STEM ON THE GROUND

CHALLENGE 1: LET'S GET MOVING!

What do you do when you have a task that is unsafe or even impossible for a human to complete? One solution is to use a remotely controlled vehicle. Sometimes referred to as a "robot," these adaptable, yet untethered, machines are used everywhere from the deepest oceans on Earth to the surfaces of other planets. In this challenge, you will be investigating the foundation of any robot that has to move across solid surfaces. You'll begin building a base that is able to move around obstacles and is adaptable to future challenges.

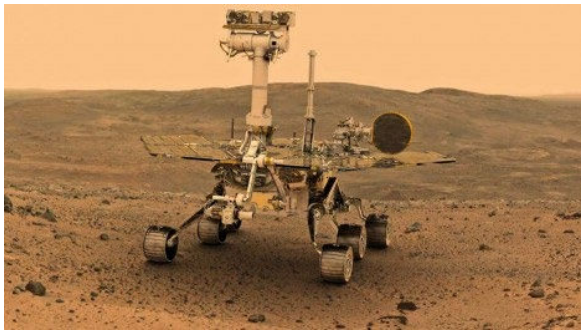
YOUR MISSION:

Design and create a remotely controlled vehicle that can move across various terrains and around a variety of obstacles. Your robot should be durable, agile, and easy to control.

PROCEDURE:

Your robot will be tested on an obstacle course that will challenge your design as well as your driving skills. Once placed on the field, your robot will need to drive around and through several obstacles. Achievements will be awarded for both accuracy and efficiency. There are four obstacles:

1. **Around the Bend:** large diameter turn
2. **Around the Corner**: small diameter turn
3. **Through the Chute:** travel between the rails
4. **Object Avoidance:** run the slalom passing through three consecutive pairs of objects



MISSION CONSTRAINTS:

- Robot must be controlled remotely.
- All team members must control the robot at least once during testing.
- An obstacle is considered "cleared" if your robot does not cross any boundaries or alter any objects while moving around the obstacle.

MISSION CRITERIA (ACHIEVEMENTS):

- Robot clears at least one obstacle when driven by each team member (minimum criteria for success).
- Robot clears all obstacles when driven by each team member.
- Robot clears all obstacles in one run.
- Robot clears all obstacles in under 2 minutes.
- Robot clears at least one obstacle while being driven in reverse.
- Robot clears all obstacles in reverse.

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MISSION ACHIEVEMENTS:

- **Robot clears at least one obstacle when driven by each team member (minimum criteria for success).**

	Team member 1	Team member 2	Team member 3	Team member 4
Around the Bend				
Around the Corner				
Through the Chute				
Object Avoidance				

- **Robot clears all obstacles when driven by each team member**

	Team member 1	Team member 2	Team member 3	Team member 4
Around the Bend				
Around the Corner				
Through the Chute				
Object Avoidance				

- **Robot clears all obstacles in one run.**

Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	

- **Robot clears all obstacles in under 2 minutes.**

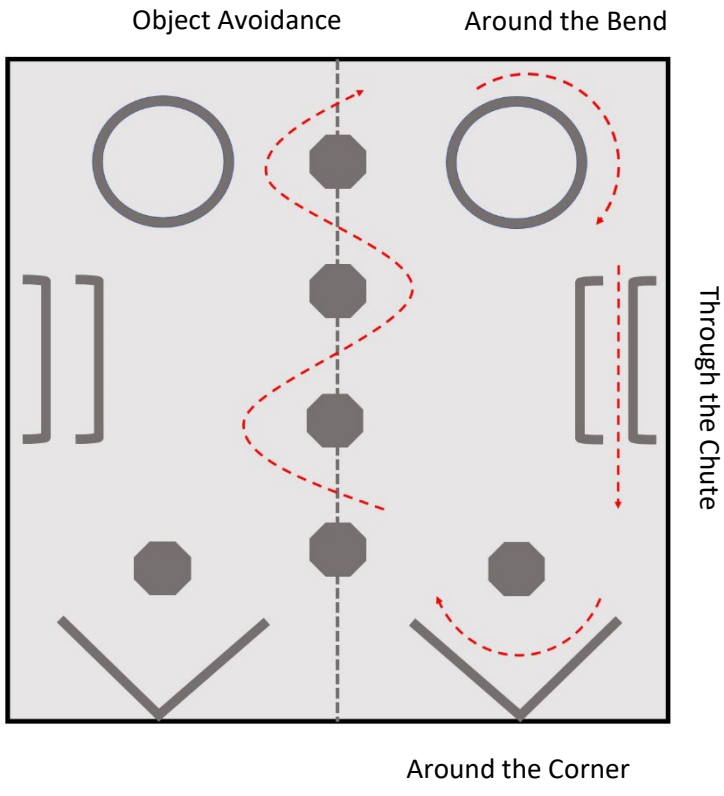
Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	

- **Robot clears at least one obstacle while being driven in reverse.**

Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	

- **Robot clears all obstacles in reverse.**

Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	



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JROTC STEM LEADERSHIP ACADEMY

STEM on the Ground

INSTRUCTOR'S GUIDE

Introduction

The design challenges of STEM on the Ground are all about robots that perform tasks remotely. Each design challenge is framed as a mission which will require teams to design, build, and control a robot to complete various mission achievements. Each mission requires a slightly more complex robot than the previous mission. Teams will use VEX Robotics competition kits to build and control their robot through a remote control.

At the start of each mission, teams are provided with a Mission Brief. This handout delivers important mission details as well as a context to help cadets understand how the robots they build would be useful in the real world. The layout of each Mission Brief is the same.

Along with instructions provided with the VEX Robotics kits, each team will also be provided a Team Engineering Notebook (TEN) and a Resource Notebook. The TEN contains necessary handouts and provides a place for teams to record their advancement through the Engineering Design Process. The Resource Notebook will contain documents with information teams will need while designing and building their robot. Teams should be encouraged to refer to the Resource Notebook while researching and brainstorming ideas.

In addition to the Mission Achievements presented with each mission, teams will be working towards General Achievements throughout the week. These achievements encourage teams to promote the overall goals of the Academy including practicing teamwork, showing leadership, and utilizing STEM learning outcomes. The General Achievements will be marked on a central record accessible by the instructional staff. It will be helpful, however, to assign one member of the instructional staff as the point person for observing and recording any achievements attained by the cadet teams.

There are five main sections:

- **THE PROBLEM**—presents a scenario in which a robot is needed to solve a problem.
- **YOUR MISSION**—describes what the robot must be able to do to be successful.
- **PROCEDURE**—explains how the scenario will be simulated during testing.
- **MISSION CONSTRAINTS**—provides a checklist of requirements and suggestions for the robot.
- **MISSION ACHIEVEMENTS**—lists a variety of accomplishments that are possible for the mission, including the minimum criteria for success.

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Design Challenge 1: *Let's Get Moving!*

(TOTAL TIME: 390 MINUTES)

Overview

Design Challenge 1: ***Let's Get Moving!*** begins with three Research Investigations in which cadets, working in assigned STEM teams, experiment with various designs for the base of a remote-controlled robot. Through these investigations cadets begin to understand how the VEX Robotics materials work while experiencing the concepts of turning radius and gear ratios. Let's Get Moving! ends with teams using their completed designs to test for mission achievements as described in the Mission Brief. Teams are allowed to adjust their designs based on testing outcomes.

Important Vocabulary

- Criteria
- Zero radius turn
- Achievements
- Drive wheel
- Constraints
- Omni directional
- Drivetrain
- Gear train
- Turning scrub
- Turning point
- Chassis
- Input
- Driving gear
- Output
- Driven gear
- Wheelbase
- Gear ratio

Learning Outcomes

- Cadets will be able to follow step-by-step instructions to complete a simple VEX V5 build.
- Cadets will be able to compare and contrast the different types of drivetrains, including the benefits and drawbacks of each type.
- Cadets will be able to use recent vocabulary in context to communicate findings.
- Cadets will be able to calculate an increase/decrease in rotational speed based on gear ratios.
- Cadets will be able to construct a gear set-up that achieves a given gear ratio.
- Cadets will be able to explain what the specific components that make up the VEX V5 System can do and how they are used to control the robot.
- Cadets will be able to set up their V5 Controller to function in driver-controlled modes.
- Cadets will be able to use the VEX V5 system to successfully control their robot in a classroom challenge.

Materials

Per Classroom (one Platoon)

- Computer and projector with sound
- General Achievements Checklist
- Design Challenge 1 Slides
- Timing device
- Chart paper & Markers
- Extension cords (for VEX batteries)

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Materials *(Continued)*

- VEX game field (start with no obstacles; can be shared between two platoons)
- Objects per half game field
  - 4 slalom markers (shared between field halves)
  - 2 chute boundary markers
  - 1 large-radius turn marker
  - 2 small-radius turn markers

Per Cadet — Mission 1 Brief handout

Per Team (4 cadets)

- Team Engineering Notebook
- Team Materials Kit
- Resource Notebook
- Sheets of blank paper
- 1 Understanding Drivetrains Handout
- 1 Basic Drivetrain Build Handout
- VEX V5 Kit (electronics kit held until Investigation 3)
- Clawbot Build Instructions booklet

Schedule: Notice in your schedules that on Monday, Tuesday and Wednesday half of the platoons will travel to industry/educational sites in the morning (Red, Yellow, Green) and the other half will travel to the off-campus sites in the afternoon/evening (Blue, Orange, Purple). Below is the implementation schedule for Design Challenge 1.

CHALLENGE1 Lesson #	Day	BOP Platoons	RYG Platoons
1	Sunday	3:15 p.m. — 6:00 p.m.	
2	Monday	8:00 a.m. — 9:00 a.m.	1:25 p.m. — 2:25 p.m.
3	Monday	9:00 a.m. — 9:45 a.m.	2:25 p.m. — 3:10 p.m.
4	Monday	9:45 a.m. — 11:45 a.m.	3:10 p.m. — 5:10 p.m.

Monday Field Trip "After Action Review" (Debriefing): Refer to the Week at a Glance and the Daily Detailed Agendas to see the times allotted (10 minutes) for debriefing Monday's field trips to BASF/SSAB. These reviews are not written in the Instructors Manual as they occur on different days/times depending on your platoon's (RYG vs. BOP) field trip/STEM lesson schedule.

Tablet Management: Cadets will use individual tablets to access Academy Journal prompts each day. They will also use these tablets to take surveys for the evaluation and research activities.

It is vitally important that every cadet understands the requirement to protect the tablets they will be using during the Academy. Below are some general guidelines to follow once the tablets have been introduced:

Tablets should be distributed when they are required and collected as soon as that activity is complete. No cadet should leave a ballroom with one of the tablets. Always have a second instructor, or the Materials Manager, check the count of tablets returned before moving to the next activity. Tablets should be stored in shelving units near the door to each classroom.

For safety issues (both people and tablets) it is preferred that no charging cables are used during activities. This may not be avoidable, but caution should be used if charging is required. Remind cadets to connect their tablet to a charger after the activity.

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Part 1: Investigating VEX V5 Materials & Drivetrain Design

Day # (Time Frame) (165 min)

Overview

This first investigation will be used to introduce teams to the technology and materials they will be using throughout the week. The Team Engineering Notebook will be distributed, and teams will learn how they can use this as a tool throughout the Engineering Design Process. They will also be oriented to the parts list and building tips provided with the VEX V5 robotics kits. Teams will then be guided through the construction of a basic drivetrain that will orient them to the VEX materials and working with the materials and tools. They will finish this investigation using their drivetrain to answer the guiding questions in their TEN as they reflect on their experiences with different designs and wheel types.

Instructional Plan:

***Let's Get Moving!* Challenge Introduction: (5 min)**

Introduce the Let's Get Moving! Challenge by giving each cadet a copy of **page #1** of the Mission Brief. Display **Slide #1** of the Design Challenge 1 Presentation and allow cadets time to read over the challenge summary in the Mission Brief. Encourage them to record any questions on the back of their handout. Be sure to highlight the constraints for this mission and the criteria, emphasizing the minimum criteria for success. Let cadets know they will learn more about the "obstacles" soon.

Slide #1

Page #1

MISSION CONSTRAINTS:

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- Robot clears all obstacles when driven by each team member.
- Robot clears all obstacles in one run.
- Robot clears all obstacles in under 2 minutes.
- Robot clears at least one obstacle while being driven in reverse.
- Robot clears all obstacles in reverse.

Conclude this introduction by letting cadets know that the next few activities will help them through the Research phase of the Engineering Design Process (EDP) so they will have background knowledge needed to complete their challenge. Once their research is completed, they will begin moving through additional steps in the EDP cycle to complete their challenge. The first research investigation involves learning more about their tools and materials.

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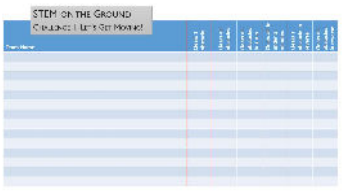
Team Engineering Notebook Introduction: (15 min)

Pass out the Team Engineering Notebook (TEN) to each team. Explain that this notebook will provide teams with useful information about their missions and will provide a place for them to record their progression through the Engineering Design Process. Point out that the first thing needed on the cover page is a team name. Before giving time for teams to discuss their team's name, have them turn to **page #1** of the TEN. Have teams read the paragraph under "Team Name and Logo." Explain the importance of a catchy, creative team name and logo that represents all team members. Tell teams they will have approximately 10 minutes to develop their team's name and logo, record them in the TEN, and complete the cover sheet of the TEN. Let them know that they may revise their logo throughout the week, but they should have a permanent team name by the end of the 10 minutes.

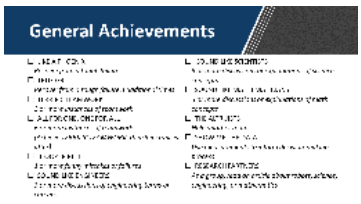
Page #1

Clarify Mission Achievements & General Achievements: (10 min)

After teams have had time to decide on a team name and logo and complete the TEN cover page, have them open to the Mission Brief on **pages #3 and #4** of the TEN. If teams are not finished with a team name or logo, let them know that they can continue to work on this task at other times throughout the week.



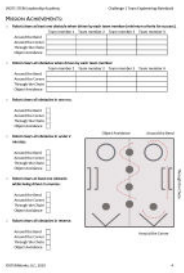
Slide #2



Slide #3

Read through the Mission Constraints on **page #3** and highlight each obstacle type on the testing field diagram. Read over the Mission Achievements on **page #4**. Highlight the minimum criteria for success. Explain that teams should attempt to complete as many mission achievements as possible, but that this criterion must be met for their robot to be considered minimally successful. Explain that they do not have to build one robot that will complete every achievement; they will be able to make adjustments to their build as they try for different goals. [NOTE: Each completed achievement should be marked in the team's TEN by the instructor observing the testing field and this instructor will also record it in the central Mission Achievements tracking document. This "central record" is **Slide #2** of the Design Challenge 1 Presentation.] Allow time for questions after the discussion.

Page #3



Page #4

Page #5

Have teams turn to the General Achievements on **page #5** in the TEN and display **Slide #3**. Go over the list of General Achievements and explain that all instructors will be looking for teams that complete these achievements throughout the week. Unlike the Mission Achievements, these achievements are not mission specific and will not reset with each new challenge. Allow time for teams to ask questions.

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GENERAL ACHIEVEMENTS

- **Like a Phoenix** (Recover from a tough failure)
- **True Grit** (Recover from 3 more tough failures)
- **Terrific Teamwork** (3 or more instances of teamwork)
- **All for One, One for All** (After Terrific Teamwork, 3 more instances of teamwork)
- **Blooper Reel** (1 or more funny mistakes or failures)
- **Sound Like Engineers** (Discussions of engineering terms or careers)
- **Sound Like Scientists** (Discussions of scientific terms or careers)
- **Sound Like Mathematicians** (Discussions of mathematical terms or careers)
- **The Altruists** (Help another team)
- **Show Me the Data** (Use measurements to inform decision making)
- **Research Partners** (As a group read an article about a STEM topic)

Recording General Achievements:

It is recommended that one Cadre per platoon take the lead in recording the General Achievements on the General Achievement Checklist., but all instructors should look for these achievements and report them to the Cadre.

When a team completes a General Achievement (or a step towards completion), the observing instructor should immediately report completed achievements to the Instructional Team member maintaining the Platoon's General Achievement Checklist. These achievements should be considered when deciding on daily awards for teams and cadets.

Research & Plan: (20 min)

Have each cadet refer back to their hard copy of the Challenge 1 Mission Brief. Ask cadets to individually record on the back of their Mission Brief what components they think a robot would need to complete Design Challenge 1. Once all cadets have recorded an answer, have cadets share their answers aloud as you record answers on a flipchart. Highlight answers such as wheels, motors, gears, and axles and briefly discuss why these components in particular will be important. (If some are not mentioned, they can be added in a later investigation.)

Inform cadets that their initial research will determine how different wheel alignments and wheel types will affect how their robot moves before adding motors and remote-control ability in a later investigation.

Have teams open **page #6** of the TEN and identify the documents they need to access for Investigation 1: the "Understanding Drivetrains Handout" and the "Parts List." Both documents can be found in the Resource Notebook; they should also receive a hard copy of the "Understanding Drivetrains Handout" and an extra copy of the "Parts List" is included with the "Clawbot Build Instructions" in the top of their kit.

Page #6

Page #7

Inform teams that they will have a maximum of 15 minutes to follow the Investigation 1 instructions on **pages #6-7** and complete numbers 1-2 in their TEN. As they complete the questions, they should have an instructor sign-off on their work. While they are working, distribute one hard copy of the "Basic Drivetrain Build" document and one container of VEX V5 building materials

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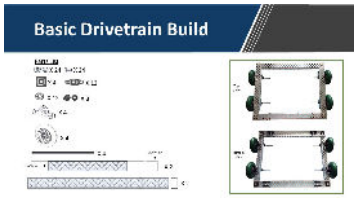
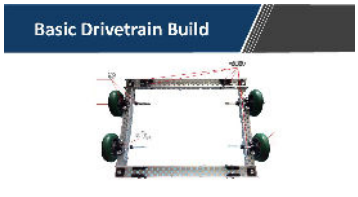
(the electronics will be passed out in a later investigation) to each team. Teams that finish early can look over the "Basic Drivetrain Build" document (also found in the Resource Notebook), but they should not remove any building materials from their kits.

Create a Prototype: (40 min)

Direct all teams to locate the "Basic Drivetrain Build" document in the Resource Notebook and the hard copy. Refer teams to **page #8** of the TEN for instructions and give them a few minutes to ask questions before allowing them to start construction of their drivetrain. Pictures from the "Basic Drivetrain Build" can be found on **Slides #4 and #5** if needed to aid in discussions. Be sure teams know the importance of keeping up with the screws, bolts, and other materials in their storage bins. Once teams begin building, allow them to move through the construction at their own pace, but watch closely for any teams that become overly frustrated with the materials or seem to be moving too slowly to finish in the allotted time. Once a team has completed building this basic drivetrain, they should complete numbers 3-4 on **pages #8-9** of the TEN.



Slide #4



Slide #5

Page #8

Page #9

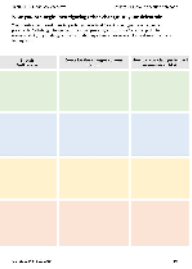
If any teams have not completed the drivetrain within 40 minutes of beginning this investigation, a member of the instructional team should work with them directly on how to work with the tools and materials and offer suggestions on working more efficiently within their group.

Test and Gather Data: (55 min)

As teams complete the questions on **pages #8-9** in the TEN they will begin investigating the effects of different wheel placements and wheel types and recording their sequential changes on **page #10** of the TEN. They will be manually pushing their robots around while gathering data on changes in the turning point and turning radius. Instructors should encourage cadets to reflect on how certain changes impact their robot's ability to complete the mission achievements for Design Challenge 1.

Page #8

Page #9



Page #10

Most of the testing can take place on the floor around a team's work area. Teams can be allowed to test on an empty field if they desire. An instructor should supervise this testing. No more than two teams at a time should be allowed on a half-field. Teams may need encouragement during this period to try different drivetrain orientations (long side vs. short side) and wheel combinations. If a team has not tried placing wheels on both the long sides and the short sides after approximately 25 mins, emphasize how researching variation of design could help as they begin to build their own robot. Remind teams that each variation should

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be recorded in the TEN along with notes about how the turning scrub and turning point were affected. An instructor should be checking each team's TEN for this information and helping teams which seem to be struggling to record appropriate information.

Wrap Up: (20 min)

The last part of this Investigation should be spent allowing teams to share information they gained during their testing. Encourage teams that tried similar designs to discuss any differences in their findings. Watch for teams that may have tried a unique design and ask them to share why they decided to try that and what they learned from their testing.

Allow approximately 5 minutes at the end of this time for teams to deconstruct their drivetrain and return the parts to the appropriate container. Stress the importance of putting materials, especially small pieces like nuts, bolts, and hex-nut holders, back in the proper bag or box. Teams may decide at this point to remove the extra cardboard and plastic packaging from inside the parts container. This can be discarded.

Part 2: Investigating Gear Ratios

Day # (Time Frame) (60 min)

Overview

The second investigation for Design Challenge 1: Let's Get Moving! will have teams explore gear ratios and their relationship with rotational speed. Teams will begin the investigation by constructing a Gear Box that will allow them to test different gear arrangements for effects on output speed. This Gear Box will be expanded to allow teams to work with gear trains as well. Teams will show evidence of learning by combining gears to complete challenges presented to the Platoon.

Instructional Plan:

Introduce the Investigation: (3min)

Tell teams they are going to complete this Investigation as part of Research and Planning for their design challenge. Identify the three items in the Resource Notebook that are needed to complete the investigation:

- Gear Train Build
- Building Tips- this document shows different ways that some parts (e.g., hex nut retainers) are used to secure larger pieces.
- Available Gears- this document gives the number of teeth on each gear in the VEX kit so that teams do not have to count for themselves.

Slide #6 *Slide #7*

The "Gear Ratio" and "Gear Trains" videos will be on **Slides #6 and #7**, respectively, of the Design Challenge 1 Presentation. Ensure that these videos can be played with sound during this investigation.

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Plan and Create: (17 min)

Instruct teams to access **page #11** of the TEN and follow the instructions. Teams will begin by opening the "Gear Train Build" instructions and completing steps 1-6 so they have two gears connected within the build. As teams work to complete the Gear Box, circulate, and provide help, as necessary.

Page #11

Test and Gather Data: (20 min)

Once teams have completed steps 1-6 of the Gear Train Build instructions, they should answer questions a and b under number 1 on **page #11**. Once all teams have had adequate time to complete number 1, play the "Gear Ratio" video from **Slide #6** for the entire classroom. At the end of the video, ask cadets to identify which gear in the video was the driving gear and which was the driven gear. (In the video, the larger gear is the driving gear. Ensure cadets understand it is called the driving gear because the presenter is spinning it, not because of its size.) After this discussion, teams should complete question 2 on page #11 of the TEN. These questions will guide teams to find differences between the two gears used in the build and differences in how they rotate when one or the other is spun. Once most teams have finished answering the questions, lead a discussion to ensure all teams have similar answers to question 2.

Slide #6

Slide #7

Page #11

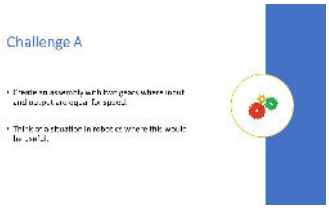
Page #12

Next, refer teams to question 3 on **page #11** of the TEN. They should complete the Gear Train Build instructions (steps 7-31) from the Resource Notebook to construct a gear train. Once teams have completed the build show the "Gear Trains" video from **Slide #7** and have teams answer question 3. Have teams share their answers and lead a discussion to resolve any differences.

As time allows, teams can then go to **page #12** of the TEN and change the gears used in the build to continue investigating the relationship between gear ratio and rotational speed increase/decrease.

Checking for Understanding and Wrap Up: (20 min)

This investigation will conclude with teams working through a series of challenges (up to 4 challenges) designed to test their knowledge of gear ratios and effects on rotational speed. The Gear Challenge Cards are part of the Design Challenge 1 Presentation. Display Gear Challenge Card A on **Slide #8**. Allow about 5-7 minutes for teams to create a gear assembly and come up with situations where their assembly would be useful. Once most teams feel they have completed the challenge, lead a discussion



Slide #8

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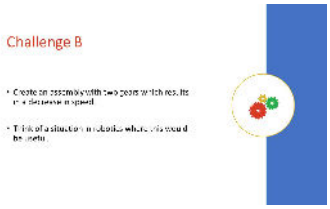
with all teams about their solutions. Take note of different ways teams solved the challenge and highlight these differences. Allow any team that did not complete the challenge to construct an appropriate solution. Move through Challenges B, C, and D shown on **Slides #9-11** in a similar way as time permits.

Slide #9



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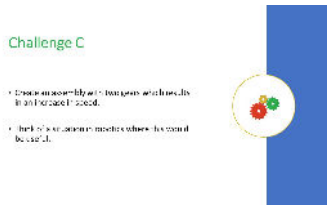
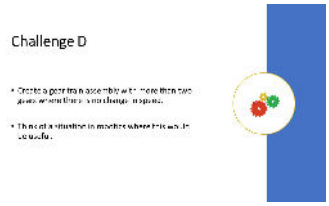


Slide #11



Below are possible answers to listen for when teams respond to the second part of each card (think of a situation in robotics where this would be useful).

Card A:

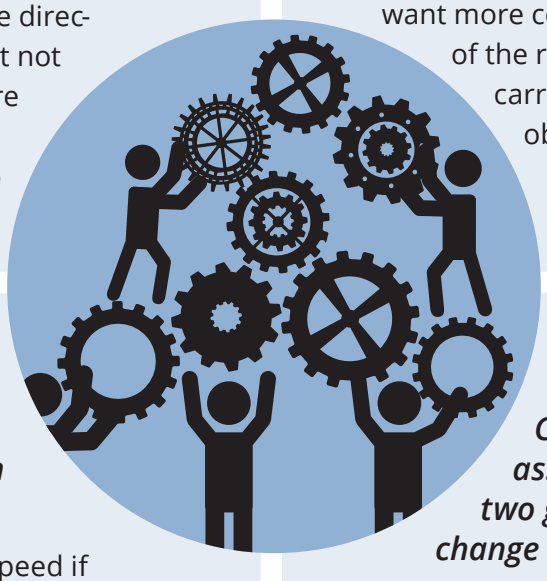
Create an assembly with two gears where input and output are equal for speed.

It can be useful to maintain a 1:1 gear ratio when you want to change the direction of rotation of an axel but not speed; the motor and axel are too far apart; or if you want to connect several motors to the same axel.

Card B:

Create an assembly with two gears which results in a decrease in speed.

It can be useful to decrease speed if you want more control over the steering of the robot; or the robot will be carrying heavy or delicate objects.



Card C:

Create an assembly with two gears which results in an increase in speed.

If can be useful to increase speed if you want to reduce the time it takes to travel a certain distance; or if you are carrying light or durable objects.

Card D:

Create a gear train assembly with more than two gears where there is no change in speed.

It can be useful to maintain a 1:1 gear ratio when you want to change the direction of rotation of an axel but not speed; the motor and axel are too far apart; or if you want to connect several motors to the same axel.

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Part 3: Investigating Remote Control

Day # (Time Frame) (45 min)

Overview

This short investigation introduces teams to the remote operation of their robots. Teams begin this investigation by following the first several steps of building the VEX Clawbot using the provided instructions. Teams will have a short time to practice driving their construction around an empty testing field before moving into the obstacle course of Design Challenge 1: Let's Get Moving!

Instructional Plan:

Introduce the Investigation: (3 min)

Tell teams they are going to complete this last investigation before they tackle this challenge's Mission Achievements. Teams should go to **page #13** of their TEN and follow the instructions. Point out the resources they will need for this Investigation.

- Clawbot Build Instructions- a hard copy of these instructions comes pre-printed in each team's VEX Building Materials bin.
- Pairing V5 Controller and Robot Brain
- VEX Electronics Quick Start Guide- this resource should be retrieved from the VEX electronics box.

Plan and Create: (37 min)

Instruct all teams to access **page #13** of the TEN and follow the instructions. Team should open their "Clawbot Build Instructions," and follow steps 1-22 of the instructions. This is the base to which they will add the robot brain which will allow them to control their build remotely. Circulate around the room to be sure teams begin the construction of the base of their robot.

As teams get close to completing the construction, distribute the electronics box. Teams need the electronic materials to complete steps 19-22 of the "Clawbot Build Instructions." When teams complete their drivetrain, direct them to begin pairing the robot brain with their joystick style V5 Controller. These instructions can be found in a "Quick Start Guide" in their kits or by accessing the "Pairing V5 Controller and Robot Brain" pages in the Resource Notebook.

Page #13

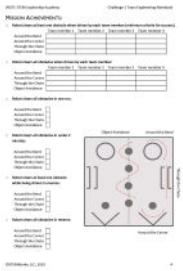
As time allows, teams should let each team member practice controlling the robot around their work area. You may also allow one team at a time to practice driving their robot in one half of the empty VEX game field.

Wrap Up: (5 min)

With about 5 minutes remaining for this investigation, have teams place their robot and joystick in the appropriate materials box and plug their robot batteries into a power cord (using a sticky note to label their battery). If any teams have NOT successfully operated their robot remotely, explain they will have more time after this discussion is complete.

Direct teams to go to **pages #3-4** of their TEN and review the Mission Brief, use **Slide #12** to emphasize the game field obstacles. Lead a whole-

Page #4



Page #5

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group discussion of the possible design changes that could be made to improve their design to meet certain Mission Achievements. These could include: a) type of wheels used, b) orientation of wheels on drivetrain, c) gear ratio used to connect wheels to motor, etc.

Slide #12

Part 4: The Challenge!

Day # (Time Frame) (120 min)

Overview

The final part of Design Challenge 1: Let's Get Moving! requires teams to apply the knowledge gained in the research investigations to complete various Mission Achievements by working through an obstacle course in the VEX game field.

Instructional Plan:

Plan and Create before Testing: (20 min)

Direct teams to **page #14** of their TEN. Explain that they will use **page #14** of the TEN to confirm the Challenge criteria and constraints before moving into the "Create" and "Test, Improve and Redesign" phases of the Engineering Design Process on **pages #15-16** of the **TEN**. Point out that teams have been working through the "Research & Plan" phases in the earlier investigations in this Challenge. Direct those teams who successfully operated their robot using the remote to begin working through **numbers 1-4** on **page #14**. Help teams that have not yet successfully constructed a remotely controlled robot to complete this step before moving to **page #14**.

Page #14 *Page #15* *Page #16*

While teams are working through numbers 1-4, use this time to set-up two obstacle courses on each field (the slalom is shared between the two courses on each testing field). Display the Mission Achievements Central Record **(Slide #2)** in the Design Challenge 1 Presentation. With 5 minutes remaining for this final planning and create phase, describe the general testing process, and identify the instructor who will be responsible for monitoring the testing (likely a Cadre). When a team is ready to test for achievements, they should bring their robot, controller, and TEN to the game field. The instructor at the field will initial or check off each achievement in the team's TEN. The team will then report these achievements to the instructor responsible for updating the Mission Achievement Central Record.

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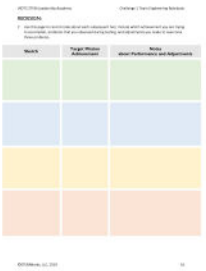
Test, Improve, Redesign & Evaluate: (75 mins)

Encourage teams to complete their construction and begin testing for achievements. Once teams begin testing on the obstacle course, only one team should be allowed to test per obstacle course. An obstacle course takes up half of the game field. If two platoons will share a testing field, each platoon should primarily test on just one half. However, all instructors can work together to use the two obstacle courses as efficiently as possible. Teams must first complete the minimum criteria for success before attempting other achievements. Teams who have not met the minimum criteria should have priority for using the field.

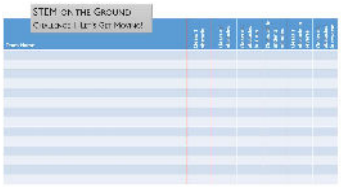
After a team completes their first test on the game field, they should record their results on **page #15** (number 5) of their TEN. They can then make changes to their design and update their TEN under number 6.

As teams go through the cycle of testing, improving, and evaluating for Mission Achievements, they should document this process on **page #16** of the TEN. Instructors should work together to initial achievements in the TEN, update the central record, and provide support to teams as needed.

Page #15



Page #16



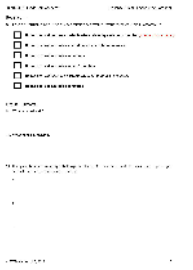
Slide #2

Keep the Mission Achievement Central Record **(Slide #2)** displayed during this time so all teams can see the overall progress of different teams in their platoon. You may also choose to switch between displaying the General Achievements Central Record and the Mission Achievements.

Wrap Up and Communicate: (25 min)

With approximately 25 minutes left for this activity have teams turn off all robot brains and controllers and return to their workstations. They should place the controller back in its place within the electronics box. Any loose materials should be placed in the appropriate container (if applicable) and put in the materials bin. Teams should also place their robot within the bin if it will fit. Both boxes and the robot, if not in the bin, should be stacked neatly on or near their table. If the robot batteries have not been charged previously, teams should remove the battery from the robot, label it with a sticky-note, and plug it in to be charged.

Once work areas have been straightened, direct teams to answer all the questions on **page #17** of their TEN. Lead a whole group discussion about how teams used what they learned in their investigations to redesign their robots to complete the different mission achievements. Note how different teams used different gear ratios on their robots and have them discuss advantages and disadvantages each ratio created. Highlight all teams that met the minimum criteria for success and any teams that completed all mission achievements. Teams should place their TEN and Resource Notebook with their VEX materials. They will need the Resource Notebook for Design Challenge 2 and may want their TEN for the poster presentation following the Final Challenge.



Page #17

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STEM on the Ground

Challenge 1: Let's Get Moving

Team Engineering Notebook

Team Name:_____

Platoon Color: _____ **Squad #**_____

Team Cadets:_____

_____

_____

_____

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TEAM NAME AND LOGO

In nearly every career field there are challenges that are too difficult for one person to tackle alone. Being able to work in a team to solve problems is a skill that must be learned and practiced. This week your team will be presented with challenges that you will need to work together on to meet. Take a few minutes now to collectively decide on a team name and a logo that represents your team as a whole unit. Use the space below to record your team's name and logo.

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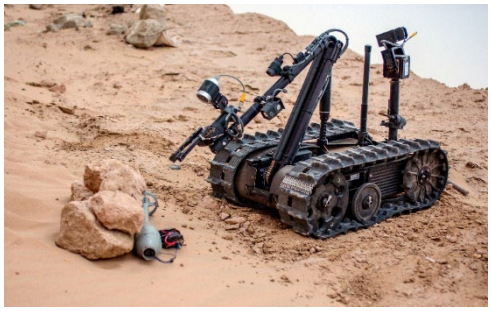


STEM ON THE GROUND

CHALLENGE 1: LET'S GET MOVING!

What do you do when you have a task that is unsafe or even impossible for a human to complete? One solution is to use a remotely controlled vehicle. Sometimes referred to as a "robot," these adaptable, yet untethered, machines are used everywhere from the deepest oceans on Earth to the surfaces of other planets. In this challenge, you will be investigating the foundation of any robot that has to move across solid surfaces. You'll begin building a base that is able to move around obstacles and is adaptable to future challenges.

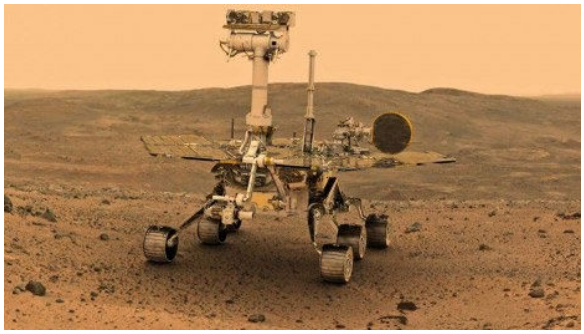
YOUR MISSION:

Design and create a remotely controlled vehicle that can move across various terrains and around a variety of obstacles. Your robot should be durable, agile, and easy to control.

PROCEDURE:

Your robot will be tested on an obstacle course that will challenge your design as well as your driving skills. Once placed on the field, your robot will need to drive around and through several obstacles. Achievements will be awarded for both accuracy and efficiency. There are four obstacles:

1. **Around the Bend:** large diameter turn
2. **Around the Corner**: small diameter turn
3. **Through the Chute:** travel between the rails
4. **Object Avoidance:** run the slalom passing through three consecutive pairs of objects



MISSION CONSTRAINTS:

- Robot must be controlled remotely.
- All team members must control the robot at least once during testing.
- An obstacle is considered "cleared" if your robot does not cross any boundaries or alter any objects while moving around the obstacle.

MISSION CRITERIA (ACHIEVEMENTS):

- Robot clears at least one obstacle when driven by each team member (minimum criteria for success).
- Robot clears all obstacles when driven by each team member.
- Robot clears all obstacles in one run.
- Robot clears all obstacles in under 2 minutes.
- Robot clears at least one obstacle while being driven in reverse.
- Robot clears all obstacles in reverse.

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MISSION ACHIEVEMENTS:

- **Robot clears at least one obstacle when driven by each team member (minimum criteria for success).**

	Team member 1	Team member 2	Team member 3	Team member 4
Around the Bend				
Around the Corner				
Through the Chute				
Object Avoidance				

- **Robot clears all obstacles when driven by each team member.**

	Team member 1	Team member 2	Team member 3	Team member 4
Around the Bend				
Around the Corner				
Through the Chute				
Object Avoidance				

- **Robot clears all obstacles in one run.**

Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	

- **Robot clears all obstacles in under 2 minutes.**

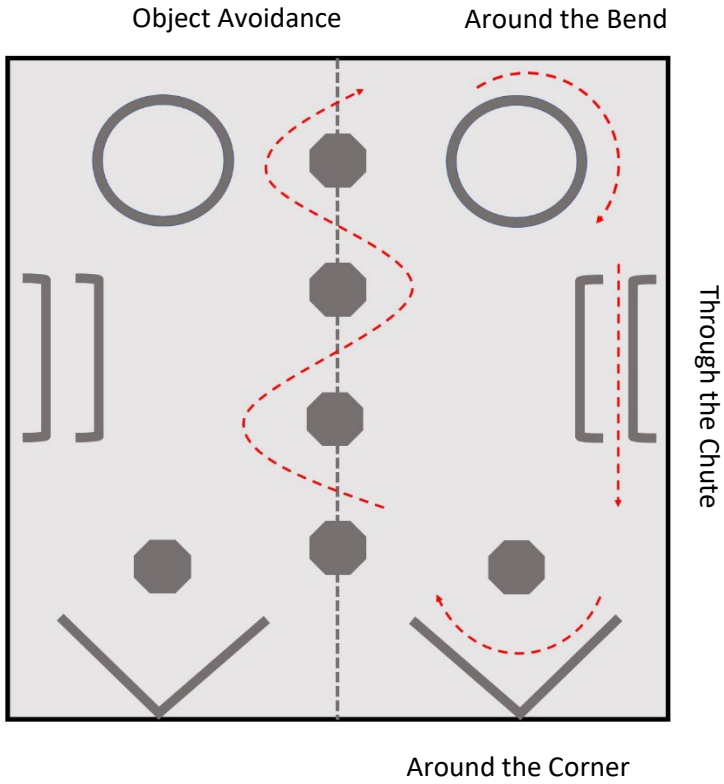
Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	

- **Robot clears at least one obstacle while being driven in reverse.**

Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	

- **Robot clears all obstacles in reverse.**

Around the Bend	
Around the Corner	
Through the Chute	
Object Avoidance	



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GENERAL ACHIEVEMENTS DESCRIPTIONS

☐ LIKE A PHOENIX
Recover from a tough failure

☐ TRUE GRIT
Recover from a tough failure 3 additional times ☐☐☐

☐ TERRIFIC TEAMWORK
3 or more instances of teamwork ☐☐☐

☐ ALL FOR ONE, ONE FOR ALL
6 or more instances of teamwork
(Achieve TERRIFIC TEAMWORK, then 3 instances after) ☐☐☐

☐ BLOOPER REEL
1 or more funny mistakes or failures

☐ SOUND LIKE ENGINEERS
3 or more discussions of engineering terms or careers ☐☐☐

☐ SOUND LIKE SCIENTISTS
3 or more discussions or explanations of science concepts ☐☐☐

☐ SOUND LIKE MATHEMATICIANS
3 or more discussions or explanations of math concepts ☐☐☐

☐ THE ALTRUISTS
Help another team

☐ SHOW ME THE DATA
Use measurements to inform decision-making process

☐ RESEARCH PARTNERS
As a group, read an article about robots, science, engineering, or mathematics

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INVESTIGATION 1- RESEARCH AND PLAN:

Directions: Begin by accessing the "Parts List" and the "Understanding Drivetrains Handout" in your Resource Notebook. The "Clawbot Build Instructions" in your VEX materials kit includes another copy of the "Parts List." Your instructor will give you a hardcopy of the "Understanding Drivetrains Handout" so your team has 2 copies of each to use while reading.

Spend a few *seconds* looking over the "Parts List." These pages contain information that you will want to reference throughout each of your design challenges. Then, read over the "Understanding Drivetrains Handout" and answer numbers 1 and 2 below.

1. In the table below, list any words on the "Understanding Drivetrains Handout" related to your build that members of your team feel are new vocabulary or have questions about. Use context clues and prior knowledge to develop your best guess about the meanings of the words you listed.

Important Words	***Your Team's Best Guess***	***Adjust your definitions here if necessary***

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2. Examine the three types of drivetrains described in the “Understanding Drivetrains” handout and answer the following questions.

   a. Why is a drivetrain important in robot design?

   b. What purpose does the drivetrain serve for the robot?

   c. Which material components are being used? (Refer to the Parts List)

   d. What is another method to make the robot move? (Look for additional pieces in the parts list.)

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3. When instructed, refer to the "Basic Drivetrain Build" handout either in the Resource Notebook or the hardcopy and follow the pictorial instructions to complete the build. Your first drivetrain should use the VEX Wheel (4" diameter) and have the wheels attached along the long side of the chassis. Once your drivetrain is complete, begin manually moving it around your work area. Answer the following questions as you maneuver your drivetrain.
   a. **How does this drivetrain design differ from the drivetrain of most automobiles?**

   b. **Why does this design introduce the problem of turning scrub?**

   c. **Where on the drivetrain did you have to apply force to get it to turn? How did your application of force affect the turning radius of the drivetrain?**

   d. **In the space below, draw at least two sketches of your drivetrain showing different ways you were able to make it turn. Use arrows on each sketch to show the position and direction of forces you applied to make the drivetrain turn. Label the approximate turning point for each diagram.**

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4. After completing your diagrams for this drivetrain, remove the wheels and move them to the shorter sides of the drivetrain. Once again, you should manually move your build around your work area. Answer the following questions while you work with your new design.

   a. What effect did this change have on your ability to maneuver your drivetrain? Be sure to include relevant terminology in your discussion.

   b. In the space below, draw at least two sketches of your drivetrain showing different ways you were able to make it turn. Use arrows on each sketch to show the position and direction of forces you applied to make the drivetrain turn. Label the approximate turning point for each diagram.

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Now you can begin investigating other changes to your drivetrain.

Your chassis should remain a rectangle, but you may try different wheel types, orientations, and placements. Each design change should be accompanied by a discussion of any changes in the maneuverability of your design and a sketch showing where forces were applied and an approximate turning point.

Sketch (with labels)	**Describe the changes to your design.**	**How did the changes impact maneuverability?**

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INVESTIGATION 2- RESEARCH AND PLAN:

One way to improve the performance of some mechanical devices is to introduce gears into the machine. In this Investigation you will explore how gears may be helpful as you design your robot to complete Design Challenge 1. When gears are used in a design, you have a **driving gear** (also called the **input**) and a **driven gear** (also called the **output**). The driving gear will be turned manually or may be attached to some powered device like a motor. The driven gear is generally attached to a wheel or lever.

1. Refer to the "Gear Train Build" instructions found in the Resource Notebook. Follow **steps 1-6** of the instructions and answer the following questions.

    a. **How do the two gears used in your build compare?**

    b. **What are some aspects of the gears you could use to quantify this comparison?**

2. The most common way to compare gears is by counting the number of teeth around the gear. By creating a ratio between the numbers of teeth on each gear we can calculate how fast one gear turns based on the other gear. After watching the "Gear Ratio 1 Video" recreate a similar experience with your build.

    a. **What is the gear ratio (input to output) of your initial build? (The Available Gears resource gives the number of teeth in each of your available gears.)**

    b. **What was the relationship between the direction of rotation between the two gears? Did they spin in the same direction or opposite directions? (Use the words "clockwise" and "counterclockwise" in your answer.**

3. Different gear ratios can be achieved by attaching gears to the axles in various configurations. A **gear train** is formed when multiple gears are connected by shared axles. Return to the "Gear Train Build" instructions and complete the remaining steps (**steps 7-31**). Then, after watching the "Gear Trains" video answer the following questions.

    a. **How many total gears were used in the video and how many axles?**

    b. **How many gears and axles are in your build?**

    c. **What is the final input to output ratio produced by your build?**

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4. Soon your instructor will challenge you to design a gear setup to achieve a specific set of criteria. If you have time before the challenge begins, explore changing the size and number of gears in your current build to discover what additional gear ratios you can create. Record your exploration below. Include the number of gears, the gear ratio between each set of connected gears, and the final input to output ratio.

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INVESTIGATION 3- RESEARCH AND PLAN:

In this investigation you will add motors to your drivetrain and begin controlling your robot remotely. It will be very important that you follow the instructions carefully. If you have questions at any point, ask your instructor for clarification.

1. Begin by following the instructions in the "Clawbot Build Instructions" booklet that was included in your materials kit. For Challenge 1 you will only work through **step 22 on page 15** of the instructions.

2. Once your drivetrain is completed you will need to establish the wireless connection that will allow you to control your robot remotely. These instructions are listed as "Pairing V5 Controller with the V5 Brain" in the Resource Notebook. You may also use the "Quick Start" guide included with the V5 electronics kit.

3. Once you attach the Robot Brain to the drivetrain, use any additional time to let each team member practice controlling the robot around your work area. Your instructor may direct you to the field to allow other teams to continue working.

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INVESTIGATION 4- THE CHALLENGE:

To complete this challenge, use the next few pages (14-16) to record your final plans, and document changes you make to your initial design, including sketches of subsequent designs.

PLAN (Review the Challenge):

1. List any **constraints** your design must meet to be considered compliant.

2. What is the minimum criteria for success for this challenge?

3. What are the first three achievements your team will attempt to complete?

CREATE:

4. In the space below provide a sketch of your initial robot design.

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TEST AND IMPROVE:

5. **Describe what you observed during your first "in the field" test of your robot**.

   a. List at least two aspects of your robot that met the expectations developed during the design process.

   b. List at least two aspects of your robot that could be improved (i.e., speed, maneuverability, control…). Include possible adjustments to fix these areas of concern. Be sure to include important vocabulary in your discussion.

Area of Concern:	**Possible adjustment:**

6. **In the space below provide a sketch of the changes you implemented to address the issues in the table above**.

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REDESIGN:

7. Use this page to record notes about each subsequent test. Include which achievement you are trying to accomplish, problems that you observed during testing, and adjustments you made to overcome those problems.

Sketch	Target Mission Achievement	Notes about Performance and Adjustments

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EVALUATE:

8. Have an instructor initial next to each mission achievement your team was able to accomplish.

- ☐ **Robot clears at least one obstacle when driven by each team member** (minimum criteria for success).
- ☐ **Robot clears all obstacles when driven by each team member.**
- ☐ **Robot clears all obstacles in one run.**
- ☐ **Robot clears all obstacles under 2 minutes.**
- ☐ **Robot clears at least one obstacle while being driven in reverse.**
- ☐ **Robot clears all obstacles in reverse.**

COMMUNICATE:

9. What worked well?

10. What needs improving?

11. Using vocabulary from today's challenge list at least 3 things that would help your team improve your obstacle course score if allowed to retry.

    a.

    b.

    c.

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