MISSION 1

RESCUE!

GOAL: CREATE A ROBOT THAT CAN RESCUE A DISTRESSED SWIMMER

THE PROBLEM

A person is enjoying a nice day at the beach. However, while swimming in the ocean, this unlucky individual is caught in a riptide and carried far away from the shore and the lifeguard station. If help doesn't arrive soon, the person will be in danger of drowning due to exhaustion.

YOUR MISSION

Create a robot that will be able to go from the beach to somewhere near the swimmer. Once the swimmer grabs onto the robot, it should back up and return to the shore, all the while holding the swimmer securely.

PROCEDURE

A ping-pong ball will be used to simulate the drowning swimmer. It will be placed at one end of the pool, and your robot will be placed at the opposite end. The robot will go as straight as possible towards the swimmer, and when the robot reaches the other side and is somewhat close, the swimmer will be placed onto a holder or platform attached to the robot. This will simulate the person grabbing onto the robot. Finally, your robot will back up to the start, carrying the person with it to safety.

REAL-LIFE ROBOT

EMILY (Emergency Integrated Lifesaving Lanyard) is a swimming robot that can rescue people faster than a human lifeguard. It can zoom along at 22 mph, provide flotation, deliver life jackets and even pull a person back to the shore.

MISSION CONSTRAINTS

Robot must

- Float on the surface of the water
- Move forward and backward in a straight line
- Use only 2 motors

MISSION ACHIEVEMENTS

SUCCESSFUL SAVE (minimum criteria for success)

Perform a successful save

RAPID RESCUE

Perform a complete rescue in 25 seconds or less

CHEETAH OF THE SEA

Perform a complete rescue in 15 seconds or less

ROOM FOR MORE

Rescue 5 or more ping-pong balls in one trip

ALL ABOARD

Rescue 10 or more ping-pong balls in one trip

HEAVY LIFT

Rescue 1 "elephant" (a heavy wiffle ball)

PACHYDERM PACKING

Rescue 2 "elephants"

ENGINEER YOUR CAREER

Mechanical Engineer
Works on the development of many kinds of machines—engines, tools, power systems, robots and more.

Naval Architect
Designs and builds marine vessels, such as boats, submarines, yachts, ferries and cruise ships.

Biomedical Engineer
Creates technologies and tools that help to improve medical diagnosis, monitoring and treatment.

STEM on the Water: Mission 1

Introduction

STEM on the Water design challenges are all about robots that perform tasks while getting wet. Each design challenge is framed as a mission which will require teams to design, build, and program a robot to complete various mission achievements. Each mission requires a slightly more complex robot than the previous mission. Teams will use LEGO parts to design a robot "body" around a water-tight plastic case. This case will hold the "brains" of the robot known as a Smart Hub. The Smart Hub uses Bluetooth technology to connect to a device (tablet, phone, Chromebook, etc.) running the LEGO Spike Prime app. Within the app teams will use block-based coding to develop programs to control their robot.

At the start of each mission, teams are provided with a Mission Brief. This one-page 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.
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 in the pool.
- 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.

And two panels:

- REAL-LIFE ROBOT side-panel—briefly profiles an actual robot that has performed a task like the one presented in the mission.
- ENGINEER YOUR CAREER bottom-panel—lists three examples of engineering careers, along with brief descriptions.

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 may find helpful 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.

STEM on the Water was adapted from the Waterbotics curriculum with permission from the Stevens Institute of Technology.

Mission 1: *Rescue!*

(Total Time: 270 minutes)

Overview

In first mission of STEM on the Water, *Rescue!*, teams will design and build a sturdy robot body that is stable in the water, investigate how gears can be used to speed up or slow down the motion of their robot, and compose a program to make the robot move forward and backward in the water.

Important Vocabulary

- Criteria
- Achievements
- Prototype
- Smart Hub Case
- Smart Hub
- Buoyant
- Gear
- Gear ratio
- Gear train

Learning outcomes

- Cadets will be able to build a sturdy structure.
- Cadets will be able to enable both forward and backward motion of their robot in the water.
- Cadets will be able to use block-based coding to write a program to control their robot.
- Cadets will be able to calculate the gear ratio between multiple gears.
- Cadets will be able to identify a gear arrangement that will either speed up or slow down the motion of their robot.

Materials Per Classroom (one Platoon)

- Computer and projector
- Mission 1 PowerPoint
- Pool (filled)
- Cloth towels at the pool area
- General Achievements Checklist
- Timing device
- "Swimmers" (16) – ping-pong balls
- "Elephants" (2) – weighted wiffle ball (~4.6 oz)

Per Cadet

- Mission 1 Brief handout

Per Team (4 cadets)

- Team Engineering Notebook
- Resource Notebook
- LEGO kits (1 EV3 and 1 Spike Prime)
- Device with Spike Prime app installed
- Smart Hub case
- Pieces of pool noodle
- Several rubber bands (assorted sizes)
- Cloth Towels
- Ping-pong ball
- Clip board
- Team Materials Kit

Day 1 Part 1: Identify the Problem then Research, Brainstorm, Design, and Build

(4:00 PM t0 5:30 PM) (90 min)

In Part 1 of Mission 1: *Rescue!*, teams will be introduced to the mission through the Mission Brief. Then, they will create the basic structure for their robot.

Prior to starting Part 1:

- ensure all Mission 1 materials are staged, including charged and updated devices and Smart Hubs
- be familiar with the *Mission 1 Brief*, particularly the Mission Constraints and Mission Achievements
- have the instructor's copy of the General Achievements Checklist prepared with an instructional staff member assigned to record teams' achievements.

Each team will need a dedicated workspace where they will design and build their robot. The area dedicated for the drop test should be designated and prepped, and teams will need access to the filled pools with plenty of cloth towels to test their designs throughout the challenge.

Introduction
(10 min)

Slide #1

Display **Slide #1**. Explain to cadets that they will continue working in their assigned STEM teams for this mission. Distribute a *Mission 1 Brief* to each cadet and go over the brief with the group.

The *Mission 1 Brief* describes an ocean swimmer, far from the shore, who is in danger of drowning. Teams must build a robot that can go straight out to the person, allow the person to get on and return to the shore. The robot will not need to dive under the water or maneuver around the surface. Rather, it simply needs to move in a straight line out to the swimmer and then straight back again.

Mission 1 Brief

To simulate this situation, each team will be given a ping-pong ball, which will represent a person. Teams are tasked with building a robot that can rescue their "person" from drowning. Each robot must have two important features. First, it must be able to move forward and backward in the water in an approximately straight line. Second, it will need to have some sort of structure, such as a platform or basket, attached to it. This will hold the ball and simulate a part of the robot that the person can grab onto or sit in.

> **NOTE:** The ball may not be placed on the Smart Hub Case or on the motor wires.

Once the robot is ready, it will be placed at one end of the pool, which represents the shore. The ping-pong ball will be placed at the other end to represent the swimmer. The robot will then move forward towards the ball. When it reaches the other side, a cadet may place the ball onto the holding structure to simulate the person climbing on. Finally, the robot will move backward to the start with the ball, simulating bringing the swimmer back to safety. After going over the mission scenario, give cadets time to ask clarifying questions.

NOTE: Unlike a real-life robot, the robots that teams design for this mission will not be able to move sideways or turn—at least not in a controlled manner. Therefore, they may end up somewhat far away from the ball. As teams test, judge how close is good enough.

After addressing cadets' questions highlight the Mission Constraints on the *Mission 1 Brief*. Mission Constraints:

- Robot must float on the surface of the water and move forward and backward in a straight line.
- Robot may incorporate only 2 motors with as many small boat propellers, as necessary.

Give cadets another opportunity to ask questions and address any questions.
Next, highlight the Mission Achievements for Mission 1, once again giving cadets an opportunity to ask questions.

Achievement	Criteria
SUCCESSFUL SAVE	Perform a successful save (minimum criteria for success)
RAPID RESCUE	Perform a complete rescue in 25 seconds or less
CHEETAH OF THE SEA	Perform a complete rescue in 15 seconds or less
ROOM FOR MORE	Rescue 5 or more ping-pong balls in one trip
ALL ABOARD	Rescue 10 or more ping-pong balls in one trip
HEAVY LIFT	Rescue 1 "elephant"
PACHYDERM PACKING	Rescue 2 "elephants" in one trip

For a design to be considered successful it must meet certain standards or criteria. For this mission **the minimum criteria for success is to perform a successful save**. This is the first objective for all teams. Once the minimum criteria has been achieved teams may test for additional achievements. Inform teams that different achievements may require adjustments to their robot design. One design of a robot is not expected to do everything well. In fact, improving one aspect of a robot's performance often comes at the expense of other capabilities. For example, as a robot gets faster, it also becomes harder to control. They are free to redesign between testing for various achievements. They should, however, inform the instructional staff member in the testing area of the particular achievement for which they are testing.

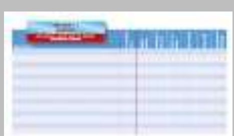
After all teams feel comfortable with the mission scenario, mission constraints, and mission achievements, briefly point out the Real-Life Robot and Engineering Your Career sections of the *Mission 1 Brief*. Let cadets know that additional information is available online if they would like to research any of these topics after today's activities.

Research, Brainstorm, Design, and Build (50 min)

TEN, page #1

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 10 minutes to develop their team 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.

Slide #2



After 10 minutes (or sooner if all teams are ready), remind teams that communication is a vital part of any design project. Display **Slide #2** showing the Mission Achievement Central Record and have teams turn to **page #3** of their *TEN.* This is where teams will record completion of any mission achievements. They should always take their *TEN* with them when going to a pool for testing. Suggest that teams use a clipboard when carrying their *TEN* back and forth from the testing area and while recording notes at the pool. An instructional staff member will initial any achievements they complete. It will be the team's responsibility to report this back to the staff member in charge of recording mission achievements in the Mission Achievement Central Record.

TEN, page #3

Direct teams to turn to **page #4** of their *TEN* and go over the General Achievements. These achievements are not mission specific and will be tracked across all design challenges during the Academy. Point out that instructional staff will be moving among teams and marking off General Achievements as they are observed. Go over each General Achievement and its requirements. Give time for a brief question and answer session about the Mission and General Achievements.

TEN, page #4

GENERAL ACHIEVEMENTS	DESCRIPTIONS
LIKE A PHOENIX	Recover from a tough failure
TRUE GRIT	Recover from a tough failure 3 times (Achieve LIKE A PHOENIX, then 2 recoveries after.)
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
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 or engineering

Next, give each team a *Resource Notebook*. This notebook gives common names of LEGO pieces to help teams communicate with each other as they build their designs. It also contains suggestions about building sturdy frames using LEGO pieces and provides a review of the science lessons that will be presented through the week to help teams improve their designs in this and later missions. Encourage teams to keep this *Resource Notebook* handy and to refer to it if they feel stuck during the design process.

Resource Notebook

Tell teams that in this session they will not be working on getting the robot to move. They will spend this time developing designs for their robot structure, building the first version of their robot, called a prototype, and running some preliminary tests. They simply need a robot body that is **buoyant** and **stable** in the water. Give cadets the following definition of a **prototype:** A model of a new product or design that can be tested and redesigned before the product becomes finalized. By the end of this session, they need a first prototype that has been tested in the pool for buoyancy and stability. They will have time in later sessions to improve their design and work on getting the robot to move in the water.

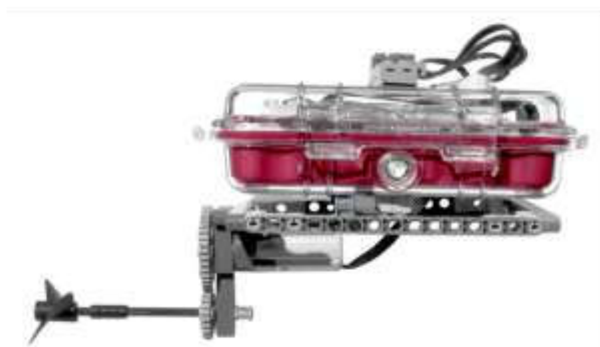
Have teams remove the Smart Hub Case from their kit. Inform teams that they should design the robot's "body" so that it can easily connect to and disconnect from the case for durability testing. This case will hold the "brains" of their robot known as the Smart Hub once they have a design for the body. Draw attention to the bricks with holes attached to the bottom of the Smart Hub Case. The holes can be used to aid in this connection. The body of the robot should be detachable and must be sturdy. Its durability will be tested with a 6-inch drop test while separated from the Smart Hub Case. The motors and propellers should be attached so that the propellers can spin in the water while the seal of the Smart Hub Case remains above the water. Additionally, once the body is connected to the Smart Hub Case, the complete structure should be stable and float evenly on the surface of the water.

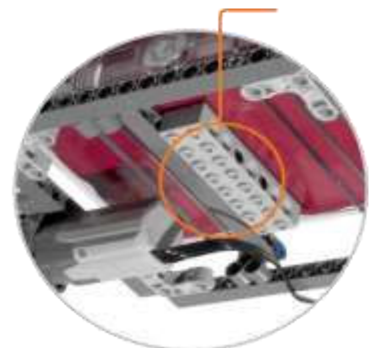
Slide #3

NOTE: It can be tricky for cadets to envision how to set things up so their robot can easily attach to and detach from the Smart Hub case, and the temptation will be to simply build their robot directly off the case. To help with this situation, an example robot is described below. You may wish to create something like it to demonstrate to cadets if necessary or display **Slide #3**.

The robot should be constructed to take advantage of the bricks with holes that are attached to the bottom of the case. To do so, a few pins can be placed in the holes, which will allow the top of the robot's frame to snap onto the bottom of the case. For this to work, the top of the robot's frame must have some available holes to latch onto the pins, as shown in the example. You may refer teams to this design if they appear to have trouble with an initial design of the robot. Although this picture contains only one motor, teams may start working with two motors in this challenge. Remind them to consider the length of the motor cables when planning their design. These cables will need to connect to the Smart Hub within the Smart Hub case.

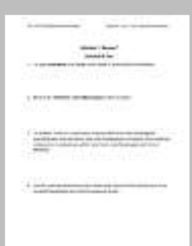
Here is a view of the complete assembly from the side, along with a close-up view of the robot-pin attachment.





> **NOTE:** This is just one example of how to make a quick attach/detach mechanism. Encourage teams to come up with their own solutions. However, if it proves to be too difficult for them to do so, let them use the solution shown in this example.

TEN, page #5



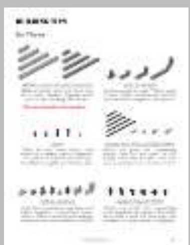
To transition teams into the brainstorming and design phases of the EDP, have cadets take 5 minutes to individually sketch a robot body design idea on the back of the Mission Brief they received earlier. At the end of this 5 minutes tell teams they should start their design process by completing **page #5** of the *TEN* and sharing their individual designs with the team, discussing the possible positives and negatives of each design. They should then work to come to consensus on their first team design. This design will be recorded on **page #6** of their *TEN*. Emphasize that all team members must contribute during the design and build, test, improve, and redesign cycle.

TEN, page #6

> **NOTE:** If you recognize that teams are struggling to involve all team members, try suggesting assigning specific tasks to sub-groups within the team (as mentioned on **page #5** of the *TEN*). Some examples would be a TEN recorder, flotation/stability team, a propulsion/control team, an arm/scoop team, or a materials procurement team. Eventually, teams could assign members to the programming team.

If more than one team is working at a single station (table) stress to cadets that team materials need to be kept separate. Teams should **not** share LEGO pieces between team kits. (Mixing between the Spike Prime and EV3 kits for one team is okay but mixing between multiple teams will hinder future uses of these materials.) Suggest teams take a few minutes before they begin building to organize their materials in the trays within each kit. This will make their building process more efficient and help to keep materials separated between teams.

Resource Notebook page 3

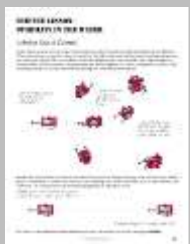


As teams complete the build of their first design, allow them to begin the drop-test of their build. Explain the importance of durable structures: The movements of the motor and the water can easily make structures fall apart. The motors should be attached for this test, but the Smart Hub Case should not be connected. A drop test should be conducted each time a team leaves the work area to test their robot at the pool. To perform the drop test, have one team member hold a ruler vertically up from a table or the floor. One person should hold the robot frame at the six-inch mark and release it. If the robot breaks apart or has pieces fall off during the drop test, suggest they reinforce the frame where the breakage occurred and try again. Remind teams it is acceptable for the robot to break since testing, improvement, and redesign are all part of the Engineering Design Process. Encourage teams to refer to the "Building Tips" section on **pages #3-6** of their *Resource Notebook* for ideas on how to make their robot designs sturdier. Explain that the motors shown in some of the diagrams look a little different than the motors they will be using, but they work the same way.

Once a robot has successfully completed the drop test, the team can connect it to the **EMPTY** Smart Hub Case and put it in the pool to see if it will float evenly. (At this point teams are checking the flotation and stability of their designs, not its movement. Therefore, the Smart Hub must not be inside the Smart Hub case during this phase of testing.) It will also be important to check for where the water line is on the Smart Hub case, keeping in mind that they will eventually be adding the extra weight of the Smart Hub. It is likely the cable running from the motors to the Smart Hub will keep the case's seal from being completely watertight. The Smart Hub must remain dry. So, teams should be instructed to modify their design to keep the Smart Hub case seal above the water line. Suggest adding pool noodle pieces with rubber bands to correct any tilting. As teams arrive at a pool for testing, hand out the towels and explain their purpose. Emphasize robots must be dried after being removed from the pool. Testing pools may be located away from the work area. Therefore, at least one staff member should be stationed at each pool to assist teams as necessary and to initial Mission Achievements once teams start testing for achievements. Minor adjustments may be made to the robot in the testing area (i.e., adding or removing flotation or ballast), but no other building materials should be carried into the testing area from the work area.

When a team is ready to test, they should carry their robot, *Team Engineering Notebook*, and the Smart Hub Case to the testing area. Remind teams that during this session they will only be testing their design for buoyancy and stability in the water. They should connect their robot to the Smart Hub Case (**without the Smart Hub**). No Mission Achievements will be completed during this session, so multiple teams can test at the same time in a pool. Each robot must pass the two tests (drop test and flotation test) each time a new design has been built.

Resource Notebook page 35



Be ready to help teams with the amount and placement of flotation material as they test their designs at the pool site. Watch for teams that have added too much (or too little) pool noodle material to their robot's body. Also watch for teams that have placed flotation in a way that makes the robot unstable in the water. Help teams understand that placing floats under the robot body can make it more likely to tip over in the water, like trying to sit on top of a beach ball in the pool. The "Science Lesson: Stability in the Water" in the *Resource Notebook*, on **pages #35-40**, gives a good explanation of how to make a floating object stable. Refer to the diagrams below to emphasize why it is a good idea to keep "floats up high and weights down low."

Research
(20 min)

With 30 minutes remaining in this session, have all teams return to their workstations, put all materials in the proper container, and place their robot design on a towel to dry. Inform teams that in the next session they will be working to get their robot to move back and forth in the water. Ask cadets to share what they know about how boats move in the water. After a few minutes of sharing, have teams remove the two small propellers (with axels) from their LEGO kits. Tell them to observe the design of the propellers and consider this as they watch the **How a Propeller Works** video. Show the video.

Resource Notebook page 20

NOTE: This video will introduce the idea of how a spinning propeller moves a boat through the water. It will be important for cadets to recognize that the direction of spin determines in which direction the boat will move. Due to the tilt of the propeller blades, the direction of spin determines which side of the blade "pushes" on the water. The water then (by Newton's Third Law) pushes back on the blade. By slowly spinning the propellers in their hand and using their finger, or other item, to represent the water, cadets should be able to "see" how the propeller blade will cut through the water and, therefore, which direction the propeller would push the robot. The diagrams on **pages #20-25** of the *Resource Notebook* can be used to reinforce the concepts covered in the video if a team needs additional help.

TEN, page #6

After viewing the video, have teams complete question 6 on **page #6** of their *TEN*. Here they will sketch each propeller and indicate the direction of spin needed to move the robot forward. Be aware that teams may have propellers with different angles of tilt so not all propellers will need the same direction of spin. Let teams know that they will learn how to control the direction of rotation in the next session so recording this information will be important. The “Science Lesson: Propulsion & Flow” on **pages #20-25** the *Resource Notebook* will reinforce this concept. Encourage teams to refer to this reminder if they have questions in future sessions.

Wrap Up
(10 min)

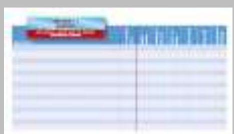
Conclude this part of the design challenge by allowing teams to share information they gained during their testing. Encourage teams that tried similar designs to discuss any differences in their findings. Watch for teams that may have tried a unique design and ask them to share why they decided to try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

Allow approximately 5 minutes at the end of this time for teams to store their current build and clean up their work area. Stress the importance of putting materials, especially small pieces back in the proper place within their team’s LEGO storage bin and that LEGO materials should not be transferred from one team’s kit to another team’s kit.

Day 2 or 3 Part 2: Test, Improve, and Redesign

(1:00 PM to 2:00 PM) (60 min)

Slide #2



In Part 2 of Mission 1 teams will learn how they will control their robots through programs written in the Spike Prime app. After writing a program to control their robot, teams will begin to test for Mission Achievements. Ensure that necessary materials are staged for implementation, including filled pools, multiple ping-pong ball “people,” and wiffle ball “elephants.” Check that multimedia equipment is ready for displaying Spike Prime app screens to share with teams. The Mission Achievement Central Record **Slide #2** will also need to be displayed as teams mark off achievements.

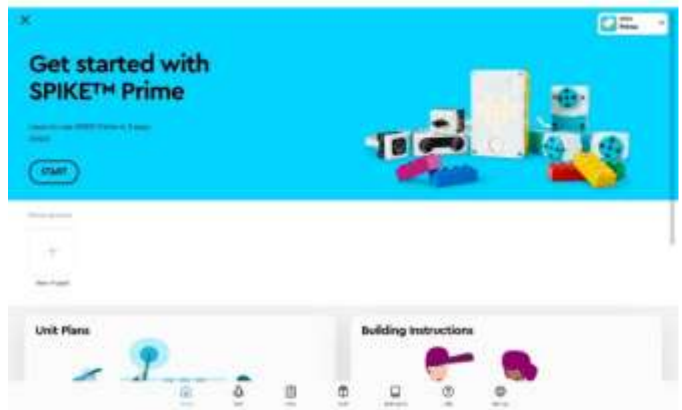
Introduction to the Spike Prime app (30 min)

Assemble all teams at their workstations. Have teams place any loose materials in their LEGO storage bin so that you have their attention during this discussion. Remind cadets of the discussion during the Project Kickoff of what makes a robot. One important aspect of a robot’s design is a way to control the robot. Explain to cadets that they will write a program using the Spike Prime app on their device to control their robot. This program will communicate with the Smart Hub placed in the Smart Hub case. When the program is run from their device, the Smart Hub will control the motors and sensors on their robot.

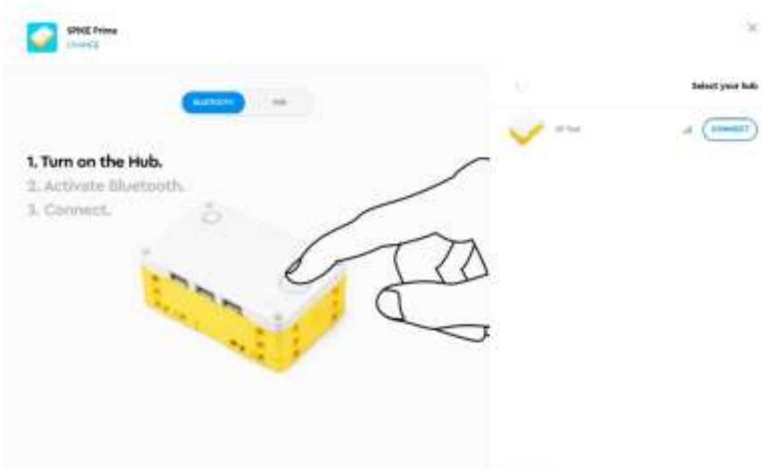
Have teams remove only the Smart Hub from their LEGO storage bin while displaying a Smart Hub for the group to see. Start by emphasizing the importance of keeping this Smart Hub dry during the testing process. This is the purpose of the Smart Hub case. Since the cables from the motors will run into the case, it might not be completely watertight. Teams should ensure that the case sits high enough in the water to keep as much water as possible from getting into the case. **If water enters the case, the Smart Hub needs to be removed and dried immediately.**

Next, point out the buttons and ports on the hub. The power button is the large round button at the bottom-center of the white surface of the hub and the Bluetooth connect button is in the upper right corner. There are six ports along the sides of the hub. Each port is labeled with a letter shown on the white surface of the hub just above the port. Motors and sensors can be attached to ports in any order. The label of the port will be important when writing the program to control the robot. The male-end of the connector on the motors and sensors will only go in the port on the Smart Hub in one direction. Cadets should not have to force a connection. (Think of this like plugging-in a USB-A cable. If it doesn’t go in easily, flip the cable over and try again.) Have teams identify the name of their Smart Hub which will be written on one side of the hub. They will need to know this name to connect the hub to the Spike Prime app on their device.

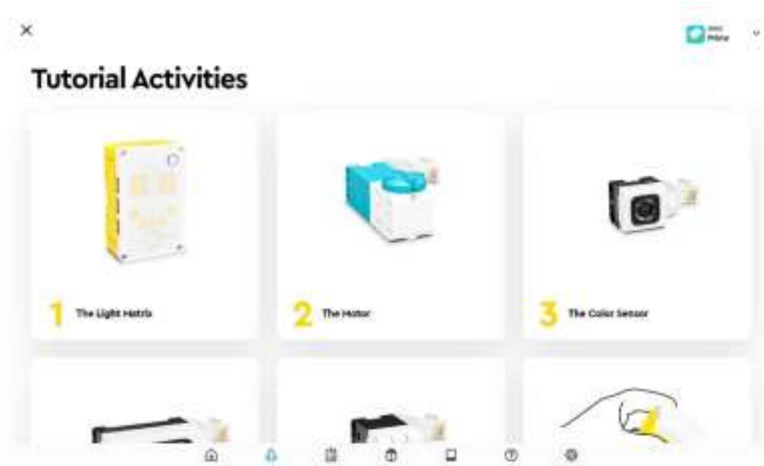
Teams will now connect the Smart Hub to their device. They should set the Smart Hub to the side and open the Spike Prime app on their device. (They will need the Smart Hub again shortly.) If an option screen is displayed, cadets should choose "Spike Prime" on the right. If the "Make sure you have everything you need." screen is displayed, cadets should select "Skip" or "Got it" from the upper left corner of the screen. Once all teams have gotten to the "Get started with SPIKE Prime" screen, they will begin a tutorial in the app that will show the basics of connecting the app to the Smart Hub and how to program the motors and sensors available in their kits. Have cadets click the "Start" button in the app to begin the tutorial.



Teams will connect the Smart Hub to the app using a Bluetooth connection. When teams start the tutorial for the first time, they are likely to see several Smart Hubs listed in the "Select your hub" menu since their device will recognize all Smart Hubs within the Bluetooth range. They should select the hub whose name matches the label on the side of their physical hub.



Once the Smart Hub and device are connected, teams should select "BACK TO PROJECT" and complete all six tutorials. They will need to access one motor, the color sensor, the distance sensor, the force sensor, and two LEGO bricks to complete the tutorials. They should not, however, need to use any additional LEGO pieces or need to build any structures while completing the tutorials.

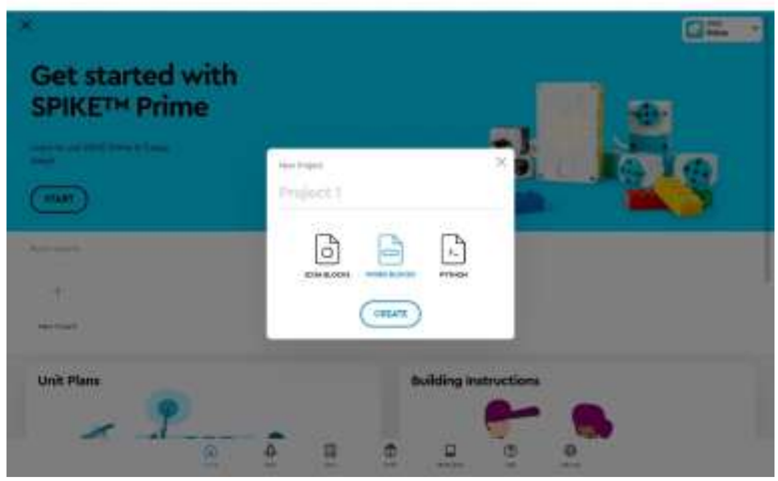


While teams are completing the tutorials, move about the room and assist teams as necessary. Encourage teams to ask questions as they work so they do not get stuck at one point for too long. Remind teams to first ask their teammates whenever they have a question. Only when no one on their team can answer the question should they then ask an instructor. If a team is not able to run a tutorial, check to make sure the sensor is plugged into the correct port. One of the steps in the tutorial has cadets program the Smart Hub to trigger a sound, so expect to hear some random sounds as teams work through this part. If a team struggles with this step, the first trouble shooting step is to ensure that the volume is up on their device. The sound will play through the device, not the Smart Hub. Some cadets may have experience with the block-based programming used in the app while others will be programming for the very first time. Tell teams it is important to ensure that all cadets on the team have a chance to complete at least one of the tutorial segments. Display **Slide #4** with some reminders teams may need as they complete the tutorials and write their own programs to work through the missions:

Slide #4

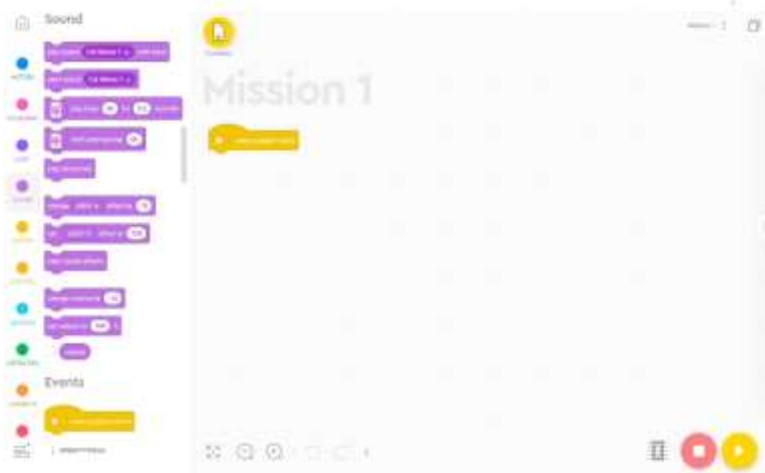
a. After a program has finished running and before making changes to or leaving the program, hit the "Stop" button (red circle with a white square in the middle)
b. If changes are made, you must hit the "Play" button (yellow circle with a white triangle in the middle) for the changes to be communicated to the Smart Hub.

When teams finish all 6 tutorials, have them return to completed segments to experiment with the different settings available in the programming blocks. Remind them that they will be using these and additional commands to complete different missions throughout the Academy. Once all tutorials have been completed, they can return to any tutorial from the home screen at any time for a refresher on how a particular item works within the program.



Once all teams have completed the tutorials, have them complete the following steps to reach the screen used to create and edit their own programs:

- Select the "Go to Home" option (bottom of the screen) or the "Home" icon (upper-left corner.
- Select "New Project" from the menu in the middle of the screen.
- Title this project "Mission 1."
- Select the "Word Blocks" icon.
- Click "CREATE."



This screen is where teams will build their programs. The menu on the far left shows the categories of programming blocks. Once a category is selected, the individual blocks used to create the programs are displayed just to the right of the menu. Cadets will drag a block over to the "workspace" to build their program just as they did in the tutorial. Take a few minutes to have teams click through each category of blocks to see what commands they contain. Remind teams that a full list of all the commands is available on **pages #42-57** of the *Resource Notebook*.

Resource Notebook page 42

In the Movement category, explain that these blocks were designed for LEGO builds with wheels, not for boats. Let teams know that their robot will not perform as expected if these blocks are used initially. The blocks in the Motors category should be used initially.

Have teams locate the distance block in the Sensors category and click on the box. Point out that there are three options to choose from. By selecting one of those options, they can adjust the units used for measuring the distance. The same is true for the force sensor. Although these may not be necessary in Mission 1, teams may use them in later missions, and knowing what units the sensor is using for its measurements will be important while gathering data to refine their program.

Build and Test (30 min)

Slide #2

Display **Slide #2**. Before allowing teams to begin programming, remind teams that, in addition to writing a program to control the robot, they will need to build a platform or holder for the ping pong ball "swimmer," and these are not to be placed on the Smart Hub Case or its wires. Hand out a ping pong ball to each team and encourage them to use it to help when designing the platform. Remind them their robot must pass the drop test (without the Smart Hub case attached) before they can place the robot in the water. Also, encourage teams to test their program before carrying their robot to the pool for testing.

TEN, page #7

TEN, page #8

TEN, page #9

Explain that teams must first get their robots moving forward and backward in an approximately straight line. Once that is done, they may then work towards completing Mission Achievements. Review how the mission achievements are being counted:

1. Mission Achievements will be tracked by the staff member assigned to each pool. Any achievements should be marked in the Team Engineering Notebook and initialed by the observer.
2. When teams return from the testing area, they should report any achievements to the instructor in the work area to be recorded on the displayed Mission Achievement Central Record.

After their first test, teams need to return to their workstation and complete **pages #7-8** of their *TEN* to help organize their thinking and record solutions to design problems. Suggest that teams identify a TEN recorder who assumes the responsibility of taking notes in their *TEN*.

Allow teams to begin building and programming their robots. As teams work, walk around and provide help as needed. Prioritize helping teams that are having issues simply getting their robots to move back and forth. The sooner teams have accomplished this, the more time they will have to work towards the achievements. If needed, remind teams that dividing into sub-groups may help them work more efficiently. While working with teams, have them refer to the Troubleshoot and Tips on **page #9** of the *TEN*. This provides helpful information and serves as a reference while having discussions about what may need to be changed on the robot and provide help with programming. Remind teams to use the "Stop" and "Play" buttons when adjusting their program. Cadets often forget this in their excitement.

Tips and Troubleshooting: Stability and Buoyancy (from TEN, page 9)
If the robot is constantly twisting or flipping over, it is not stable. An object on the water will be stable when it has its lightest, least dense parts at or near the top and its most dense parts at or near the bottom. If an object does not meet this condition, simply add low-density objects such as foam near the top and/or high-density objects such as heavy LEGO bricks to the bottom.

- Make sure the robot is balanced on the surface of the water and has a symmetrical design. Use a combination of pool noodle, heavy LEGO bricks, and weights to accomplish this.
- Use these objects (the pool noodles, etc.) wisely.

Tip and Troubleshooting: Propulsion (from TEN, page 9)

If a team's robot appears to have difficulty moving, the motors could be running in the wrong direction. To troubleshoot, have teams double check the direction of rotation recorded in their TEN during Part 1.

- Hold the robot at the surface of the water so that the propellers are partially submerged in water.
- Test out a direction of rotation (clockwise or counterclockwise).
- Ask the cadets to look at the movement of the water and tell you which direction (forward or backward) each propeller is trying to push the robot.
- If they notice one or both motors are not running in the correct direction, they can switch the motor direction in their program commands.
- The commands in the Movement tab of the Spike Prime app are designed for robots with wheels and will not work as expected if both motors are facing the same direction. If a team tries to use these commands early in the design process, encourage them to try a different method. If they move quickly through the mission achievements, they can return to those commands and try to incorporate them into their program.

If a team does not succeed in an attempt, encourage them to try again. Remind them of the importance of failure in the EDP. Make suggestions for improvement if necessary. Remember that minor adjustments can be made at the pool area, but no extra LEGO materials should be brought from the work area. Teams may adjust their Spike Prime program while at the pool, but they should remove the robot from the pool while making adjustments.

TEN, page #9

Discuss with teams that getting the robot to go perfectly straight both forward and backward is extremely difficult. Often, the robot will have some sort of bias to rotate in a certain direction. Let the teams know that they may use this spinning to their advantage, and anything they can do to get the robot to get to the other side and back is allowed. (Aside from physically manipulating the robot and/or pool.) If a team feels frustrated because their robot rotates a lot, refer them back to **page #9** of the *TEN* and point out some suggestions:

Tip and Troubleshooting: Movement (from TEN, page 9)

- Make sure the robot is balanced and stable on the surface of the water and has a symmetrical design. Use a combination of pool noodle and weights to accomplish this.
- Try adding on fins (probably on the sides of the robot to help with stabilization), rudders (movable pieces to help with steering), or a keel (usually a single piece on the bottom of the robot to decrease drifting side-to-side). Try different sizes and note the effects.
- Look at the propulsion trails coming from the propellers. When these hit the robot, some unintended movement can result.

TEN, page #7

TEN, page #8

Teams should take notes of any adjustments that need to be made and return to the work area to complete their redesign.

You may wish to allow teams to time how long it takes for their robot to complete a task. They can then use this information later, when they experiment with gears, to see how effective their new designs are. Note that some teams may need a stopwatch to work on certain achievements. Again, remind teams to record notes on **pages #7-8** in their *TEN*.

With approximately 5 minutes left for this session, direct teams to return to their work areas and place their robots on a towel to dry. The Smart Hub can be turned off by holding down the power button for a few seconds. The Smart Hub will automatically power down after several minutes of inactivity. Staff will ensure the robots and equipment are thoroughly dried while teams are introduced to gears in the next activity.

Day 2 or 3 Part 3: Investigation: Gears

(2:00 PM to 2:50 PM) (50 min)

Gears are a type of simple machine that can help increase or decrease the speed of robots in the water. In this activity, cadets learn how gears work by creating a LEGO® gear set and examining the speed differentials. Cadets will have an opportunity to experiment with the gear sets for further exploration. After this activity, cadets will be able to incorporate gears into their robot designs. Ensure that multimedia equipment is prepped to display the gear videos, and diagrams for cadets and that materials for the instructor's gear apparatus is staged.

Investigate Gears
(50 min)

Slide #5

Direct cadets to return to their team workspaces, display **Slide #5**, and ask each pair of cadets within a team to take the following materials from their kits:

a. 1 long beam (at least 7 holes)
b. 1 large gear (40 teeth)
c. 1 small gear (8 teeth)
d. 2 bushings
e. 2 axles of slightly different sizes
f. 2 large "teeth" with axle hole

Have the pairs of cadets fit the gears together as shown. Instruct them to put the axles through the middle hole of each gear. The axles can then be put through the holes on the beam and secured with the bushings. Have them put a "tooth" on the end of each axle so they can observe the relative speed of the gear. Have an instructor's version available to show cadets as they work.

Play the **Gear Video 1** of a demonstration using the gear apparatus to show how gear ratios affect motion. Allow cadets to use their gear apparatus to repeat the demonstration as you lead a discussion of the following questions:

1. How many times did the small gear turn when the large gear turned once?
   Answer: 5 times
2. How does the number of turns of each gear relate to the speed of rotation?
   Answer: The gear that makes more turns is rotating at a faster rate.
3. In which direction did the gears turn? (clockwise/counterclockwise)
   Answer: The gears spin in opposite directions from each other.
4. How could you use gears to speed up or slow down rotation? (Clarifying question: If you had the motor attached to the big gear and the propeller attached to the small gear, would you speed up or slow down the robot?)
   Answer: Having the small gear on the propeller axel will speed up the robot.

Once cadets show a basic understanding of how gears could be helpful to speed up or slow down the rate of rotation, ask more specific questions. These questions will help cadets complete the calculations necessary to gauge how much faster or slower a specific combination of gears will make the propellers spin.

- What is the gear ratio of the gears in the video?
- What would the gear ratio be if you used a 24-tooth gear instead of the 8-tooth gear?

Answer: The gear ratio is 40-tooth/8-tooth = 5:1. This means that the smaller gear will spin 5 times faster than the larger gear. If the 24-tooth gear is used, then the gear ratio would be 40-tooth/24-tooth = 5:3 = 1.67. This means that the 24-tooth gear would spin 1.67 times faster than the 40-tooth gear. The smaller the gear used against the 40-tooth gear, the larger the gear ratio will be and the faster the axle through the small gear will spin.

Slide #6

Display **Slide #6**. Allow a couple of minutes for teams to discuss what would happen if they put another 40-tooth gear on the other side of the 8-tooth gear (as shown in diagram A). Then, have them predict the following:

- What would happen to the rotation?
- What would be the relative speed of the new 40-tooth gear compared to the first 40-tooth gear?
- To the 8-tooth gear?

Play the **Gear Train Video** and instruct cadets to listen for the answers to the above questions. After the video lead a short discussion of the answers.

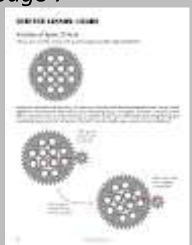
Answers: The direction of rotation alternates for each gear, so the new 40-tooth gear will rotate in the same direction as the first 40-tooth gear, and at the same speed as the first 40-tooth gear.

Ask cadets how, based on what they saw in the video, they would get a gear ratio higher than 5:1 with the gears in these kits?

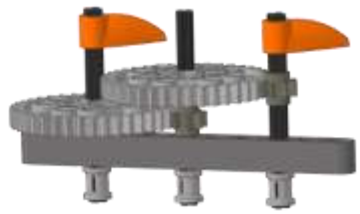
Answer: This could be accomplished using a gear train. If they were to add another large gear to the same axle as the small gear, then that large gear would also be spinning at that same fast speed. If they then were to connect another small gear with an axle to that larger gear, then the second small gear would be even 5 times faster. That’s 25 times faster than that first large gear!

Reiterate to cadets how they should attach the gears in their robot to either speed up or slow down its motion. Faster = small gear axle; Slower = large gear axle

Resource Notebook page 7



Discuss with cadets how technically there is no limit to the number of gears you can have in a gear train, but there is a tradeoff. You can keep adding gears in a gear train and get a very large speed. However, as the speed increases, the force of the spin decreases. So, it is possible to make the spin amazingly fast, yet too weak to move any water. Furthermore, you can sometimes make the robot go so fast that it is hard to control.



TEN, page #10

Remind cadets they can refer to the “Science Lesson: Gears” on **pages #7-19** in their *Resource Notebook* as they try to incorporate gears into their designs. Tell teams to complete the questions on **page #10** of their *TEN***.** Give teams any remaining time to experiment with the gears and brainstorm how they could incorporate gears into their robot design. They should also think about which mission achievements may require the use of gears to complete.

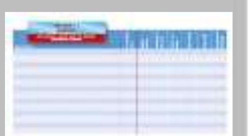
Day 2 or 3 Part 4: Redesign and Evaluate

(2:50 PM to 4:00 PM) (70 min)

In the final part of Mission 1, teams will have an opportunity to apply their knowledge of gears and gear ratios to redesign their robot. They will also be allowed to test for multiple achievements. Filled pools will be accessed extensively by teams during this time. One member of the instructional staff should remain in the pool area while the other staff assists teams in their work area. The instructional staff should continue to watch for teams that complete a General Achievement and ensure the achievement is marked on the team's checklist.

Redesign and Evaluate
(60 min)

Slide #2



Display **Slide #2**. Inform cadets that this is an opportunity to modify their robots using the knowledge gained in the last activity. Changing the speed of the robot will come in handy for certain achievements. Provide teams with the following tips:

- Try pairing gears of different sizes and observing the effect on the speed of the propeller. Test different gear combinations (in the water, if possible) and time how long it takes your robot to travel a certain distance.
- Adding gears can change the way the robots move, so they may need to redesign their structure. Also, when attaching gears to the robot, they must be sturdy and reinforced, so the robot does not break in the water. Redesigned robots must still pass the drop test (with an **empty** Smart Hub case).
- The robots do not need to have gears on the final design but trying to include them will help with some of the achievements in this mission and in future missions. Teams may make any modifications to their robot they feel are necessary to complete a specific Mission Achievement.

TEN, page #11

Allow teams to begin working and let them know how much time is allocated. Walk around and assist teams as necessary. Have timing devices available at each pool to be used for the time-based achievements. Periodically let the teams know how much time is left (15 minutes, 10 minutes, etc.). Prioritize helping teams that are having difficulty completing any of the achievements. The first achievement is the easiest to accomplish, so focus on that one first. Both Mission Achievements and General Achievements should be tracked as before. Remember to display the Mission Achievements Central Record so everyone can see to track Mission Achievements as teams complete testing.

Once a team's final mission achievement has been recorded, direct them to **page #11** of their *TEN*. Recording this information is part of the Research phase of the EDP and could come in handy during later missions.

Wrap Up
(10 min)

TEN, page #11

With 10 minutes left, have all teams return to their workstations. Give them a couple of minutes to clean their work area and store their robot on a towel to dry. Remind teams to keep LEGO parts separated between teams using the same work area. Use this time to ensure all teams have completed **page #11** of the *TEN*. All teams will need to complete this before moving to the next activity. Also, highlight teams that performed well in the Mission Achievements and point out a few General Achievements that were completed. If time allows, have teams share what they learned through their experiences in Mission 1.

STEM on the Water

Mission 1

Team Engineering Notebook

Team Name:______________________________________

Platoon Color: _______________ **Squad #**________

Team Cadets: ________________________________

____

____

____

Team Name and Logo

A good team name can help build cohesiveness among team members and gives a way for your team to be recognized as a single unit rather than individual members. Most teams (and some businesses) have a branded logo that is just as recognizable as their name. A catchy name and logo draws attention to your team and helps people feel connected to your work. Use this page to come to consensus on a team name and logo that is representative of all members of your team.

Mission 1 Brief

MISSION 1

RESCUE!

GOAL: CREATE A ROBOT THAT CAN RESCUE A DISTRESSED SWIMMER

THE PROBLEM

A person is enjoying a nice day at the beach. However, while swimming in the ocean, this unlucky individual is caught in a riptide and carried far away from the shore and the lifeguard station. If help doesn't arrive soon, the person will be in danger of drowning due to exhaustion.

YOUR MISSION

Create a robot that will be able to go from the beach to somewhere near the swimmer. Once the swimmer grabs onto the robot, it should back up and return to the shore, all the while holding the swimmer securely.

PROCEDURE

A ping-pong ball will be used to simulate the drowning swimmer. It will be placed at one end of the pool, and your robot will be placed at the opposite end. The robot will go as straight as possible towards the swimmer, and when the robot reaches the other side and is somewhat close, the swimmer will be placed onto a holder or platform attached to the robot. This will simulate the person grabbing onto the robot. Finally, your robot will back up to the start, carrying the person with it to safety.

REAL-LIFE ROBOT

EMILY (Emergency Integrated Lifesaving Lanyard) is a swimming robot that can rescue people faster than a human lifeguard. It can zoom along at 22 mph, provide flotation, deliver life jackets and even pull a person back to the shore.

MISSION CONSTRAINTS

Robot must

- Float on the surface of the water
- Move forward and backward in a straight line
- Use only 2 motors

MISSION ACHIEVEMENTS

SUCCESSFUL SAVE (minimum criteria for success)
Perform a successful save

RAPID RESCUE
Perform a complete rescue in 25 seconds or less

CHEETAH OF THE SEA
Perform a complete rescue in 15 seconds or less

ROOM FOR MORE
Rescue 5 or more ping-pong balls in one trip

ALL ABOARD
Rescue 10 or more ping-pong balls in one trip

HEAVY LIFT
Rescue 1 "elephant" (a heavy wiffle ball)

PACHYDERM PACKING
Rescue 2 "elephants"

ENGINEER YOUR CAREER

Mechanical Engineer
Works on the development of many kinds of machines—engines, tools, power systems, robots and more.

Naval Architect
Designs and builds marine vessels, such as boats, submarines, yachts, ferries and cruise ships.

Biomedical Engineer
Creates technologies and tools that help to improve medical diagnosis, monitoring and treatment.

Mission 1 Achievements

These are all of the achievements for Mission 1. When you test your prototype at the pool, have an instructor write his/her initials in the box next to the achievement you completed to verify your accomplishment. When you return to the ballroom, show this checklist to your instructor so he/she can update the Mission Achievement Central Record display. This will allow other teams to see what your team has accomplished!

Achievement	**Instructor Initials**
SUCCESSFUL SAVE ***Perform a successful save*** ***(minimum criteria for success)***	
RAPID RESCUE ***Perform a complete rescue in 25 seconds or less***	
CHEETAH OF THE SEA ***Perform a complete rescue in 15 seconds or less***	
ROOM FOR MORE ***Rescue 5 or more ping-pong balls in one trip***	
ALL ABOARD ***Rescue 10 or more ping-pong balls in one trip***	
HEAVY LIFT ***Rescue 1 "elephant"(a heavy wiffle ball)***	
PACHYDERM PACKING ***Rescue 2 "elephants" in one trip***	

GENERAL ACHIEVEMENTS DESCRIPTIONS

☐ LIKE A PHOENIX
Recover from a tough failure

☐ TRUE GRIT
Recover from a tough failure 3 times (Achieve LIKE A PHOENIX, then 2 recoveries after.)

☐ 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

☐ 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 or engineering

Mission 1: Rescue!

Research & Plan

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

2. What is the **minimum criteria for success** in this mission?

3. List at least 2 distinct components of your robot that could be designed separately and then combined into your final product. (Assigning these separate components to sub-groups within your team could make your work more efficient.)

4. Use this space to write some notes about any important discussions your team has while developing your initial consensus design.

Mission 1: Rescue!

Research and Plan

5. In the space below provide a sketch of your initial robot design. Be sure to include the placement of motors and your rescue device. Also list the first three achievements your team will attempt to complete.

6. Provide a quick sketch of each of the propellers in your materials kit. For each propeller, indicate in which direction the propeller should spin to move the robot forward.

Mission 1: Rescue!

Test, Improve, and Redesign

7. Describe what you observed during the first “on the water” 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., sturdiness, balance, control, flotation, speed…). Include possible adjustments to fix these areas of concern.

Area of Concern:	**Possible adjustment:**

8. In the space below sketch a diagram of how you plan to implement the changes recorded in the table above.

9. Use this page to record notes about each subsequent test. Include problems that you observed during testing as well as adjustments you made to overcome those problems. You should also note any adjustments you made in order to complete different mission achievements. If you collect data to help reach a mission achievement, record that data here.

Mission 1: Rescue!
Tips and Troubleshooting

Bouyancy and Stability

If the robot is constantly twisting or flipping over, it's not stable. An object on the water will be stable when it has its lightest, least dense parts at or near the top and its most dense parts at or near the bottom. If an object doesn't have this condition, simply add low-density objects such as foam to the top and/or high-density objects such as heavy bricks to the bottom

- Make sure the robot is balanced on the surface of the water and has a symmetrical design. Use a combination of pool noodle, heavy bricks, and weights to accomplish this.
- Use these objects (the pool noodles, etc.) wisely.

FLOATS up HIGH

WEIGHTS down LOW

Propulsion

If your robot appears to have difficulty moving, the motors could be running in the wrong direction. To troubleshoot, double check the direction of rotation recorded on page 6 of your TEN and check the following:

- Hold the robot at the surface of the water so that the propellers are partially submerged in water.
- Test out the direction of rotation (clockwise or counterclockwise).
- Look at the movement of the water and observe which direction (forward or backward) each propeller is trying to push the robot.
- If one or both of the motors are not running in the correct direction, switch the motor direction in the program commands.
- The commands in the Movement tab of the Spike Prime app are designed for robots with wheels and will not work as expected if both motors are facing the same direction.

Movement

Getting the robot to go perfectly straight both forward and backward is extremely difficult. If your robot rotates a lot, try using the following suggestions:

- Make sure the robot is balanced on the surface of the water and has a symmetrical design. Use a combination of pool noodle and weights to accomplish this.
- Try adding on fins (probably on the sides of the robot to help with stabilization), rudders (movable pieces to help with steering), or a keel (usually a single piece on the bottom of the robot to decrease drifting side-to-side). Try different sizes and note the effects.
- Look at the propulsion trails coming from the propellers. When these hit the robot, some unintended movement can result.

Programming

- After a program has finished running, you must hit the "Stop" button (red circle with a white square in the middle) before making changes to or leaving the program.
- If changes are made, you must hit the "Play" button (yellow circle with a white triangle in the middle) for the changes to be communicated to the Smart Hub.

Mission 1: Rescue!

Test, Improve, and Redesign

10. Why might a team consider including gears in their robot design?

11. If your team were to include gears as part of your next design, how would you include them? Provide a sketch showing this implementation. Include labels that indicate the number of teeth of each gear used. Below the sketch give the gear ratio of each gear set and state whether this should speed up or slow down your robot.

Mission 1: Rescue!

Evaluate and Communicate

Results

List the title of any mission achievements your team was able to accomplish in this mission.

Observations

a. What worked well?

b. What needs improving?

c. Using vocabulary from your research, list at least 3 things that would help your team complete additional achievements. (If all achievements were accomplished, list ideas to improve the overall functionality of your robot.)
   1.
   2.
   3.