid running into them and damaging components
3. identify the boundaries of a “safe zone” to stay within areas having safe levels of solar radiation (marked off by white tape in the test field)
4. avoid objects it has detected and identified to limit the damage it takes
5. display information in a form that is readable to mission control operators who are monitoring and controlling its activities
6. receive commands from mission control
7. navigate the course and reach the goal area within a time limit so that it does not miss the transmission window
8. make decisions about movement without operator commands (in case commands cannot be received)
9. determine the type of object it has detected to help determine how it will avoid the object



Part I. Communication with the Autonomous Vehicle

Since a key objective of this project is information collection, you will be required to implement some form of user interface (UI) that can be used to retrieve information from the Cybot and also to control the Cybot.

One example of a simple UI would be a terminal interface in which the base station would send single characters as commands to the robot. Such a terminal interface would be a text-only interface. The design of the user interface is up to your team, however, it must provide the following functionality.

1. Show the current state of these sensors:
    a. iRobot Bump Sensors
    b. iRobot Cliff Sensors
2. Control these functions remotely:
    a. Moving the robot
    b. Taking a sweep of distance measurements (should transmit to the user interface either raw data, or information about the objects detected)

Command Priority

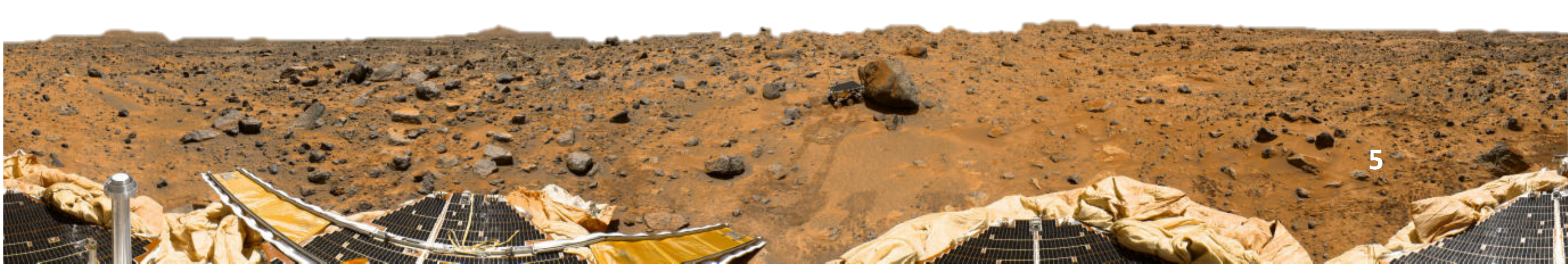
Along with controlling the Cybot, you must ensure that a command sent to it will not potentially damage it. The iRobot portion of the Cybot has cliff sensors, which should be checked frequently (e.g., you should not be able to command the robot to drive forward off a cliff). For this reason, you should check the priority of any command before executing it. Enforce these command priorities:

- (Highest Priority) Emergency stop initiated by the sensors (bump, cliff sensors)
- Base station commands
- (Lowest Priority) Local robot control (i.e., any automation you've programmed)

Completion Requirements

This part will be considered successfully completed when:

- The user interface for monitoring and controlling the Cybot is usable.
- The user interface contains the minimum required functionality.
- Commands to the Cybot are executed with the proper priority.



Part II. Movement and Navigation in a Test Field

The Cybot needs to respond quickly to the bump and cliff sensors. Because of this, the Cybot cannot wait for a response from the base station operators on how to respond. Therefore, your embedded program should have some preprogrammed, automatic response to a bump sensor. The lack of response will be indicated by the Cybot continuing to drive forward while still in contact with the object. Some latency is acceptable, but only about one second.

CAUTION: The response of the robot to the sensors should be comprehensive. For example, if the robot bumps into an object, it should not back up into a hole.

Completion Requirements

This part will be considered successfully completed when:

- Using the functionality from Part I, the Cybot reaches the destination zone and fulfills the goals of the application.

If the Cybot does not reach the destination zone, partial credit may be awarded based on the demonstration and other application goals achieved.

Note: Teams will **NOT** be able to see the test field with obstacles during the demonstration. This means that teams will have to rely solely on the sensor information to visualize the test environment and navigate the robot to its final destination.

A reasonable effort must be made to navigate around obstacles. A random walk in the test field is not a reasonable effort and does not satisfy project requirements.

Part III. Positioning the AV at a Destination

Once the destination zone has been identified, the base station operators should be able to properly position the Cybot within the zone according to the needs of the application. The Cybot should then signal that it is in the zone.

The pillars marking the destination zone are durable and heavy enough to withstand minor contact, but they should not be moved significantly during the process of positioning the Cybot in the zone.

Completion Requirements

This part will be considered successfully completed when:

- The Cybot is within the destination zone and sends a signal.

Unexcused absence penalty*:* Attendance will be taken during the lab project. If a team member is absent without being excused and notifying both the team and the lab instructor **prior to the absence**, then that team member will have 10 points deducted for each missed lab meeting. Teams who finish early will not be required to attend lab after they have demonstrated their project.