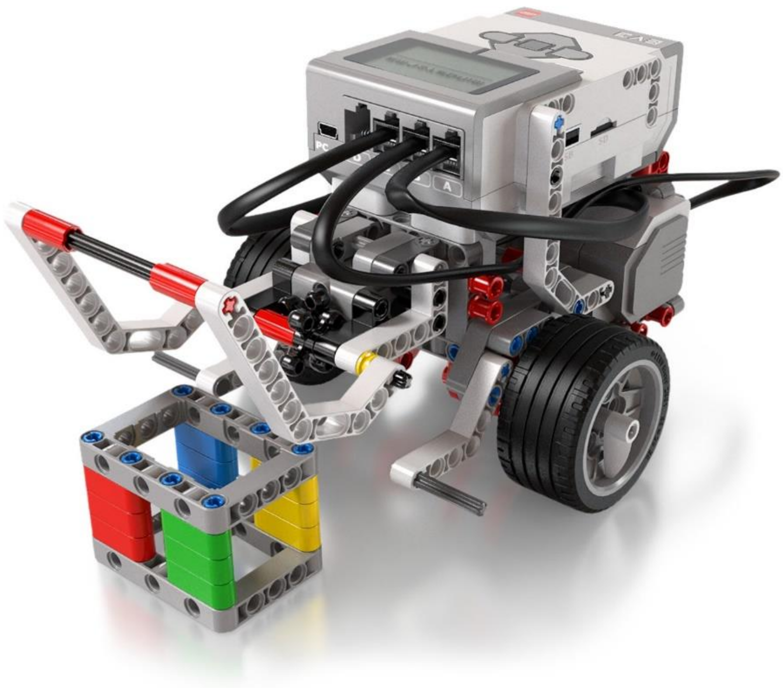


Robot trainer

In this unit, your students will learn the basics of building and programming autonomous robots, using an actuation base as a modular platform. Each lesson introduces a new extension to be built on top of the driver base. These extensions enable it to detect obstacles, move objects, follow lines and turn at precise angles. The unit concludes with a factory-themed challenge that will test your students ' robotics skills!

1. Move and turn

Use the drive base for precise and controlled movement. 45-90 minutes , beginners , grades 6-8

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Gather some information about encoded motors and how they are used in wheeled robots.
- ✧ You will need a tape measure to measure the drive distance of the drive base.
- ✧ If you feel necessary, plan your lessons using the "Getting Started" materials in the app. This will help your students become familiar with the LEGO® Mindstorms® Education EV3 .
- ✧ To complete this course, students must build a driver base model from the " *Start Moving " activity, which takes approximately 30 minutes.*

2. Participate (10 minutes)

- ✧ Watch the unit video and use the ideas in the "Start a Discussion" section below to engage your students in *discussions related* to this unit and lesson .
- ✧ Divide your class into pairs.

3. Explore (15 minutes)

- ✧ Allow your students some time to explore the motion of the drive base using the provided programming stack.
- ✧ Ask them to describe the different turns they observed.
- ✧ Have them rearrange the programming stack to explore different actions.

4. Explanation (10 minutes)

- ✧ Facilitate discussion about the importance of each step of the planning program.
- ✧ Explain what pseudocode is and how it can help students as they plan their lessons.

5. Detailed explanation (10 minutes)

- ✧ Have your students find a way to move their drive base 84cm / 33in.
- ✧ Don’t forget to set aside some time for cleanup.

6. Evaluation

- ✧ Provide feedback on each student's performance.

✧ You can use the provided rubrics to streamline the process.

spark discussion

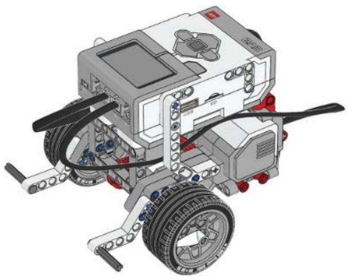
Autonomous wheeled robots are a common type of mobile robot. Although they are not yet common in homes, they are widely used in factories and warehouses around the world to automate tasks. The most basic task any wheeled robot should be able to do is make precise and controlled movements using its motors.

✧ How to configure and program a wheeled robot to perform a specific task?

✧ What actions should they be able to perform?

✧ How do they work safely alongside human workers?

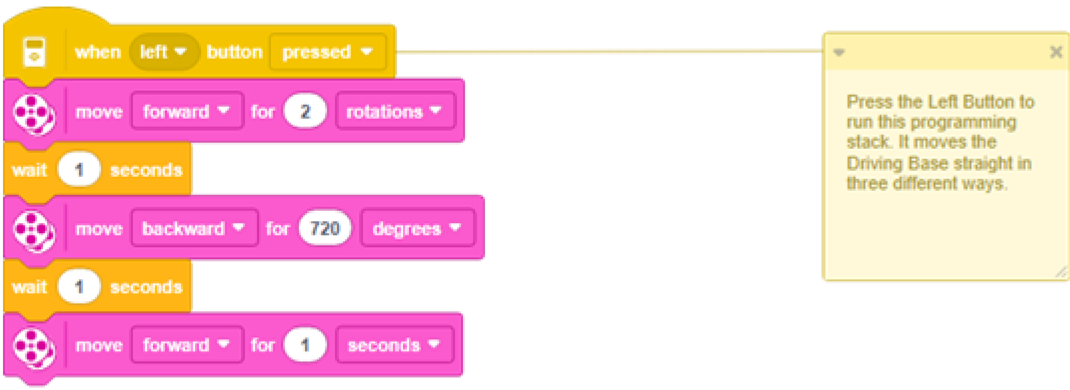
Building Tips



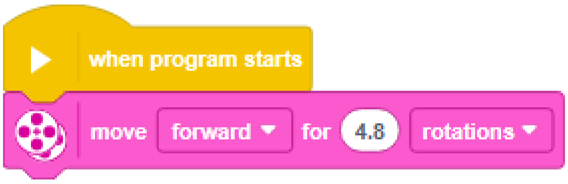
Building instructions

Keep the drive base assembled after use, not disassembled.

Coding tips



possible solutions



Building instructions

differentiation

Simplify this course by:

✧ Spend extra time explaining what each parameter of the programming block controls

Take this course to the next level with:

✧ Have students program the drive base to track the number eight, the first letter of their name, or other letters or numbers

✧ Create an obstacle course that requires different turning methods to complete

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed

2、 Fully completed

3、 Overachieved

Use the following success criteria to evaluate student progress:

✧ Students can select appropriate blocks to perform controlled movements.

✧ Students can iteratively change the parameters of the block.

✧ Students can stack appropriate moving blocks together to create programs.

Self-assessment

allows each student to select the level they feel best represents their performance.

✧ Bronze: I made the drive base move one way.

✧ Silver : I made the drive base move in different ways.

✧ Gold Medal: I created a procedure to move the drive base forward 84cm / 33 inches.

✧ Platinum: I used math to create a program that moves the drive base forward 84 cm/ 33 inches.

2. objects and obstacles

Use ultrasonic sensors to detect and react to cuboids. 45-90 minutes , beginners , grades 6-8

lesson plan

1. Prepare

- Read through the student materials in the EV3 Classroom app.
- Gather some information about how ultrasonic sensors work.
- In this lesson you will need a tape measure to measure where to place the cuboid.
- To complete this course, students must build a driver base model, which takes approximately 30 minutes.

2. Participate (5 minutes)

- Use the ideas in the "Start a Discussion" section below to engage your students in *discussions related* to this lesson .
- Divide your class into pairs.

3. Explore (20 minutes)

- Have each pair of students build the cuboid and the ultrasonic sensor extension that will drive the base.
- Give students some time to explore how to use ultrasonic sensors using the provided programming stack.

4. Explanation (5 minutes)

- Promote discussion on how to measure distance using ultrasonic sensors.

5. Detailed explanation (15 minutes)

- beep faster or louder when near the cuboid .
- Don’t forget to set aside some time for cleanup.

6.Evaluation _

- Provide feedback on each student's performance.
- You can use the provided rubrics to streamline the process.

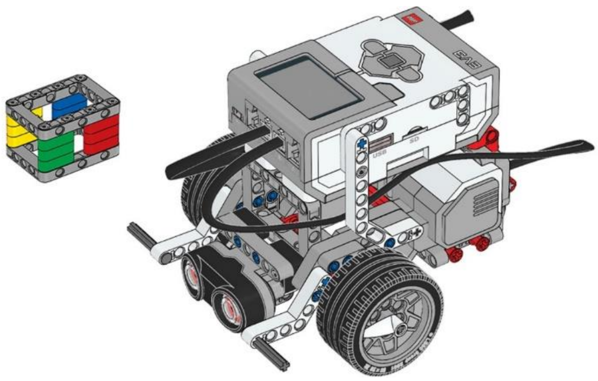
spark discussion

Modular robots are useful because they can be expanded and reconfigured to perform a variety of tasks. Adding sensors allows them to react to their environment so they can do things like detect obstacles and avoid collisions.

Use these questions to engage your students in a discussion about robots that can detect objects:

- ✧ Do you know of any robots that can detect objects?
- ✧ Why would it be useful for a robot to be able to detect objects?
- ✧ What is *ultrasound* and how do ultrasonic sensors work?

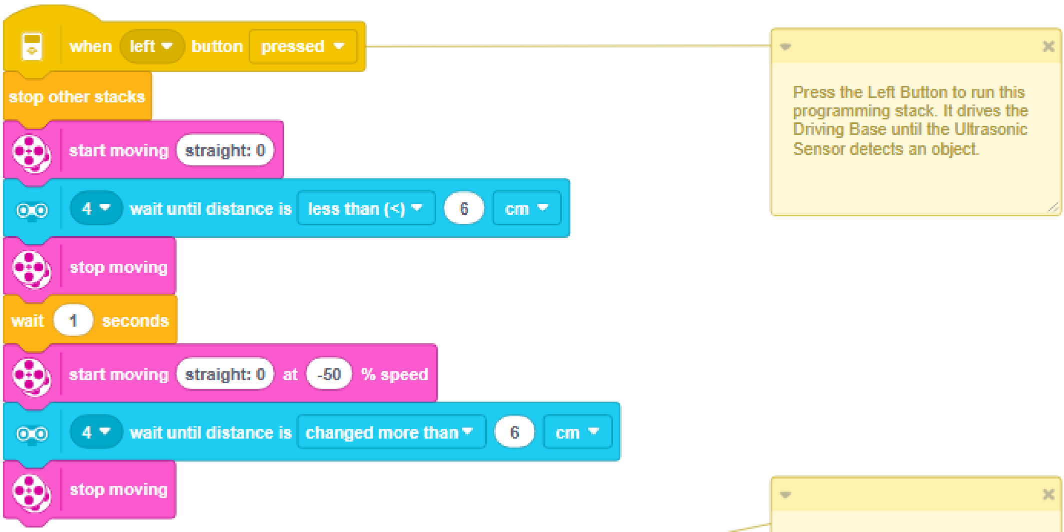
Building Tips

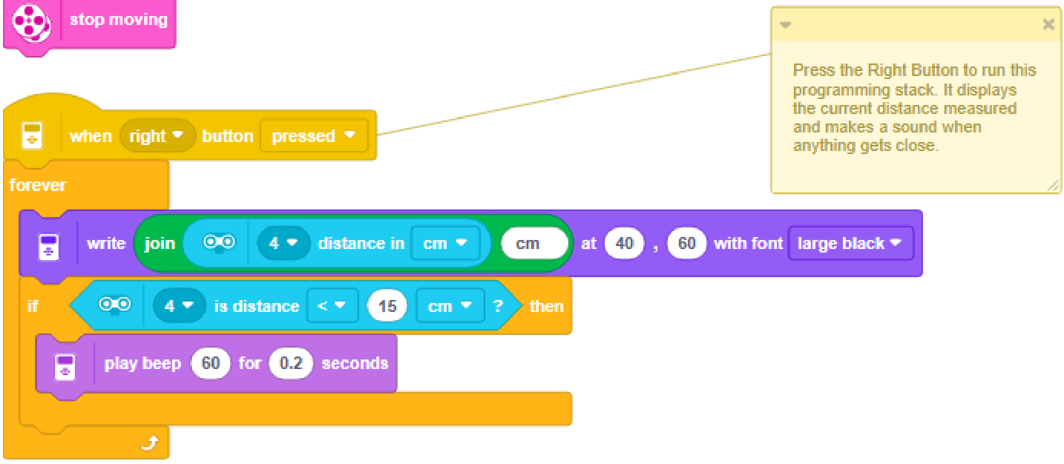


Building instructions

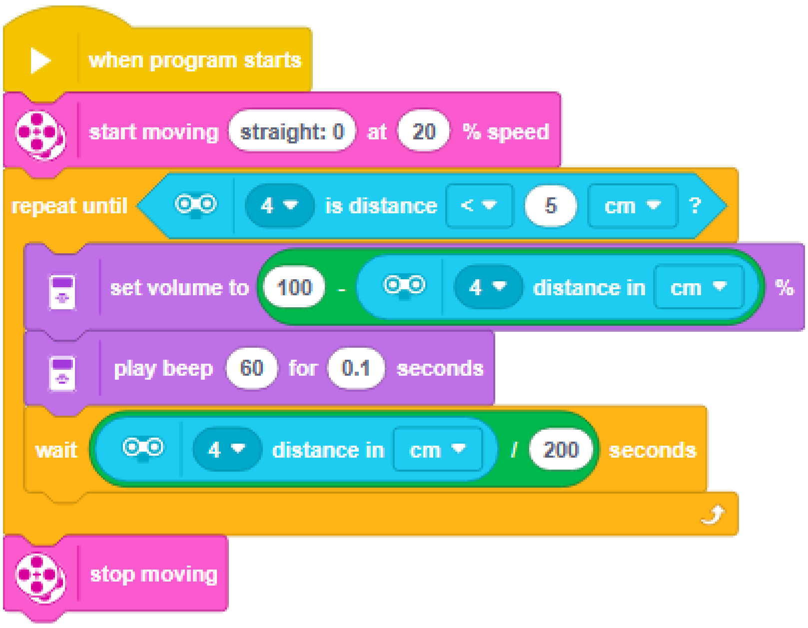
- ✧ Drive base
- ✧ Ultrasonic Sensor – Driving Base
- ✧ Cuboid

Coding tips





possible solutions



differentiation

Simplify this course by:
- ✧ Spending extra time explaining how to use the Ultrasonic Sensor

Take this course to the next level with:
- ✧ Challenging your students to program an autonomous robot that avoids obstacles
- ✧ Having your students change the Ultrasonic Sensor to a Touch Sensor for detecting obstacles

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:
1. partially completed
2. Fully completed
3. Overachieved

Use the following success criteria to evaluate student progress:
- ✧ Students can use the Ultrasonic Sensor to detect an object.
- ✧ Students can change the parameters of the Ultrasonic Sensor Blocks to detect different distances.
- ✧ Students can expand their program to react dynamically to the detected distance.

Self-assessment

allows each student to select the level they feel best represents their performance.
- ✧ Bronze: I've used the Ultrasonic Sensor to stop at an object.
- ✧ Silver: I've used the Ultrasonic Sensor to detect the distance to an object.
- ✧ Gold: I've made one aspect of the program react dynamically to the distance to an object.
- ✧ Platinum: I've made several aspects of the program react dynamically to the distance to an object.

3. grab and release

Build a power tool to move objects. 45-90 minutes , beginners , grades 6-8

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about motorized tools and how they're used in robotics.
- ✧ To complete this course, students must build a driver base model, which takes approximately 30 minutes.

2. Participate (5 minutes)

- ✧ Use the ideas in the "Start a Discussion" section below to engage your students in *discussions related* to this lesson .
- ✧ Divide your class into pairs.

3. Explore (20 minutes)

- ✧ Have each pair of students build the Cuboid, and the Medium Motor and Ultrasonic Sensor extensions for their Driving Base.
- ✧ Give the students some time to use the programming stacks provided to explore how this motorized tool can be used to move the Cuboid.

4. Explanation (5 minutes)

- ✧ Facilitate a discussion about the key features of the Medium Motor extension and its limitations.

5. Detailed explanation (15 minutes)

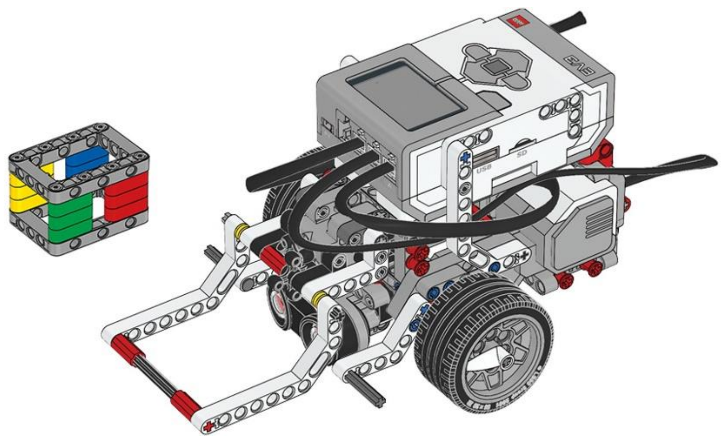
- ✧ Challenge your students to program their Driving Bases to use the Ultrasonic Sensor to stop near the Cuboid and then lower the arm to collect and return the Cuboid.
- ✧ Don't forget to set aside some time for cleanup.

spark discussion

Motorized tools can be attached to robots to enable them to perform different tasks. Some are very specialized and optimized for a single purpose, whereas others are more versatile. Use these questions to engage your students in a discussion about ways robots could use motorized tools:

- ✧ What tasks should a motorized tool designed to handle objects be able to do?
- ✧ In which situations would you choose a highly optimized motorized tool?
- ✧ In which situations would a versatile motorized tool be better?

Building Tips

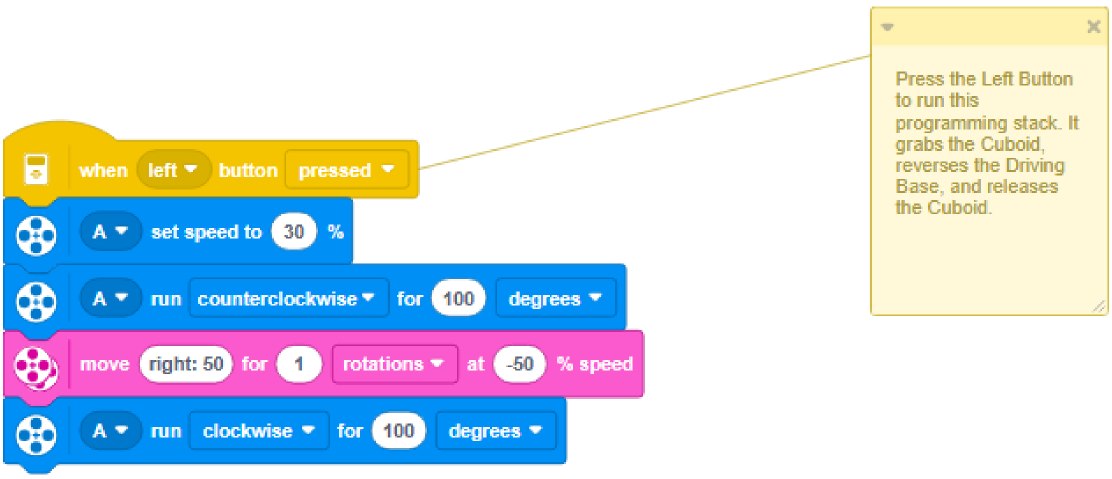


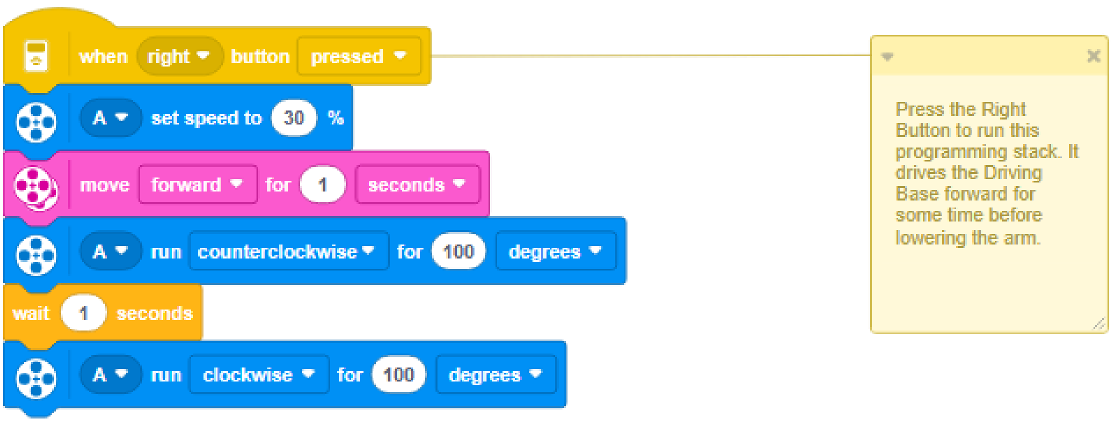
Building instructions

- ✧ Drive base
- ✧ Medium Motor – Driving Base
- ✧ Ultrasonic Sensor – Driving Base
- ✧ Cuboid

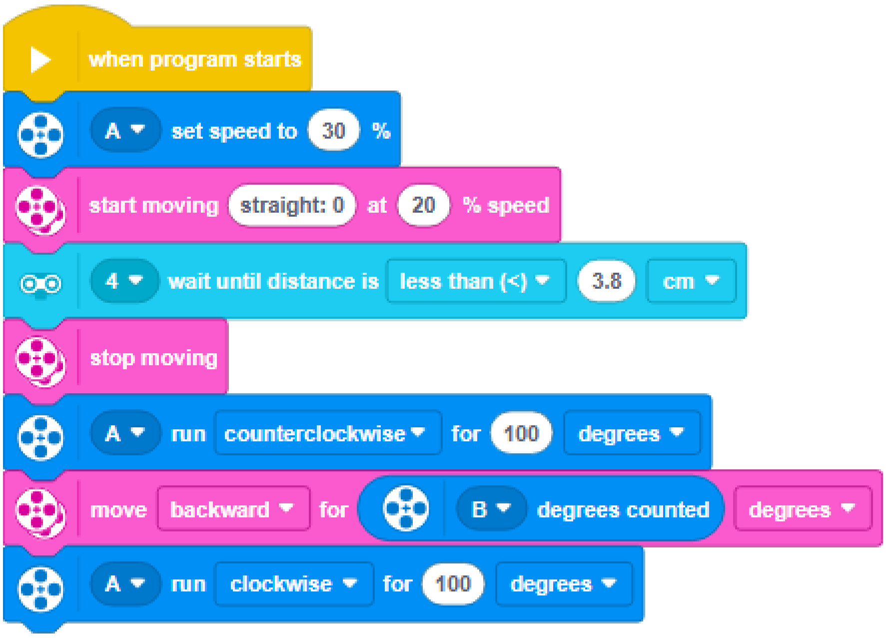
Keep the drive base assembled after use, not disassembled.

Coding tips





possible solutions



Differentiation

Simplify this lesson by:

✧ Allowing the students to place the Cuboid at a known and fixed distance

✧ Spending extra time explaining how to use the Ultrasonic Sensor

Take this lesson to the next level by:

✧ Asking your students to modify the Medium Motor extension to move objects of different shapes and sizes

✧ Challenging your students to create their own Driving Base tools

Assessment Opportunities

Teacher Observation Checklist

Create a scale that matches your needs, for example:

1、 Partially accomplished

2、 Fully accomplished

3、 Overachieved

Use the following success criteria to evaluate student progress:

✧ Students can use a motorized tool to move and release an object.

✧ Students can use the Ultrasonic Sensor to determine when to activate the motorized tool.

✧ Students can expand their program to return an object to the starting position of the Driving Base.

Self-assessment

allows each student to select the level they feel best represents their performance.

✧ Bronze: I've used a motorized tool to move and release the Cuboid.

- ✧ Silver: I've used the Ultrasonic Sensor to activate a motorized tool at the right time to move and release the Cuboid.
- ✧ Gold: I've used the Ultrasonic Sensor to activate a motorized tool at the right time and have moved the Cuboid to the starting position of the Driving Base.
- ✧ Platinum: I've used the Ultrasonic Sensor to activate a motorized tool at the right time and have moved different objects to the starting position of the Driving Base.

4. colors and lines

Use color sensors to detect and track lines.

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about how the Color Sensor works, and how the Color and Reflected Light Intensity Modes could be used.
- ✧ You'll need black tape to create a thick black line.
- ✧ To complete this course, students must build a driver base model, which takes approximately 30 minutes.

2. Participate (5 minutes)

- ✧ Use the ideas in the "Start a Discussion" section below to engage your students in *discussions related* to this lesson .
- ✧ Divide your class into pairs.

3. Explore (20 minutes)

- ✧ Have each pair of students build the Color Sensor Down extension for their Driving Base.
- ✧ Give the students some time to use the programming stacks provided to explore how the Color Sensor can be used to detect and follow a line.

4. Explanation (10 minutes)

- ✧ Have your students use the programming stacks to calibrate the Color Sensor and then observe its effect.
- ✧ Facilitate a discussion about why it's important to calibrate the Color Sensor.

5. Detailed explanation (10 minutes)

- ✧ Challenge the students to program a better line-follower program.
- ✧ Don’t forget to set aside some time for cleanup.

6. Evaluation

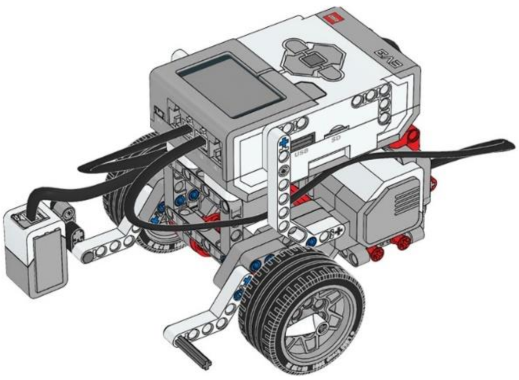
- ✧ Provide feedback on each student's performance.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

Hardcoding the exact movements that a robot has to make isn't very efficient. Therefore, robots have different guiding systems to help them navigate their environment. One simple yet effective option is to use colored lines on the floor, which a robot can follow using a sensor. Use these questions to engage your students in a discussion about robots that can detect colors:

- ✧ Do you know of any robots that can detect colors?
- ✧ What are the advantages and limitations of using colored lines as a means of navigation?
- ✧ What's *reflected light intensity* , and how does a Color Sensor work?

Building Tips



Building Instructions

- ✧ Driving Base
- ✧ Color Sensor Down – Driving Base

Keep the Driving Base assembled after use, rather than taking it apart.

Setting Up the Path

Provide your students with black tape to create a thick black line to detect and follow. Let them explore different types of lines but advise them that very sharp angles are hard to follow.

Using the Color Sensor

The Color Sensor can be used in 2 different modes to solve this challenge (ie, Color Mode or Reflected Light Intensity Mode).

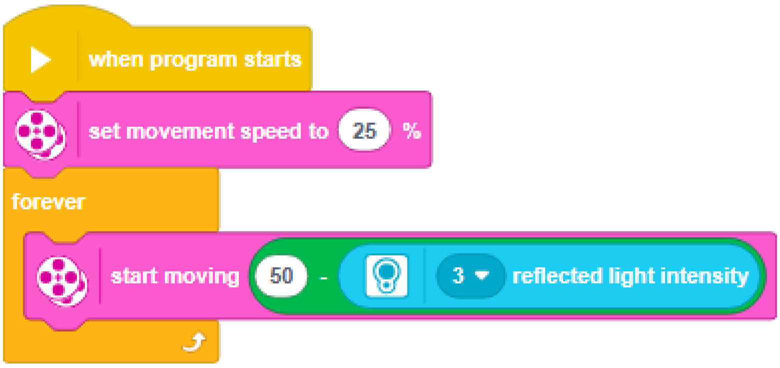
The Reflected Light Intensity Mode of the Color Sensor will give maximum precision. Following a line is done by alternating the detection of 2 colors or 2 reflected light intensities. Spend some time with your students exploring how the sensor reports values.

Coding Tips

Main Program


when left button pressed
stop other stacks
C start motor at 50 % speed
3 wait until color is black
C stop motor
Press the Left Button to run this programming stack. It turns the Driving Base until the Color Sensor detects the black line.
when right button pressed
forever
if 3 is reflected light intensity < 50 %? then
start moving at 50 0 % speed
else
start moving at 0 50 % speed
Press the Right Button to run this programming stack. It gets the Driving Base to follow a line.
Press the Up Button to run this programming stack. It'll calibrate the maximum reflected light intensity to the current Color Sensor reading. Run it while the Color Sensor is above the lightest surface it might encounter.
when up button pressed
calibrate reflected light intensity maximum to 3 reflected light intensity
play beep 72 for 0.2 seconds
Press the Down Button to run this programming stack. It'll calibrate the minimum reflected light intensity to the current Color Sensor reading. Run it while the Color Sensor is above the middle of the black line.
when down button pressed
calibrate reflected light intensity minimum to 3 reflected light intensity
play beep 60 for 0.2 seconds
Press the Center Button to run this programming stack, which resets the Color Sensor calibration. Run it if your calibration went wrong.
when center button pressed
reset reflected light intensity calibration
play beep 66 for 0.2 seconds

Possible Solution



Differentiation

Simplify this lesson by:

- ✧ Explaining the Reflected Light Intensity Mode of the Color Sensor
- ✧ Simplifying the line that the Driving Base should follow

Take this lesson to the next level by:

- ✧ Challenging your students to modify their programs to follow lines of different sizes, colors, and shapes
- ✧ Presenting a program called simple *proportional line follower* (see the *Coding Tips* section above) and having your students try to decode how the program works

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed

2、 Fully completed

3、 Overachieved

Use the following success criteria to evaluate student progress:

1、 Students can program their Driving Base to react to lines using the Color Sensor.

2、 Students can calibrate the Color Sensor and explain the importance of sensor calibration.

3、 Students can optimize their line-following program to be more accurate.

Self-assessment

allows each student to select the level they feel best represents their performance.

- ✧ Bronze: I've made the Driving Base stop at a line.
- ✧ Silver: I've programmed the Driving Base to follow a line.
- ✧ Gold: I've programmed the Driving Base to follow a line and calibrated the Color Sensor to account for changing light conditions.
- ✧ Platinum: I've not only programmed the Driving Base to follow a line and calibrated the Color Sensor to account for changing light conditions, but I've also optimized it to move the Driving Base faster and more effectively.

5. angles and patterns

Use the gyro sensor to turn at precise angles and use My Blocks to organize your programs.

lesson plan

1. Prepare

- Read through the student materials in the EV3 Classroom app.
- Collect some information about how the Gyro Sensor works.
- It's recommended that students complete the other lessons in this unit before beginning this challenge.
- To complete this course, students must build a driver base model, which takes approximately 30 minutes.

2. Participate (5 minutes)

- Use the ideas in the "Start a Discussion" section below to engage your students in *discussions related* to this lesson .
- Divide your class into pairs.

3. Explore (20 minutes)

- Have each pair of students build the Gyro Sensor extension for their Driving Base.
- Give them some time to use the programming stacks provided to explore how the Gyro Sensor can be used to detect changes in orientation and how My Blocks can be used to organize programs.

4. Explanation (5 minutes)

- Facilitate a discussion about how My Blocks can be used to organize and reuse code.

5. Detailed explanation (15 minutes)

- Challenge your students to use the Gyro Sensor tand My Blocks to program their Driving Bases to drive in a square three times and then drive in a triangle.
- Don’t forget to set aside some time for cleanup.

6. Evaluation

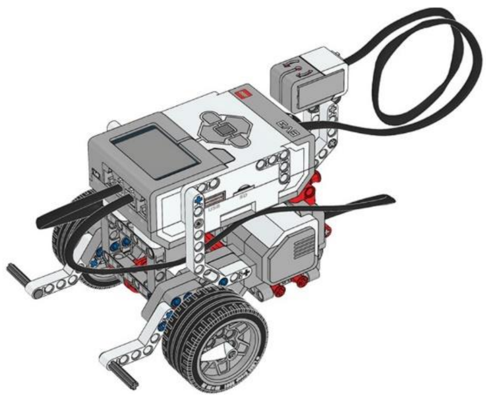
- Provide feedback on each student's performance.
- You can use the provided rubrics to streamline the process.

spark discussion

Gyro Sensors measure changes in rotation to help determine orientation. Wheeled robots can use such sensors to navigate, make precise turns, and keep track of their position.
Use these questions to engage your students in a discussion about how robots can use Gyro Sensors:

- ✧ In which situations is it useful to detect changes in orientation so that a robot can navigate?
- ✧ Can you name some devices that use a Gyro Sensor?
- ✧ How does a Gyro Sensor work?

Building Tips



Building instructions

- ✧ Driving Base
- ✧ Gyro Sensor – Driving Base

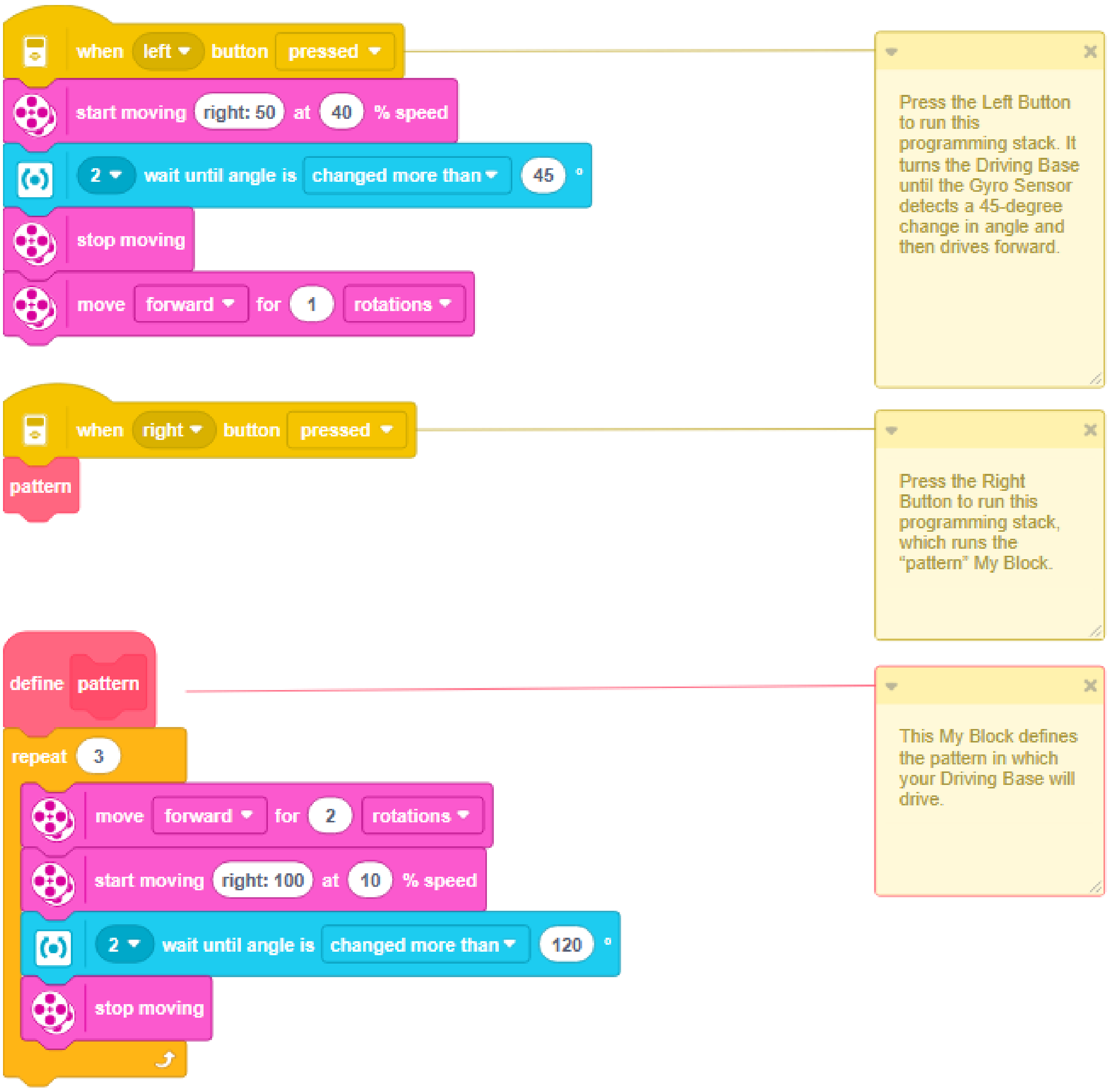
Keep the Driving Base assembled after use, rather than taking it apart.

Using the Gyro Sensor

The Gyro Sensor must be completely motionless while it's being plugged into the EV3 Brick and during start-up of the EV3 Brick. If the Gyro Sensor's angle readings change while the Driving Base is standing still, unplug the sensor and plug it back in.

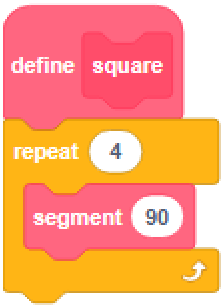
Coding Tips

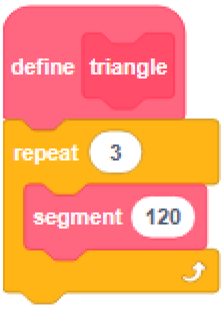
Main Program

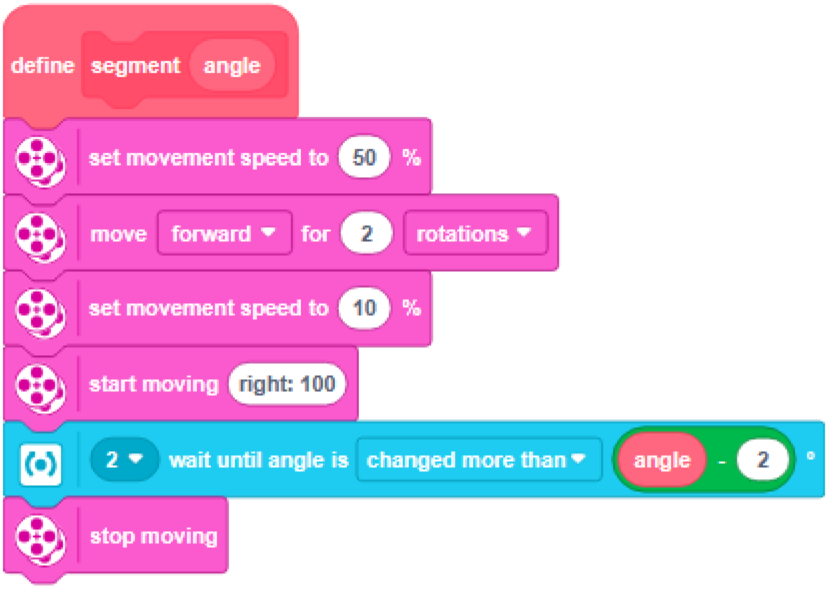


Possible Solution


when program starts
repeat 3
square
triangle


define square
repeat 4
segment 90


define triangle
repeat 3
segment 120


define segment angle
set movement speed to 50 %
move forward for 2 rotations
set movement speed to 10 %
start moving right: 100
2 wait until angle is changed more than angle - 2 °
stop moving

Differentiation

Simplify this lesson by:

- ✧ Spending extra time explaining how to use the Gyro Sensor
- ✧ Explaining how to create and use My Blocks

Take this lesson to the next level by:

- ✧ Challenging your students to create a program that will make their Driving Base trace out the letter “Z”
- ✧ Creating a maze and challenging your students to see how fast they can create a program to navigate through it

Assessment Opportunities

Teacher Observation Checklist

Create a scale that matches your needs, for example:

- ✧ Partially accomplished
- ✧ Fully accomplished
- ✧ Overachieved

Use the following success criteria to evaluate your students' progress:

- ✧ Students can program their Driving Base to drive in patterns using the Gyro Sensor's angle readings.
- ✧ Students can construct a My Blocks program.
- ✧ Students understand how My Blocks can be used to tidy up their programs and make them easier to manage.

Self-assessment

allows each student to select the level they feel best represents their performance.

- ✧ Bronze: I've made the Driving Base turn 45 degrees based on the Gyro Sensor's angle readings.
- ✧ Silver: I've used a My Block to make the Driving Base drive in a triangle based on the Gyro Sensor's angle readings.
- ✧ Gold: I've created a My Block to make the Driving Base drive in a square based on the Gyro Sensor's angle readings.
- ✧ Platinum: I've created and used a My Block to organize my program, which makes the Driving Base repeatedly drive in a square based on Gyro Sensor angle readings.

6. factory robot

Design and build the extension on the driver base and program it to accomplish two tasks.

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about the tasks autonomous wheeled robots perform in factories and warehouses.
- ✧ You'll need black tape, markers, a measuring tape, and a large object to create the factory path for this lesson.
- ✧ It's recommended that students complete the other lessons in this unit before beginning this challenge.
- ✧ To complete this course, students must build a driver base model, which takes approximately 30 minutes.
- ✧ If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- ✧ Use the ideas in the "Start a Discussion" section below to engage your students in *discussions related* to this lesson .
- ✧ Divide your class into pairs.

3. Explore (35 minutes)

- ✧ Have your students brainstorm ideas for extending their Driving Base so that it grabs the Cuboid and releases it in the center of the target circle (ie, the “drop-off zone”).
- ✧ Encourage them to create multiple prototypes, exploring both building and programming.
- ✧ Allow the students time to build and test their solutions.

4. Explanation (10 minutes)

- ✧ Facilitate a discussion about the key functionalities of the robot in following the line and stopping in front of the large object.

5. Detailed explanation (35 minutes)

- ✧ Have your students brainstorm ideas for extending their Driving Base so that it follows the line and stops as close as possible to the large object.
- ✧ Let them continue to work on their robots until they're ready to complete the challenge.
- ✧ Don’t forget to set aside some time for cleanup.

6. Evaluation

- ✧ Provide feedback on each student's performance.
- ✧ Evaluate the creativity of their solution and how well their team worked together.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

One of the tasks of autonomous wheeled robots in the LEGO ® factory is moving boxes between the different work stations. These fully autonomous robots even find their own way to a charging station when their battery gets low! They perform their tasks efficiently, without bumping into walls, people, or other robots.

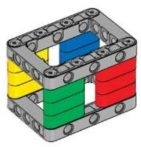
Use these questions to engage your students in a discussion about how the Driving Base could perform similar tasks to the LEGO factory robots:

- ✧ Do you think the Driving Base could be used to perform similar tasks to the LEGO factory robots?
- ✧ Which of the extensions from the previous lessons would be useful for these tasks?

Project Brief

Design and build extensions to your Driving Base and program it to:

- ✧ Grab the Cuboid and bring it as close as possible to the center of the target circle and then release it.
- ✧ Detect and follow the line, and stop as close as possible to the large object, without touching it.



Building Tips

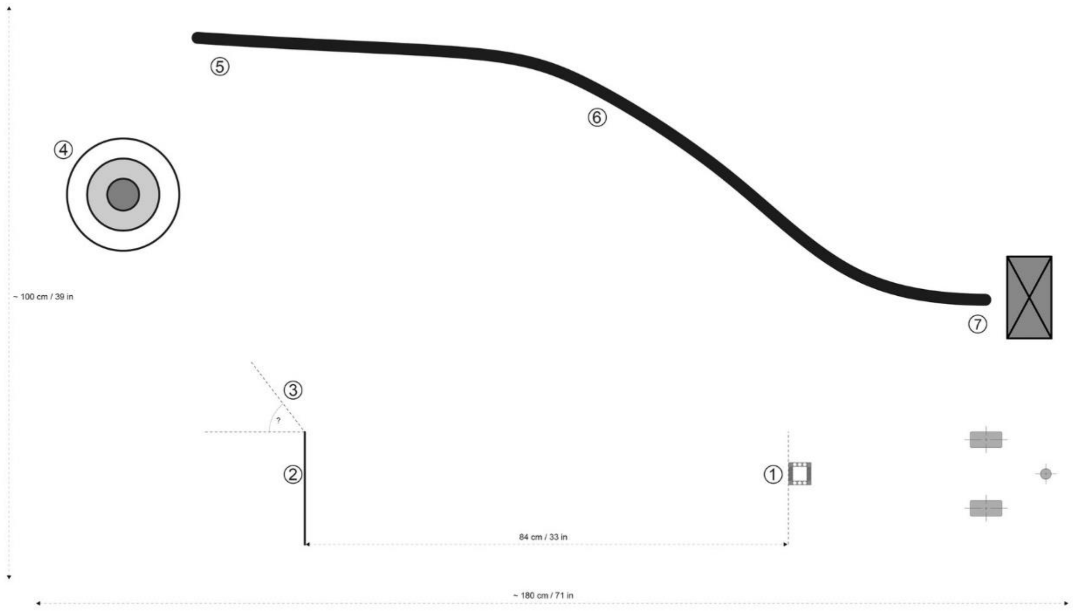
Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help the teams brainstorm ideas for solving the project brief:

- ✧ How could the robot navigate to the center of the drop-off zone?
- ✧ How could the robot stop following the line as close as possible to the large object?

Setting Up the Factory Path

To create the path illustrated below, the students will need black tape, markers, a measuring tape, the Cuboid, and a large object to place at the end of the black line. The measurements given are only meant as suggestions and can be loosely followed. However, the example solution and solution program are based on these measurements.



Example Solution

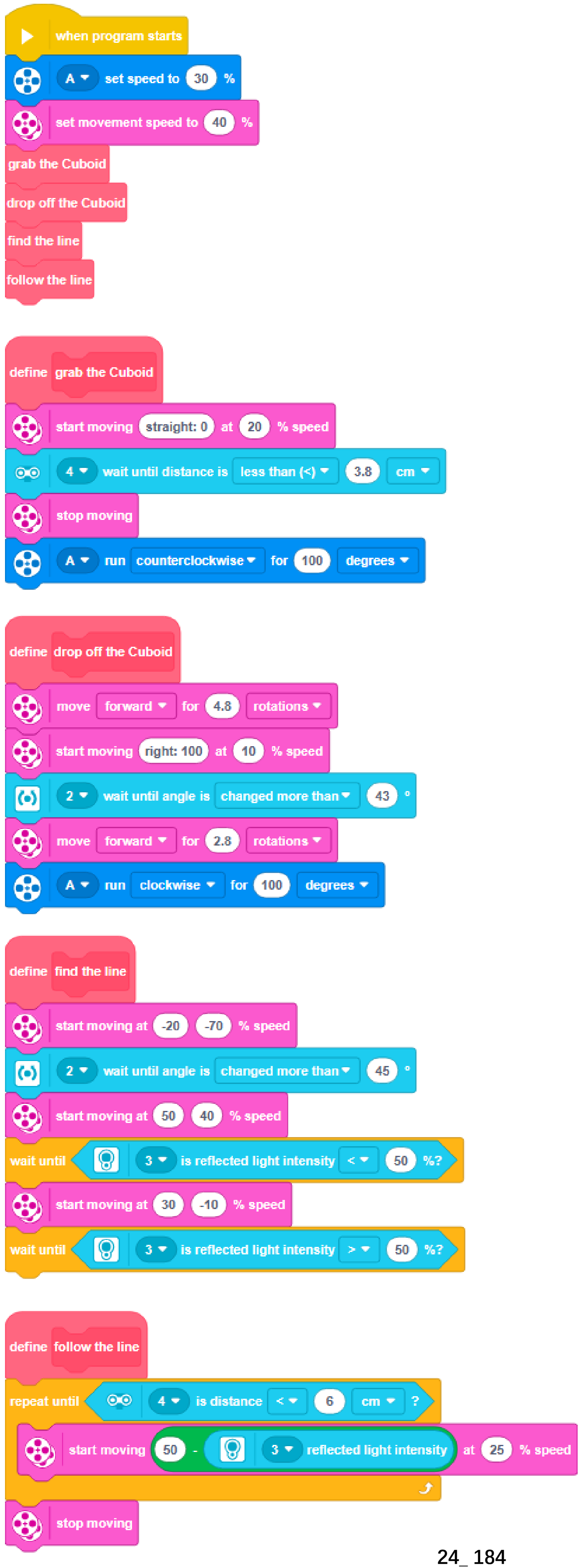
The example solution combines the following extensions:

- ✧ Drive base
- ✧ Medium Motor – Driving Base
- ✧ Ultrasonic Sensor – Driving Base
- ✧ Color Sensor Down – Driving Base
- ✧ Gyro Sensor – Driving Base

Using the Gyro Sensor

The Gyro Sensor must be completely motionless while it's being plugged into the EV3 Brick and during start-up of the EV3 Brick. If the Gyro Sensor's angle readings change while the Driving Base is standing still, unplug the sensor and plug it back in.

Coding tips


when program starts
A set speed to 30 %
set movement speed to 40 %
grab the Cuboid
drop off the Cuboid
find the line
follow the line
define grab the Cuboid
start moving straight: 0 at 20 % speed
4 wait until distance is less than (<) 3.8 cm
stop moving
A run counterclockwise for 100 degrees
define drop off the Cuboid
move forward for 4.8 rotations
start moving right: 100 at 10 % speed
2 wait until angle is changed more than 43 °
move forward for 2.8 rotations
A run clockwise for 100 degrees
define find the line
start moving at -20 -70 % speed
2 wait until angle is changed more than 45 °
start moving at 50 40 % speed
wait until 3 is reflected light intensity < 50 %?
start moving at 30 -10 % speed
wait until 3 is reflected light intensity > 50 %?
define follow the line
repeat until 4 is distance < 6 cm ?
start moving 50 - 3 reflected light intensity at 25 % speed
stop moving

differentiation

Simplify this course by:

- ✧ Working side-by-side with your students to help them figure out how to stop following the line when the large object is detected
- ✧ Suggesting that the students revisit the previous lessons in this unit
- ✧ Allowing the students to drive toward the large object without following the line
- ✧ Encouraging peer-to-peer learning and coaching

Take this course to the next level with:

- ✧ Challenging the students to drive forward exactly 84 cm/33 in after picking up the Cuboid and then use the Gyro Sensor to point the robot toward the target circle
- ✧ Using tape of a different color than what was used in the *Colors and Lines* lesson

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed
2、 Fully completed
3、 Overachieved

Use the following success criteria to evaluate student progress:

- ✧ Students designed a robot that meets the requirements of the project brief.
- ✧ Students came up with creative solutions and considered multiple solutions.
- ✧ Students worked together as a team to complete the challenge.

Self-assessment

allows each student to select the level they feel best represents their performance.

- ✧ Bronze: I did the best I could under difficult circumstances.
- ✧ Silver: I had a few accidents along the way, but I still completed one of the tasks.
- ✧ Gold: I've completed both tasks with excellent results.
- ✧ Platinum: I've not only completed both tasks, but I've also added features that were original and effective.

7. Guidance Tasks 2021-22

Guide your team through their first real LEGO League mission to prepare them for the challenges ahead!

Lesson Plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ To complete this lesson, your students will build a Driving Base.

2. Participate (10 minutes)

- ✧ Use the ideas in the "Start a Discussion" section below to engage your students in *discussions related* to this lesson .
- ✧ Use the video to explain the lesson.

3. Explore (30 minutes)

- ✧ Ask them to set up the Guided Mission model on the game field.
- ✧ Have them follow the instructions to write a program to drive their robot to the model and activate it.

4. Explanation (10 minutes)

- ✧ Facilitate a discussion about the key functionalities the robot must use in order to trigger the model to release the package.

5. Detailed explanation (40 minutes)

- ✧ Have each team practice lining up their robot and sending it on a mission to activate the model.
- ✧ Ask whether they've noticed anything to be especially aware of during this mission (ie, it's over the far side of the field, it passes other missions on the way).
- ✧ Prompt a discussion about what they've learned about following lines that could help them in accessing other missions.
- ✧ Don’t forget to set aside some time for cleanup.

6. Evaluation

- ✧ Provide feedback on each student's performance.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

Use these questions to engage your students in a discussion about how they can use what they've learned so far to successfully complete this mission:

- ✧ What's the robot doing?
- ✧ How does the robot reach the model?
- ✧ How does the robot activate the model?
- ✧ What's the ideal balance between speed and accuracy for this mission?

Have your students watch the video to see what they're about to do.

Building Tips

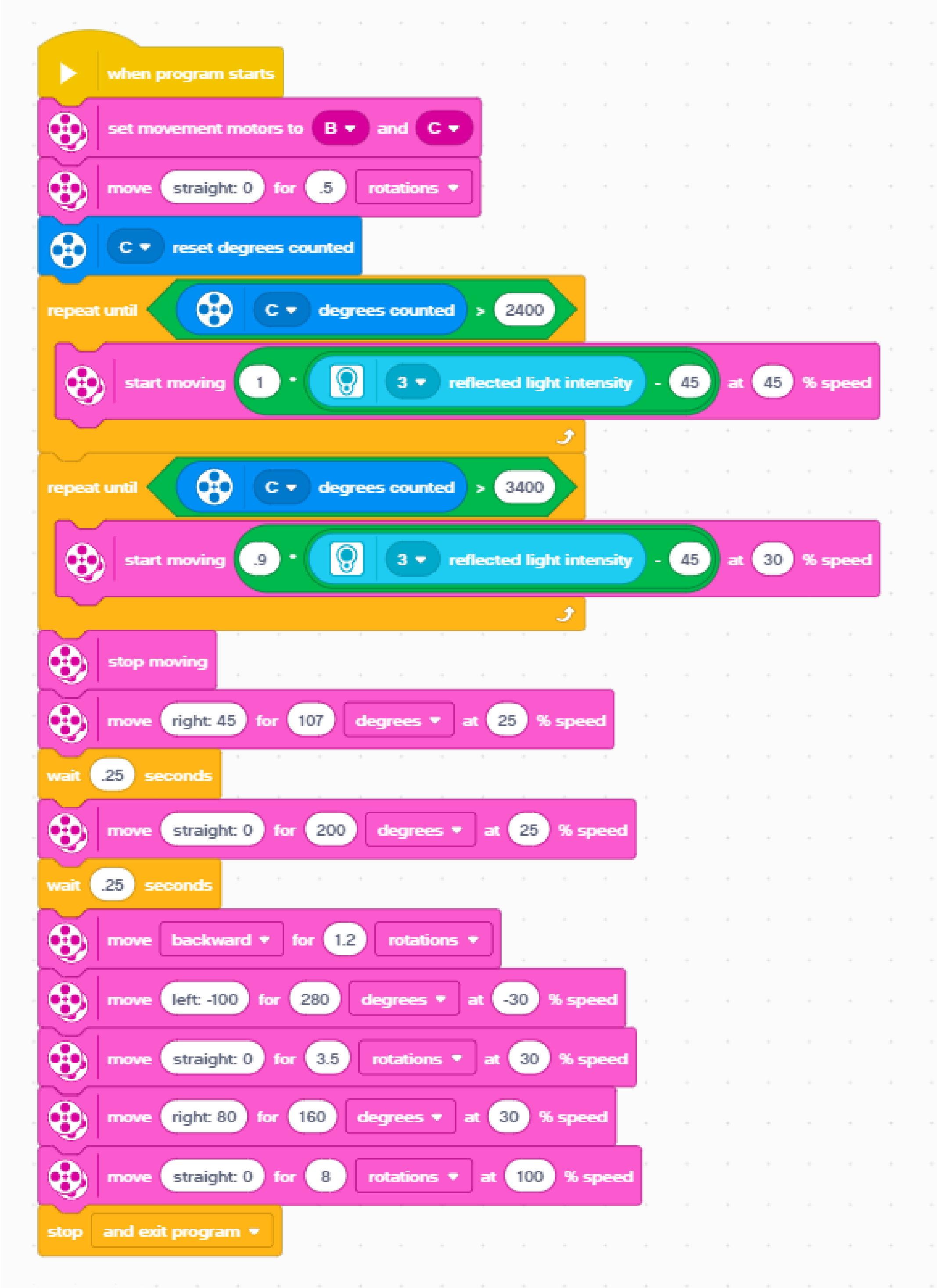
Setting Up the Guided Mission Model

Share these tips with your students as they're setting up the model:

- ✧ Check the Robot Game Rulebook for the correct position of the model on the mat.
- ✧ Make sure the model is built correctly and operates as it should.
- ✧ Carefully apply the Dual Lock and correctly position the model on the mat.

Coding tips

main program



differentiation

Simplify this course by:

✧ Focusing on the robot's accuracy in following the line to reach the mission

✧ Solving one part of the mission with your students as a group

Take this course to the next level with:

- ✧ Challenging your students to follow other lines on the game field
- ✧ Assigning another one of this year's FIRST LEGO League challenges to be done before or after this mission

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed

2、 Fully completed

3、 Overachieved

Use the following success criteria to evaluate student progress:

- ✧ Students worked well as a team to complete the mission.
- ✧ Students worked together as a team to complete more missions in the same run.
- ✧ Students can present their robot, program, and mission strategy, explaining how they've successfully completed each mission.

Self-Assessment

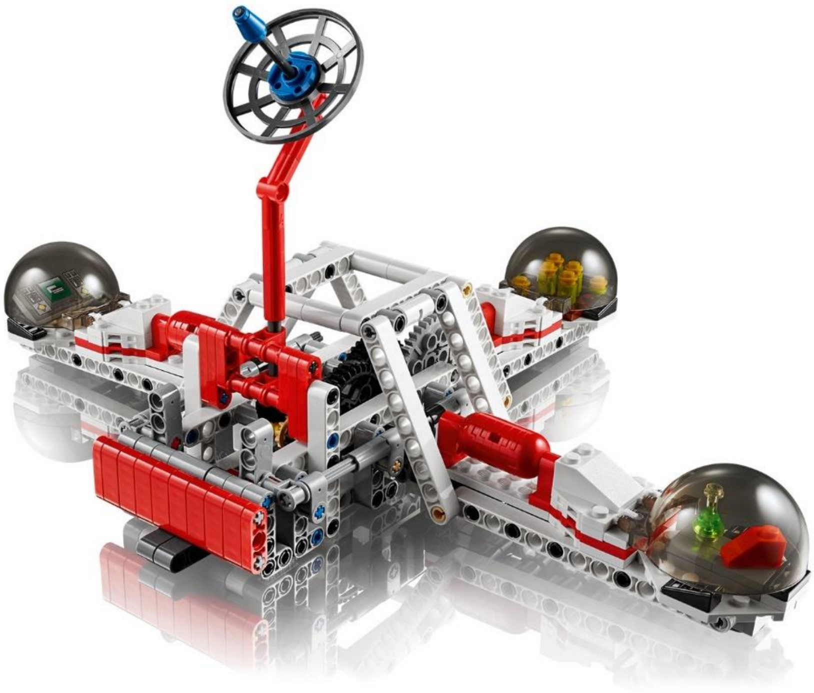
Have each student choose the brick that they feel best represents their performance.

- ✧ Bronze: I've successfully completed one mission.
- ✧ Silver: I've successfully completed more than one mission.
- ✧ Gold: Along with my team, I've presented our robot, program, and mission strategy to our coach with each team member participating.
- ✧ Platinum: Along with my team, I've presented outstanding ideas for our robot, using innovative ideas, and a deep mission strategy to our coach.

Peer-Assessment

Encourage your students to provide feedback to others by:

- ✧ Having one student score the performance of another using the scale above
- ✧ Asking them to present constructive feedback to each other so that they can improve their group's performance during the next lesson



space challenge

In this unit, your students will work as scientists and engineers. They'll immerse themselves in motivating STEM activities that prompt creative problem-solving, communication, and teamwork. They'll work on the Challenge Mat, an engaging and motivating platform where they 'll creatively apply their STEM knowledge and expand their problem-solving skills as they develop their Space Challenge solutions.

8. Get Ready to Go to Mars

Get started with the Space Challenge.

lesson plan

1. Prepare

Read through the student materials in the EV3 Classroom app.

2. Participate (10 minutes)

- Watch the unit video and use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to a human mission to Mars.
- Explain the rules of the Space Challenge, and it's objective.
- Split your class into six teams.

3. Explore (25 minutes)

- Have your students build the models they'll need for the Space Challenge. There are six groups of models. To equalize the workload, some teams will build multiple small models, while others will build a single big model.
- When the teams have finished building, ask them to set up their models on the Challenge Mat.

4. Explanation (5 minutes)

- Have each team explain what role their model(s) could play in a human mission to Mars.

5. Explain in detail (5 minutes)

- Encourage your students to come up with a plan for tackling the Space Challenge.
- Don't forget to set aside some time for cleanup.
- Keep the models intact after use, rather than taking them apart. Preserve them by wrapping them in cloth, paper, or bubble wrap.

6. Evaluation

- Provide feedback on each student's performance.
- You can use the provided rubrics to streamline the process.

spark discussion

People have long been fascinated by Mars, the planet in our solar system that's most like Earth. Uncrewed missions have sent orbiters, probes, and rovers to explore the planet since the 1960s, but what would it take to carry out a successful human mission to Mars?
Ask your students to think about these questions:

- What's needed to support human life on Mars?
- How can robots help humans explore Mars?
- What could we learn from going to Mars?
- How could a space crew on Mars communicate with a mission control center on Earth?

Space Challenge Objective

Students are awarded a bronze, silver, gold, or platinum achievement badge for each mission they complete. The objective of the Space Challenge is to complete as many successful missions as possible before launching the rocket to the Mars Outpost in the *final* mission .
Each mission comes with an objective and its own particular set of rules but there are five overall rules your students should know before they start:

- Complete as many missions as you can.
- You decide in which order you try the missions.
- You can try each mission more than once.
- The *Initiate Launch* mission is the final mission and ends the Space Challenge.
- The judge decides which achievement badges you'll be awarded.

Building Tips

Building Instructions

These eight models make up the Space Challenge playing field:

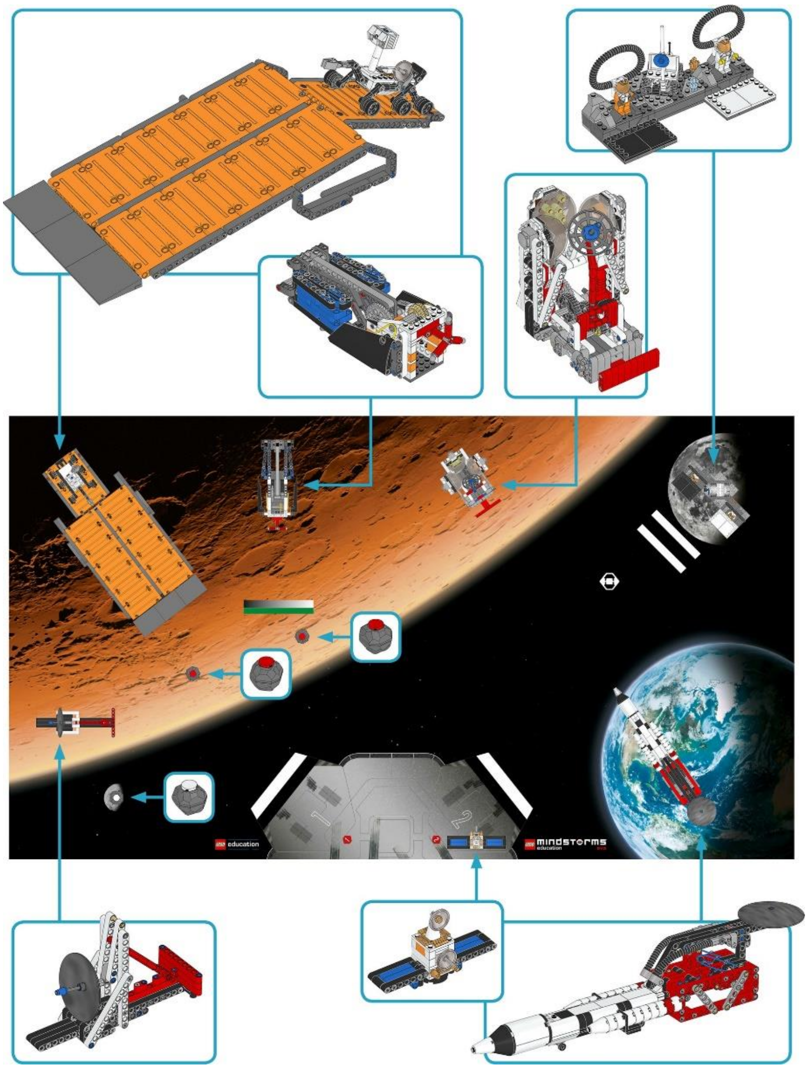
- Communications Station
- Satellite
- Flight Crew
- Crater and MSL
- Rock Samples

- ✧ Solar Panel
- ✧ Rocket and Launcher
- ✧ Mars Outpost

Setting Up the Models

As they set up their models, give your students these tips:

- ✧ Make sure that each model has been built correctly and that all of their mechanisms operate as they should.
- ✧ To see how to set and reset models, refer to the last page(s) of the building instructions
- ✧ The *Flight Crew* , *Crater* , *Solar Panel* , *Launcher* , and *Mars Outpost* models use Dual Lock fasteners to keep them in place.
- ✧ Carefully apply the Dual Lock fasteners and place the model in the correct position on the Challenge Mat.
- ✧ Refer to the Challenge Mat overview for the correct placement of the models.



differentiation

Simplify this course by:

- ✧ Helping your students as they apply the Dual Lock fasteners and place the models on the Challenge Mat

Take this course to the next level with:

- ✧ Encouraging your students to examine all of the models to learn how each of them operates

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed

2、 Fully completed

3、 Overachieved

Use the following success criteria to evaluate student progress:

- ✧ Students were able to describe the role of their model(s) in a human mission to Mars.
- ✧ Students worked as a team toward a common goal.
- ✧ Students examined how their model(s) worked in order to come up with strategies for solving their first mission.

Self-Assessment

Have each student choose the achievement badge that they feel best represents their performance.

- ✧ Bronze: We've built and placed the model(s) on the Challenge Mat.
- ✧ Silver: We've built and placed the model(s) on the Challenge Mat and explained the role of our model(s) in a human mission to Mars.
- ✧ Gold: We've built and examined the model(s) on the Challenge Mat and explained the role of our model(s) in a human mission to Mars.
- ✧ Platinum: We've not only explained the role of our model(s) in a human mission to Mars, but we've also built and examined the model(s) on the Challenge Mat and came up with a plan for tackling our first mission!

9. Activate Communications

Design, build, and program a robot that can navigate to the satellite dish and then push on it until it's fully upright.

lesson plan

1. Prepare

- Read through the student materials in the EV3 Classroom app.
- Collect some information about satellite dishes and how they're used in deep space communication.
- If you feel it's needed, plan a few lessons to go through the *Robot Trainer* unit in the app. This will help familiarize your students with LEGO ® MINDSTORMS ® Education EV3.
- To complete this lesson, your students will have to have built the eight Space Challenge models and set up the Challenge Mat.
- If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- Use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to this mission.
- Explain the objective, rules, and achievement badges for this mission.
- Split your class into teams.

3. Explore (25 minutes)

- ✧ Have your students brainstorm ideas for solving this mission.
- ✧ Encourage them to create multiple prototypes, exploring both building and programming.
- ✧ Allow the teams some time to work independently on building and testing their solutions.

4. Explanation (10 minutes)

- ✧ Facilitate a discussion about the key functionalities the robot must have in order to navigate to the *Communications Station* and push the satellite dish into an upright position.

5. Detailed explanation (45 minutes)

- ✧ Have each team practice lining up their robot and sending it on the mission to activate the *Communications Station* .
- ✧ Let them continue working on their robots until they're ready for a judged attempt.
- ✧ Don’t forget to set aside some time for cleanup.

6. Evaluation

- ✧ Award achievement badges based on how well each team solved the mission.
- ✧ Evaluate the creativity of each team's solution and how well their team worked together.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

Satellite dishes are a type of antenna that uses radio waves to receive or transmit data. On a human mission to Mars, they'd be used to transmit messages between Earth and Mars. Radio waves travel at the speed of light, and because the distance between Earth and Mars is variable, there's an approximate delay of between four and twenty-four minutes in communication between the planets.

Use these questions to engage your students in a discussion about how satellite dishes can be used in deep space communication:

- ✧ What's a satellite dish?
- ✧ How are satellite dishes used in deep space communication?

Mission Goal

The robot navigates to the satellite dish and then pushes on it until it's fully upright.

Here's an example mission solution that completes this mission:

Mission Rules

There are five rules that apply to all of the Space Challenge missions. Make sure your students know all of them before they start:

- ✧ Your robot must always start the mission from the base area.
- ✧ Your robot must leave the base area before carrying out the mission.

- ✧ A "successful robot return" occurs when any part of the robot crosses over any part of the base area line.
- ✧ You're not allowed to touch your robot while it's outside of the base area.
- ✧ If you touch your robot while it's completely outside of the base area and it's holding an object, the object must be returned to its original position and you must begin the mission again.

Mission Achievement Badges

There are four levels of achievement badges. Explain that each team will be awarded an achievement badge based on how well they accomplish the mission. Refer to the *Assessment Opportunities* section below for a description of the achievement badges for this mission.

Building Tips

Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help teams brainstorm ideas for solving this mission:

- ✧ What are some ways the robot could navigate to the *Communications Station* ?
- ✧ Can you think of some ways the robot could push the satellite dish carefully and accurately into an upright position?

Example Mission Solution

The example mission solution is comprised of the following solution extensions:

- ✧ Space Driving Base
- ✧ Ultrasonic Sensor
- ✧ Color Sensor Down

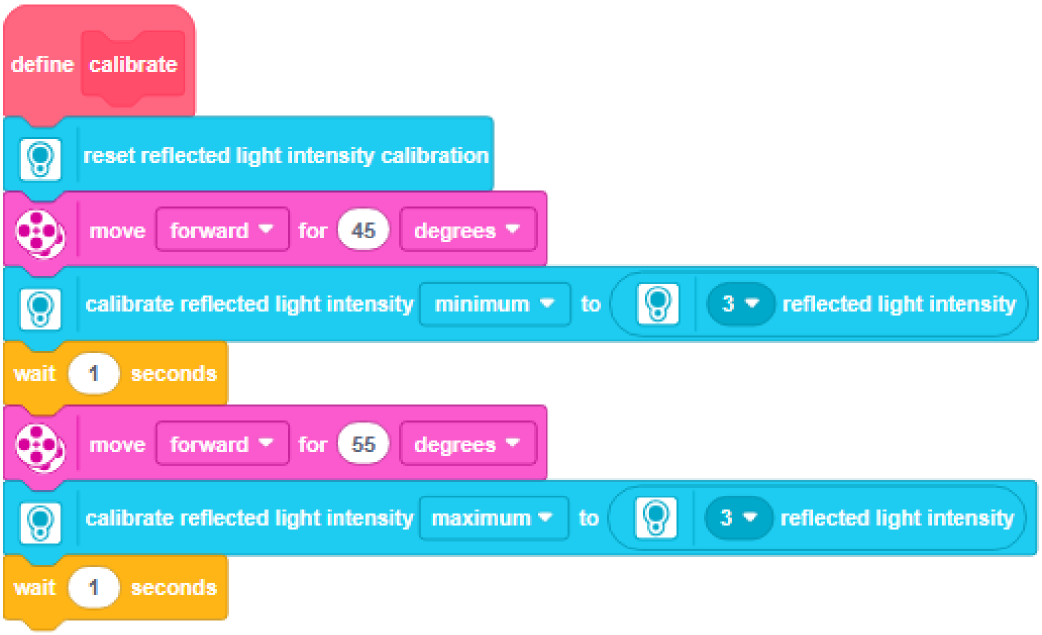
Execute the Mission

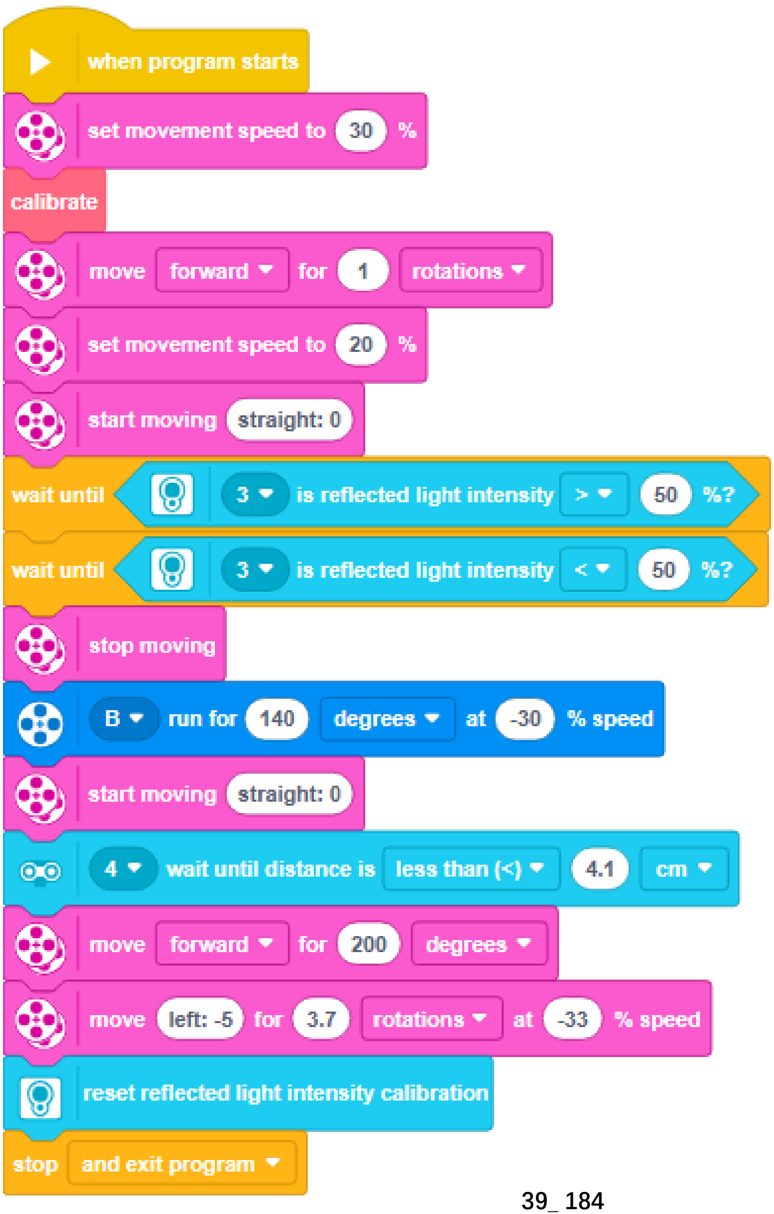
Reset the *Communications Station* , place the example solution model in starting position "1" on the Challenge Mat, and execute the mission.

Mission Troubleshooting

To avoid pushing on the satellite dish too much, use the Ultrasonic Sensor to detect the red wall of beams. Use the Color Sensor in Reflected Light Intensity Mode to detect where the robot is on the Challenge Mat. If the Color Sensor doesn' t detect changes in color on the Challenge Mat, try calibrating the sensor.

Coding tips


define calibrate
reset reflected light intensity calibration
move forward for 45 degrees
calibrate reflected light intensity minimum to 3 reflected light intensity
wait 1 seconds
move forward for 55 degrees
calibrate reflected light intensity maximum to 3 reflected light intensity
wait 1 seconds


when program starts
set movement speed to 30 %
calibrate
move forward for 1 rotations
set movement speed to 20 %
start moving straight: 0
wait until 3 is reflected light intensity > 50 %?
wait until 3 is reflected light intensity < 50 %?
stop moving
B run for 140 degrees at -30 % speed
start moving straight: 0
4 wait until distance is less than (<) 4.1 cm
move forward for 200 degrees
move left: -5 for 3.7 rotations at -33 % speed
reset reflected light intensity calibration
stop and exit program

differentiation

Simplify this course by:

- ✧ Working side-by-side with your students to figure out how to push the satellite dish up from a specified distance (ie, instead of starting from the base area)
- ✧ Having your students complete the *Objects and Obstacles* lesson in the *Robot Trainer* unit before attempting this mission
- ✧ Encouraging peer-to-peer learning and coaching

Take this course to the next level with:

- ✧ Randomly switching the position of the communication antenna and having the students create a program that responds to this variable
- ✧ Limiting the amount of time the students have to solve the mission
- ✧ Challenging the students to use both a Color Sensor and an Ultrasonic Sensor to solve this mission
- ✧ Adding design constraints by limiting the number of LEGO ® elements available or assigning a “price” to each type of LEGO element and a maximum “cost” per robot

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed
2、 Fully completed
3、 Overachieved

Use the following success criteria to evaluate student progress:

- ✧ Students designed a robot that meets the requirements of the mission.
- ✧ Students came up with creative solutions and considered multiple solutions.
- ✧ Students worked together as a team to complete the mission.

Achievement Badges

Award an achievement badge based on how well the team solved the challenge mission.

- ✧ Bronze: The robot went out and pushed on the satellite dish, but the satellite dish didn't stay upright because the robot pushed too much or not enough.
- ✧ Silver: The satellite dish stayed upright but at a lower position because the robot didn't push hard enough.
- ✧ Gold: The satellite dish stayed upright.
- ✧ Platinum: The satellite dish stayed upright and the team also went beyond the mission requirements by adding features to their design.

Self-Assessment

Have each student choose the achievement badge that they feel best represents their performance.

- ✧ Bronze: We did the best we could under difficult circumstances.
- ✧ Silver: We had a few accidents along the way but we still battled on to the end of the mission.

- ✧ Gold: We've accomplished the mission with excellent results.
- ✧ Platinum: We've not only completed the mission but also added original and effective features to our design.

10. Assemble Your Crew

Design, build, and program a robot that can navigate to the lunar base, pick up the flight commander, and set her down at the base area.

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about how astronauts prepare for space missions.
- ✧ If you feel it's needed, plan a few lessons to go through the *Robot Trainer* unit in the app. This will help familiarize your students with LEGO ® MINDSTORMS ® Education EV3.
- ✧ To complete this lesson, your students will have to have built the eight Space Challenge models and set up the Challenge Mat.
- ✧ If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- ✧ Use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to this mission.
- ✧ Explain the objective, rules, and achievement badges for this mission.
- ✧ Split your class into teams.

3. Explore (25 minutes)

- Have your students brainstorm ideas for solving this mission.
- Encourage them to create multiple prototypes, exploring both building and programming.
- Allow the teams some time to work independently on building and testing their solutions.

4. Explanation (10 minutes)

- Facilitate a discussion about the key functionalities the robot must have in order to navigate to the lunar base and pick up the flight commander.

5. Detailed explanation (45 minutes)

- Have each team practice lining up their robot and sending it on the mission to pick up the flight commander.
- Let them continue working on their robots until they're ready for a judged attempt.
- Don’t forget to set aside some time for cleanup.

6. Evaluation

- Award achievement badges based on how well each team solved the mission.
- Evaluate the creativity of each team's solution and how well their team worked together.
- You can use the provided rubrics to streamline the process.

spark discussion

On a human mission to Mars, the crew must endure darkness, low gravity, and isolation. A lunar base could be used to prepare the crew for this, both physically and mentally. On Earth, a research station in Antarctica is used to simulate the conditions of Mars missions.
Use these questions to engage your students in a discussion about how astronauts train and prepare for space missions:

- What's an astronaut?
- How can astronauts prepare for space missions?

Mission Goal

The robot navigates to the lunar base, picks up the flight commander, and sets her down at the base area.
Here's an example mission solution that completes this mission:

Mission Rules

There are five rules that apply to all of the Space Challenge missions. Make sure your students know all of them before they start:

- Your robot must always start the mission from the base area.
- Your robot must leave the base area before carrying out the mission.
- A “successful robot return” occurs when any part of the robot crosses over any part of the base area line.

- ✧ You're not allowed to touch your robot while it's outside of the base area.
- ✧ If you touch your robot while it's completely outside of the base area and it's holding an object, the object must be returned to its original position and you must begin the mission again.

Mission Achievement Badges

There are four levels of achievement badges. Explain that each team will be awarded an achievement badge based on how well they accomplish the mission. Refer to the *Assessment Opportunities* section below for a description of the achievement badges for this mission.

Building Tips

Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help teams brainstorm ideas for solving this mission:

- ✧ Can you think of some ways the robot could navigate to the lunar base?
- ✧ Which type of motorized mechanism can be used to pick up the flight commander?

Example Mission Solution

The example mission solution is comprised of the following solution extensions:

- ✧ Space Driving Base
- ✧ Transmission Module
- ✧ Crew Module
- ✧ Color Sensor Down

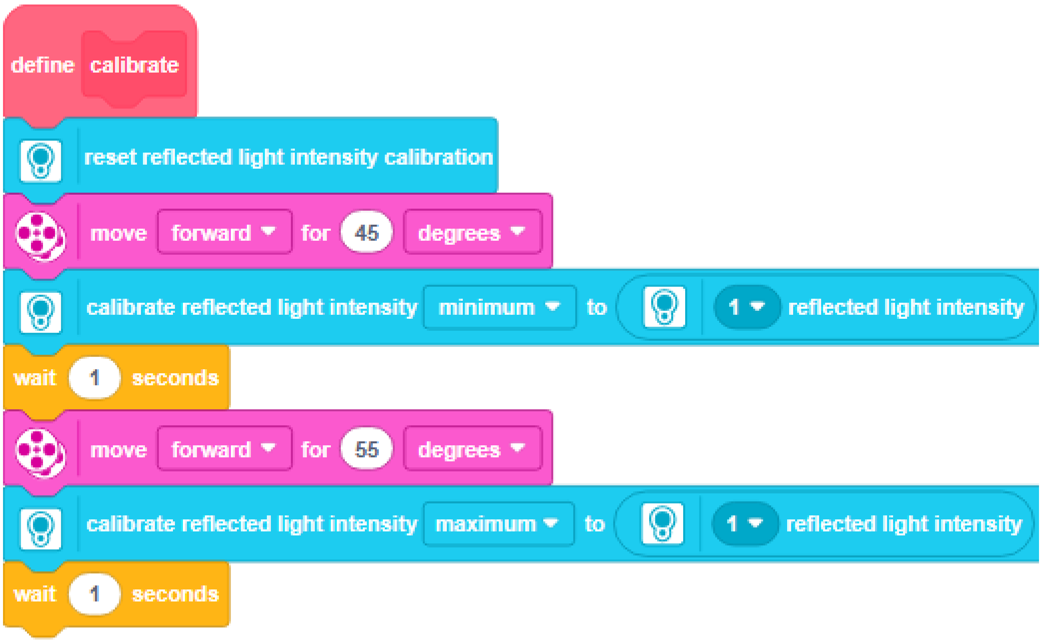
Execute the Mission

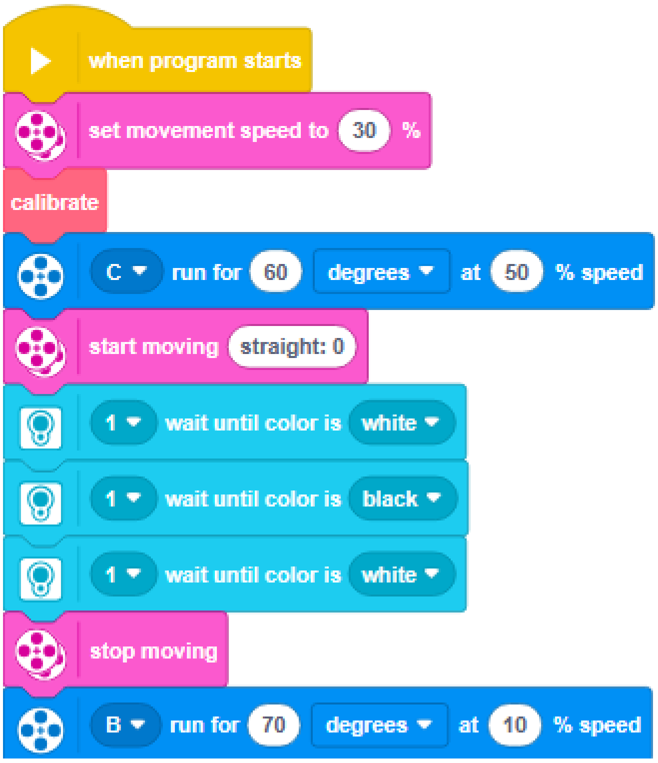
Place the example solution model in starting position “2” on the Challenge Mat and execute the mission. Make sure that the *Crew Module* is positioned as shown in the video.

Mission Troubleshooting

Use the Color Sensor in Color Mode to detect when the robot reaches the lunar base on the Challenge Mat. Use the Color Sensor in Reflected Light Intensity Mode to identify the flight commander. If the Color Sensor doesn't detect changes in color on the Challenge Mat, try calibrating the sensor.

Coding tips





differentiation

Simplify this course by:

- ✧ Working side-by-side with your students to help them figure out how to detect when the robot reaches the lunar base
- ✧ Having your students complete the *Colors and Lines* lesson in the *Robot Trainer* unit before attempting this mission
- ✧ Encouraging peer-to-peer learning and coaching

Take this course to the next level with:

- ✧ Randomly switching the position of the two astronauts and having the students create a program that responds to this variable
- ✧ Limiting the amount of time the students have to solve the mission
- ✧ Challenging the students to use a Color Sensor to solve this mission
- ✧ Adding design constraints by limiting the number of LEGO ® elements available or assigning a “price” to each type of LEGO element and a maximum “cost” per robot

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed
2、 Fully completed
3、 Overachieved

Use the following success criteria to evaluate student progress:

- ✧ Students designed a robot that meets the requirements of the mission.
- ✧ Students came up with creative solutions and considered multiple solutions.
- ✧ Students worked together as a team to complete the mission.

Achievement Badges

Award an achievement badge based on how well the team solved the challenge mission.

- ✧ Bronze: The team picked up another mission specialist instead of the flight commander.
- ✧ Silver: The team managed to pick up the flight commander but didn't make the return trip to the base area.
- ✧ Gold: The team picked up the flight commander and made it back to the base area.
- ✧ Platinum: The team picked up the flight commander and made it back to the base area. The team also went beyond the mission requirements by adding features to their design.

11. Free the MSL Robot

Design, build, and program a robot that can navigate to the crater and free the MSL robot so that all six of its wheels are back on the Martian surface.

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about planetary rovers and how they're used in space exploration.
- ✧ If you feel it's needed, plan a few lessons to go through the *Robot Trainer* unit in the app. This will help familiarize your students with LEGO ® MINDSTORMS ® Education EV3.
- ✧ To complete this lesson, your students will have to have built the eight Space Challenge models and set up the Challenge Mat.
- ✧ If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- ✧ Use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to this mission.
- ✧ Explain the objective, rules, and achievement badges for this mission.
- ✧ Split your class into teams.

3. Explore (25 minutes)

- ✧ Have your students brainstorm ideas for solving this mission.
- ✧ Encourage them to create multiple prototypes, exploring both building and programming.
- ✧ Allow the teams some time to work independently on building and testing their solutions.

4. Explanation (10 minutes)

- ✧ Facilitate a discussion about the key functionalities the robot must have in order to navigate to the crater and free the MSL robot.

5. Detailed explanation (45 minutes)

- ✧ Have each team practice lining up their robot and sending it on the mission to free the MSL robot.
- ✧ Let them continue working on their robots until they're ready for a judged attempt.
- ✧ Don't forget to set aside some time for cleanup.

6. Evaluation

- ✧ Award achievement badges based on how well each team solved the mission.
- ✧ Evaluate the creativity of each team's solution and how well their team worked together.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

The Mars Science Laboratory (MSL) robot is a radioisotope thermoelectric-powered rover that's been exploring the Martian surface since 2012. With various drills, scoops, and other equipment, the robot can study the Martian climate and geology.
Use these questions to engage your students in a discussion about the role of planetary rovers in space exploration:

- ✧ What are planetary rovers?
- ✧ How can they help humans explore space?

Mission Goal

The robot navigates to the crater and frees the MSL robot so that all six of its wheels are back on the Martian surface.
Here's an example mission solution that completes this mission:

Mission Rules

There are five rules that apply to all of the Space Challenge missions. Make sure your students know all of them before they start:

- ✧ Your robot must always start the mission from the base area.
- ✧ Your robot must leave the base area before carrying out the mission.
- ✧ A "successful robot return" occurs when any part of the robot crosses over any part of the base area line.
- ✧ You're not allowed to touch your robot while it's outside of the base area.
- ✧ If you touch your robot while it's completely outside of the base area and it's holding an

object, the object must be returned to its original position and you must begin the mission again.

Mission Achievement Badges

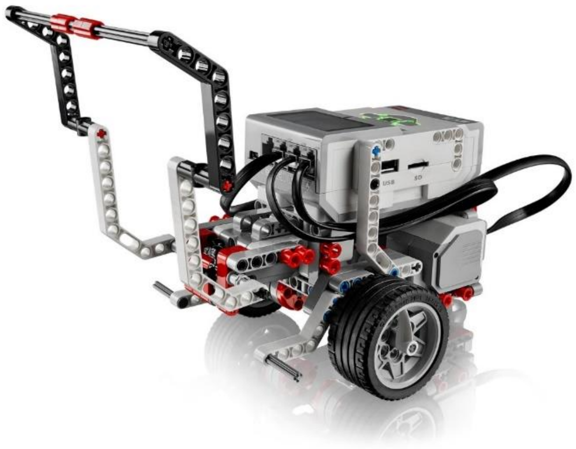
There are four levels of achievement badges. Explain that each team will be awarded an achievement badge based on how well they accomplish the mission. Refer to the *Assessment Opportunities* section below for a description of the achievement badges for this mission.

Building Tips

Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help teams brainstorm ideas for solving this mission:

- ✧ Can you think of some ways the robot could navigate to the crater?
- ✧ Which type of motorized mechanism can be used to free the MSL robot?



Example Mission Solution

The example mission solution is comprised of the following solution extensions:

- ✧ Space Driving Base
- ✧ Transmission Module
- ✧ Collector Module

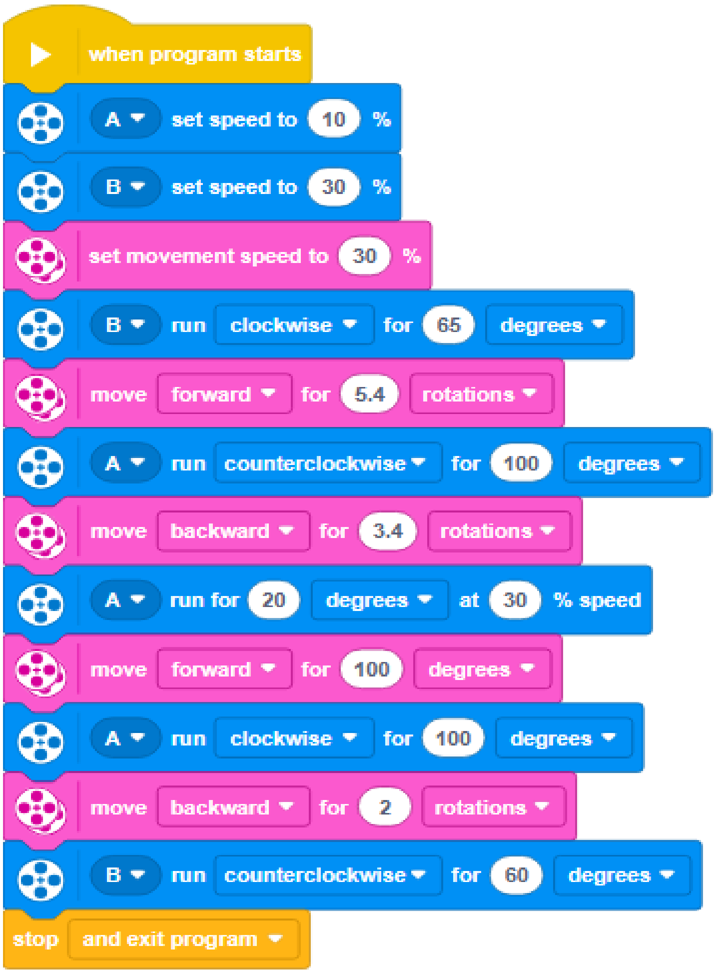
Execute the Mission

Place the example solution model in starting position “1” on the Challenge Mat and execute the mission. Make sure that the *Collector Module* is positioned as shown in the video.

Mission Troubleshooting

If students run into the *Rock Sample* that's in front of the crater, suggest that they complete the *Return the Rock Samples* mission first.

Coding tips



differentiation

Simplify this course by:

- ✧ Removing the *Rock Sample* that's in front of the crater
- ✧ Working side-by-side with your students to help them figure out how to free the MSL robot once their robot is on top of the crater
- ✧ Having your students complete the *Grab and Release* lesson in the *Robot Trainer* unit before attempting this mission
- ✧ Encouraging peer-to-peer learning and coaching

Take this course to the next level with:

- ✧ Limiting the amount of time the students have to solve the mission
- ✧ Adding design constraints by limiting the number of LEGO ® elements available or assigning a “price” to each type of LEGO element and a maximum “cost” per robot

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed
2、 Fully completed
3、 Overachieved

Use the following success criteria to evaluate student progress:

- ✧ Students designed a robot that meets the requirements of the mission.
- ✧ Students came up with creative solutions and considered multiple solutions.
- ✧ Students worked together as a team to complete the mission.

Achievement Badges

Award an achievement badge based on how well the team solved the challenge mission.

- ✧ Bronze: The team didn't remove the robot from the crater but a clear attempt was made.
- ✧ Silver: The team moved the robot from its original position but it's still touching the crater or some of its wheels still aren't touching the Martian surface.
- ✧ Gold: The team rescued the robot from the crater and all six of its wheels are back on the Martian surface.
- ✧ Platinum: The team rescued the robot from the crater and all six of its wheels are back on the Martian surface. The team also went beyond the mission requirements by adding features to their design.

Self-Assessment

Have each student choose the achievement badge that they feel best represents their performance.

- ✧ Bronze: We did the best we could under difficult circumstances.
- ✧ Silver: We had a few accidents along the way but we still battled on to the end of the mission.
- ✧ Gold: We've accomplished the mission with excellent results.
- ✧ Platinum: We've not only completed the mission but also added original and effective features to our design.

12. Launch the Satellite

Design, build, and program a robot that can place the *Satellite* inside the marked area on the Challenge Mat.

lesson plan

1. Prepare

- Read through the student materials in the EV3 Classroom app.
- Collect some information about communication satellites and how they're used in deep space communication.
- If you feel it's needed, plan a few lessons to go through the *Robot Trainer* unit in the app. This will help familiarize your students with LEGO ® MINDSTORMS ® Education EV3.
- To complete this lesson, your students will have to have built the eight Space Challenge models and set up the Challenge Mat.
- If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- Use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to this mission.
- Explain the objective, rules, and achievement badges for this mission.
- Split your class into teams.

3. Explore (25 minutes)

- Have your students brainstorm ideas for solving this mission.
- Encourage them to create multiple prototypes, exploring both building and programming.
- Allow the teams some time to work independently on building and testing their solutions.

4. Explanation (10 minutes)

- Facilitate a discussion about the key functionalities the robot must have in order to navigate to the marked area and place the *Satellite* inside it.

5. Detailed explanation (45 minutes)

- Have each team practice lining up their robot and sending it on the mission to launch the *Satellite* .
- Let them continue working on their robots until they're ready for a judged attempt.
- Don’t forget to set aside some time for cleanup.

6.Evaluation _

- ✧ Award achievement badges based on how well each team solved the mission.
- ✧ Evaluate the creativity of each team's solution and how well their team worked together.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

A communication satellite relays and amplifies radio waves from an Earth-centered orbit to different locations on Earth. Radio waves travel in a straight line, so there needs to be a line-of-sight between the sender and receiver. Satellites in orbit are better Suitable to maintain a line-of-sight with Mars than Earth-based antennae. They're also relatively unaffected by electromagnetic interference or atmospheric disturbances.

Use these questions to engage your students in a discussion about how communication satellites can be used in deep space communication:

What's a communication satellite?

How are satellites used in deep space communication?

Mission Goal

The robot navigates to the marked area and places the satellite inside it.

Here's an example mission solution that completes this mission:

Mission Rules

There are five rules that apply to all of the Space Challenge missions. Make sure your students know all of them before they start:

- ✧ Your robot must always start the mission from the base area.
- ✧ Your robot must leave the base area before carrying out the mission.
- ✧ A “successful robot return” occurs when any part of the robot crosses over any part of the base area line.
- ✧ You're not allowed to touch your robot while it's outside of the base area.
- ✧ If you touch your robot while it's completely outside of the base area and it's holding an object, the object must be returned to its original position and you must begin the mission again.

Mission Achievement Badges

There are four levels of achievement badges. Explain that each team will be awarded an achievement badge based on how well they accomplish the mission. Refer to the *Assessment Opportunities* section below for a description of the achievement badges for this mission.

Building Tips

Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help teams brainstorm ideas for solving this mission:

- ✧ What are some ways the robot could navigate to the marked area?
- ✧ Which type of motorized mechanism can be used to place the *Satellite* carefully and

accurately in the marked area?

Example Mission Solution

The example mission solution is comprised of the following solution extensions:

- Space Driving Base
- Transmission Module
- Satellite Module

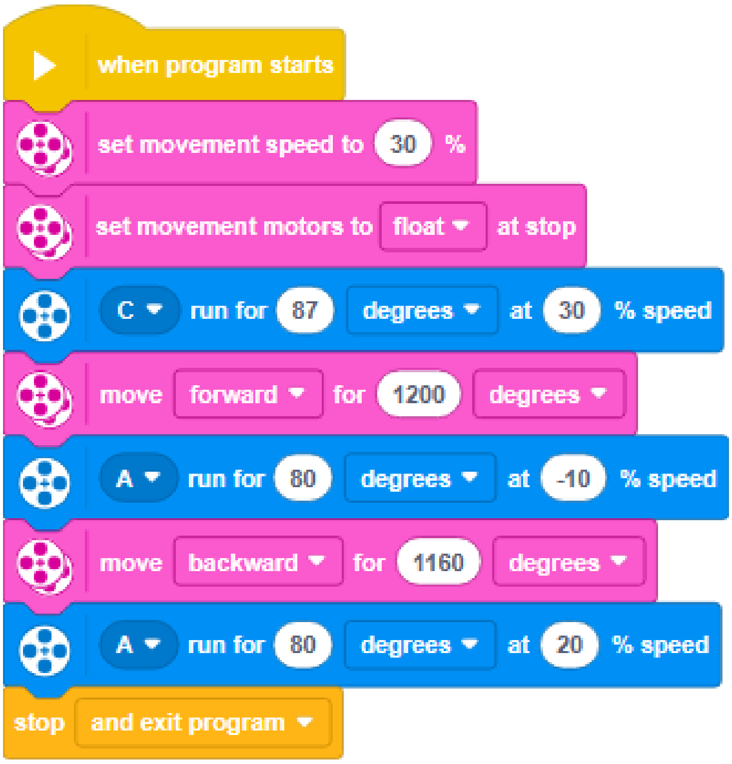
Execute the Mission

Place the example solution model in starting position “2” on the Challenge Mat, place the *Satellite* on the *Satellite Module* , and execute the mission.

Mission Troubleshooting

Rather than using the Color Sensor to find the marked area on the Challenge Mat, measure the angle and distance to navigate a carefully planned trajectory instead.

Coding Tips



Differentiation

Simplify this lesson by:

Working side-by-side with your students to help them figure out how to navigate to the marked area

Having your students complete the *Moves and Turns* lesson in the *Robot Trainer* unit before attempting this mission

Encouraging peer-to-peer learning and coaching

Take this lesson to the next level by:

- ✧ Limiting the amount of time the students have to solve the mission
- ✧ Adding design constraints by limiting the number of LEGO ® elements available or assigning a “price” to each type of LEGO element and a maximum “cost” per robot

Assessment Opportunities

Teacher Observation Checklist

Create a scale that matches your needs, for example:

- ✧ Partially accomplished
- ✧ Fully accomplished
- ✧ Overachieved

Use the following success criteria to evaluate your students' progress:

- ✧ Students designed a robot that meets the requirements of the mission.
- ✧ Students came up with creative solutions and considered multiple solutions.
- ✧ Students worked together as a team to complete the mission.

Achievement Badges

Award an achievement badge based on how well the team solved the challenge mission.

- ✧ Bronze: No part of the *Satellite* rests inside the marked area.
- ✧ Silver: Parts of the *Satellite* rest outside the marked area.
- ✧ Gold: Every part of the *Satellite* rests inside the marked area.
- ✧ Platinum: Every part of the *Satellite* rests inside the marked area. The team also went beyond the mission requirements by adding features to their design.

Self-Assessment

Have each student choose the achievement badge that they feel best represents their performance.

- ✧ Bronze: We did the best we could under difficult circumstances.
- ✧ Silver: We had a few accidents along the way but we still battled on to the end of the mission.
- ✧ Gold: We've accomplished the mission with excellent results.
- ✧ Platinum: We've not only completed the mission but also added original and effective features to our design.

13. Return the Rock Samples

Design, build, and program a robot that can navigate to the *Rock Samples* , collect them, and return them to the base area.

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about Martian rocks and what scientists have learned from studying them.
- ✧ If you feel it's needed, plan a few lessons to go through the *Robot Trainer* unit in the app. This will help familiarize your students with LEGO ® MINDSTORMS ® Education EV3.
- ✧ To complete this lesson, your students will have to have built the eight Space Challenge models and set up the Challenge Mat.
- ✧ If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- ✧ Use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to this mission.
- ✧ Explain the objective, rules, and achievement badges for this mission.
- ✧ Split your class into teams.

3. Explore (25 minutes)

- ✧ Have your students brainstorm ideas for solving this mission.
- ✧ Encourage them to create multiple prototypes, exploring both building and programming.
- ✧ Allow the teams some time to work independently on building and testing their solutions.

4. Explanation (10 minutes)

- ✧ Facilitate a discussion about the key functionalities the robot must have in order to collect the *Rock Samples* and return them to the base area.

5. Detailed explanation (45 minutes)

- ✧ Have each team practice lining up their robot and sending it on the mission to return the *Rock Samples* .
- ✧ Let them continue working on their robots until they're ready for a judged attempt.
- ✧ Don’t forget to set aside some time for cleanup.

6. Evaluation

- ✧ Award achievement badges based on how well each team solved the mission.
- ✧ Evaluate the creativity of each team's solution and how well their team worked together.
- ✧ You can use the provided rubrics to streamline the process.

Ignite a Discussion

Studying the composition of rocks from the Martian surface can help scientists understand the history and evolution of its surface. Organic molecules containing carbon and hydrogen are of particular interest because they're associated with biological processes and potential indicators of life.

Use these questions to engage your students in a discussion about what we could learn from studying Martian rocks:

- ✧ What are *Martian rocks* ?
- ✧ What could we learn from investigating them?

Mission Goal

The robot collects the *Rock Samples* and returns all three of them to the base area.

Here's an example mission solution that completes this mission:

Mission Rules

There are five rules that apply to all of the Space Challenge missions. Make sure your students know all of them before they start:

- ✧ Your robot must always start the mission from the base area.
- ✧ Your robot must leave the base area before carrying out the mission.
- ✧ A "successful robot return" occurs when any part of the robot crosses over any part of the base area line.
- ✧ You're not allowed to touch your robot while it's outside of the base area.
- ✧ If you touch your robot while it's completely outside of the base area and it's holding an object, the object must be returned to its original position and you must begin the mission again.

Mission Achievement Badges

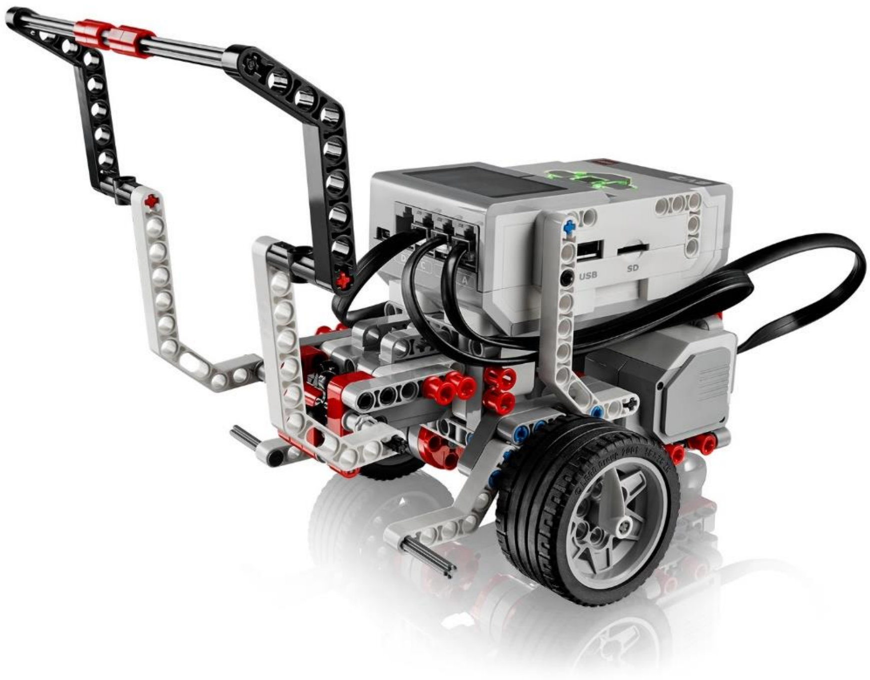
There are four levels of achievement badges. Explain that each team will be awarded an achievement badge based on how well they accomplish the mission. Refer to the *Assessment Opportunities* section below for a description of the achievement badges for this mission.

Building Tips

Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help teams brainstorm ideas for solving this mission:

- ✧ What are some ways the robot could navigate to the three *Rock Samples* ?
- ✧ Which type of motorized mechanism can be used to collect the *Rock Samples* carefully and securely?



Example Mission Solution

The example mission solution is comprised of the following solution extensions:

✧ Space Driving Base
✧ Transmission Module
✧ Collector Module

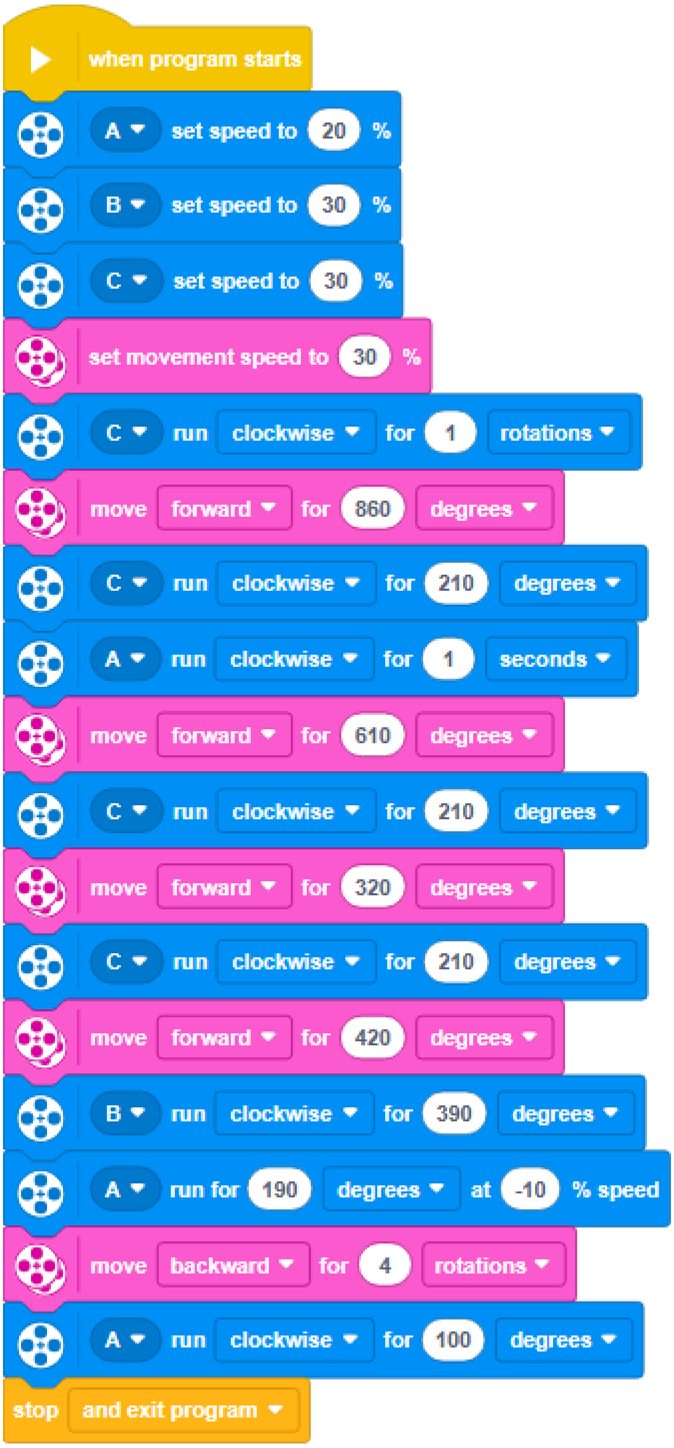
Execute the Mission

Place the *Rock Samples* in their initial positions, place the example solution model in starting position "2" on the Challenge Mat, and execute the mission. Make sure that the *Collector Module* is positioned as shown in the video.

Mission Troubleshooting

Suggest that the students build a module that's big enough to collect all three *Rock Samples* in one run.

Coding tips



differentiation

Simplify this course by:

✧ Working side-by-side with your students to help them figure out how to navigate a carefully planned trajectory to collect the *Rock Samples*

- ✧ Having your students complete the *Grab and Release* lesson in the *Robot Trainer* unit before attempting this mission
- ✧ Encouraging peer-to-peer learning and coaching

Take this course to the next level with:

- ✧ Randomly switching the position of the *Rock Samples* and having the students create a program that only returns the rocks marked with red
- ✧ Limiting the amount of time the students have to solve the mission
- ✧ Adding design constraints by limiting the number of LEGO ® elements available or assigning a "price" to each type of LEGO element and a maximum "cost" per robot

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed
2、 Fully completed
3、 Overachieved

Use the following success criteria to evaluate student progress:

- ✧ Students designed a robot that meets the requirements of the mission.
- ✧ Students came up with creative solutions and considered multiple solutions.
- ✧ Students worked together as a team to complete the mission.

Achievement Badges

Award an achievement badge based on how well the team solved the challenge mission.

- ✧ Bronze: Only one of the *Rock Samples* was delivered to the base area.
- ✧ Silver: Two or more *Rock Samples* were returned to the base area in any number of runs.
- ✧ Gold: The team managed to get all of the *Rock Samples* in one run and return them to the base area.
- ✧ Platinum: The team managed to get all of the *Rock Samples* in one run and return them to the base area. They also went beyond the mission requirements by adding features to their design.

Self-Assessment

Have each student choose the achievement badge that they feel best represents their performance.

- ✧ Bronze: We did the best we could under difficult circumstances.
- ✧ Silver: We had a few accidents along the way but we still battled on to the end of the mission.
- ✧ Gold: We've accomplished the mission with excellent results.
- ✧ Platinum: We've not only completed the mission but also added original and effective features to our design.

14. Secure the Power Supply

Design, build, and program a robot that can navigate to the *Solar Panel* and rotate the handle to unfold it.

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about solar power and how it's used in space.
- ✧ If you feel it's needed, plan a few lessons to go through the *Robot Trainer* unit in the app. This will help familiarize your students with LEGO ® MINDSTORMS ® Education EV3.
- ✧ To complete this lesson, your students will have to have built the eight Space Challenge models and set up the Challenge Mat.
- ✧ If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- ✧ Use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to this mission.
- ✧ Explain the objective, rules, and achievement badges for this mission.
- ✧ Split your class into teams.

3. Explore (25 minutes)

- ✧ Have your students brainstorm ideas for solving this mission.
- ✧ Encourage them to create multiple prototypes, exploring both building and programming.
- ✧ Allow the teams some time to work independently on building and testing their solutions.

4. Explanation (10 minutes)

Facilitate a discussion about the key functionalities the robot must have in order to navigate to the *Solar Panel* and rotate the handle.

5. Detailed explanation (45 minutes)

- ✧ Have each team practice lining up their robot and sending it on the mission to unfold the *Solar Panel* .
- ✧ Let them continue working on their robots until they're ready for a judged attempt.
- ✧ Don't forget to set aside some time for cleanup.

6. Evaluation

- ✧ Award achievement badges based on how well each team solved the mission.
- ✧ Evaluate the creativity of each team's solution and how well their team worked together.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

Solar arrays consist of multiple solar panels and are useful as a power supply for space exploration. The amount of sunlight on a planet decreases as the distance to the Sun increases. This means that Mars receives less than half the amount of sunlight that we have on Earth. However, with a big enough solar array, plenty of power can be generated!
Use these questions to engage your students in a discussion about the advantages and disadvantages of solar power in space:

- ✧ What's a *solar array* ?
- ✧ What are the strengths and weaknesses of using solar arrays as a power supply for the *Mars Outpost* ?

Mission Goal

The robot navigates to the *Solar Panel* and rotates the handle until it's fully unfolded and stays in an upright position.
Here's an example mission solution that completes this mission:

Mission Rules

There are five rules that apply to all of the Space Challenge missions. Make sure your students know all of them before they start:

- ✧ Your robot must always start the mission from the base area.
- ✧ Your robot must leave the base area before carrying out the mission.
- ✧ A "successful robot return" occurs when any part of the robot crosses over any part of the base area line.

- ✧ You're not allowed to touch your robot while it's outside of the base area.
- ✧ If you touch your robot while it's completely outside of the base area and it's holding an object, the object must be returned to its original position and you must begin the mission again.

Mission Achievement Badges

There are four levels of achievement badges. Explain that each team will be awarded an achievement badge based on how well they accomplish the mission. Refer to the *Assessment Opportunities* section below for a description of the achievement badges for this mission.

Building Tips

Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help teams brainstorm ideas for solving this mission:

- ✧ What are some ways the robot could navigate to the *Solar Panel* ?
- ✧ Which type of motorized mechanism can be used to rotate the handle?

Example Mission Solution

The example mission solution is comprised of the following solution extensions:

- ✧ Space Driving Base
- ✧ Solar Module
- ✧ Color Sensor Down

Execute the Mission

Reset the *Solar Panel* , place the example solution model in starting position “1” on the Challenge Mat, and execute the mission.

Mission Troubleshooting

Use the Color Sensor in Color Mode to detect the green line on the Challenge Mat. Use the Color Sensor in Reflected Light Intensity Mode to line up the robot using the gradient. For consistent results, start by calibrating the Color Sensor using the black and white lines that are just outside the base area.

Coding tips


define calibrate
reset reflected light intensity calibration
move forward for 45 degrees
calibrate reflected light intensity minimum to 3 reflected light intensity
wait 1 seconds
move forward for 55 degrees
calibrate reflected light intensity maximum to 3 reflected light intensity
wait 1 seconds
when program starts
set movement speed to 30 %
calibrate
start moving straight: 0
wait until 3 is reflected light intensity < 50 %?
stop moving
wait 1 seconds
B run for 200 degrees at 30 % speed
set movement speed to 20 %
start moving straight: 0
3 wait until color is green
move forward for 30 degrees
C run for 3 reflected light intensity - 65 * 1.8 degrees at 20 % speed
A start motor at 100 % speed
set movement motors to float at stop
move forward for 432 degrees
wait 3 seconds
A stop motor
move right: 5 for 4 rotations at -30 % speed
reset reflected light intensity calibration
stop and exit program

differentiation

Simplify this course by:

Working side-by-side with your students to help them figure out how to rotate the *Solar Panel* handle

Having your students complete the *Colors and Lines* lesson in the *Robot Trainer* unit before attempting this mission

Encouraging peer-to-peer learning and coaching

Take this course to the next level with:

- Limiting the amount of time the students have to solve the mission
- Challenging the students to use a Color Sensor to solve this mission
- Adding design constraints by limiting the number of LEGO ® elements available or assigning a “price” to each type of LEGO element and a maximum “cost” per robot

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed

2、 Fully completed

3、 Overachieved

Use the following success criteria to evaluate student progress:

Students designed a robot that meets the requirements of the mission.

Students came up with creative solutions and considered multiple solutions.

Students worked together as a team to complete the mission.

Achievement Badges

Award an achievement badge based on how well the team solved the challenge mission.

- Bronze: The team hasn't managed to successfully unfold the *Solar Panel* .
- Silver: The team has managed to unfold the *Solar Panel* but it doesn't stay upright.
- Gold: The team has unfolded the *Solar Panel* and it stays in an upright position.
- Platinum: The team has unfolded the *Solar Panel* and it stays in an upright position. They also went beyond the mission requirements by adding features to their design.

Self-Assessment

Have each student choose the achievement badge that they feel best represents their performance.

- Bronze: We did the best we could under difficult circumstances.
- Silver: We had a few accidents along the way but we still battled on to the end of the mission.
- Gold: We've accomplished the mission with excellent results.
- Platinum: We've not only completed the mission but also added original and effective features to our design.

15. Initiate Launch

Design, build, and program a robot that can navigate to the launch site and press the launch button to launch the *Rocket* and activate the *Mars Outpost* .

lesson plan

1. Prepare

- ✧ Read through the student materials in the EV3 Classroom app.
- ✧ Collect some information about rockets and how they're launched into outer space.
- ✧ If you feel it's needed, plan a few lessons to go through the *Robot Trainer* unit in the app. This will help familiarize your students with LEGO ® MINDSTORMS ® Education EV3.
- ✧ To complete this lesson, your students will have to have built the eight Space Challenge models and set up the Challenge Mat.
- ✧ If you don't have double-block class time, plan to run this lesson over multiple sessions.

2. Participate (10 minutes)

- ✧ Use the ideas in the *Ignite a Discussion* section below to engage your students in a discussion related to this mission.
- ✧ Explain the objective, rules, and achievement badges for this mission.
- ✧ Split your class into teams.

3. Explore (25 minutes)

- ✧ Have your students brainstorm ideas for solving this mission.
- ✧ Encourage them to create multiple prototypes, exploring both building and programming.
- ✧ Allow the teams some time to work independently on building and testing their solutions.

4. Explanation (10 minutes)

- ✧ Facilitate a discussion about the key functionalities the robot must have in order to navigate to the launch site and press the launch button.

5. Detailed explanation (45 minutes)

- ✧ Have each team practice lining up their robot and sending it on the mission to launch the *Rocket* to the *Mars Outpost* .
- ✧ Let them continue working on their robots until they're ready for a judged attempt.
- ✧ Don’t forget to set aside some time for cleanup.

6. Evaluation

- ✧ Award achievement badges based on how well each team solved the mission.
- ✧ Evaluate the creativity of each team's solution and how well their team worked together.
- ✧ You can use the provided rubrics to streamline the process.

spark discussion

The distance between Earth and Mars varies greatly, and they're closest to each other about every 2 years. They're about 55 million km apart at their closest, which provides a convenient launch opportunity. A rocket going to Mars first has to reach an escape velocity of over 11 km/s to escape Earth's gravity and then embark on the journey to Mars, which takes approximately 150 to 300 days.

Use these questions to engage your students in a discussion about how rockets are launched into outer space:

- ✧ What are *space rockets* ?
- ✧ How are they launched?

Mission Goal

The robot navigates to the launch site and presses the launch button. The *Rocket* launches and when it reaches the *Mars Outpost* , it activates it.

Here's an example mission solution that completes this mission:

Mission Rules

There are five rules that apply to all of the Space Challenge missions. Make sure your students know all of them before they start:

- ✧ Your robot must always start the mission from the base area.
- ✧ Your robot must leave the base area before carrying out the mission.

- ✧ A "successful robot return" occurs when any part of the robot crosses over any part of the base area line.
- ✧ You're not allowed to touch your robot while it's outside of the base area.
- ✧ If you touch your robot while it's completely outside of the base area and it's holding an object, the object must be returned to its original position and you must begin the mission again.

Mission Achievement Badges

There are four levels of achievement badges. Explain that each team will be awarded an achievement badge based on how well they accomplish the mission. Refer to the *Assessment Opportunities* section below for a description of the achievement badges for this mission.

Building Tips

Open-Ended Solutions

This project is designed so that every team can have a unique solution. Use these questions to help teams brainstorm ideas for solving this mission:

- ✧ What are some ways the robot could navigate to the launch site?
- ✧ Which type of motorized mechanism can be used to press the launch button?

Example Mission Solution

The example mission solution is comprised of the following solution extensions:

- ✧ Space Driving Base
- ✧ Launcher Module
- ✧ Color Sensor Down

Execute the Mission

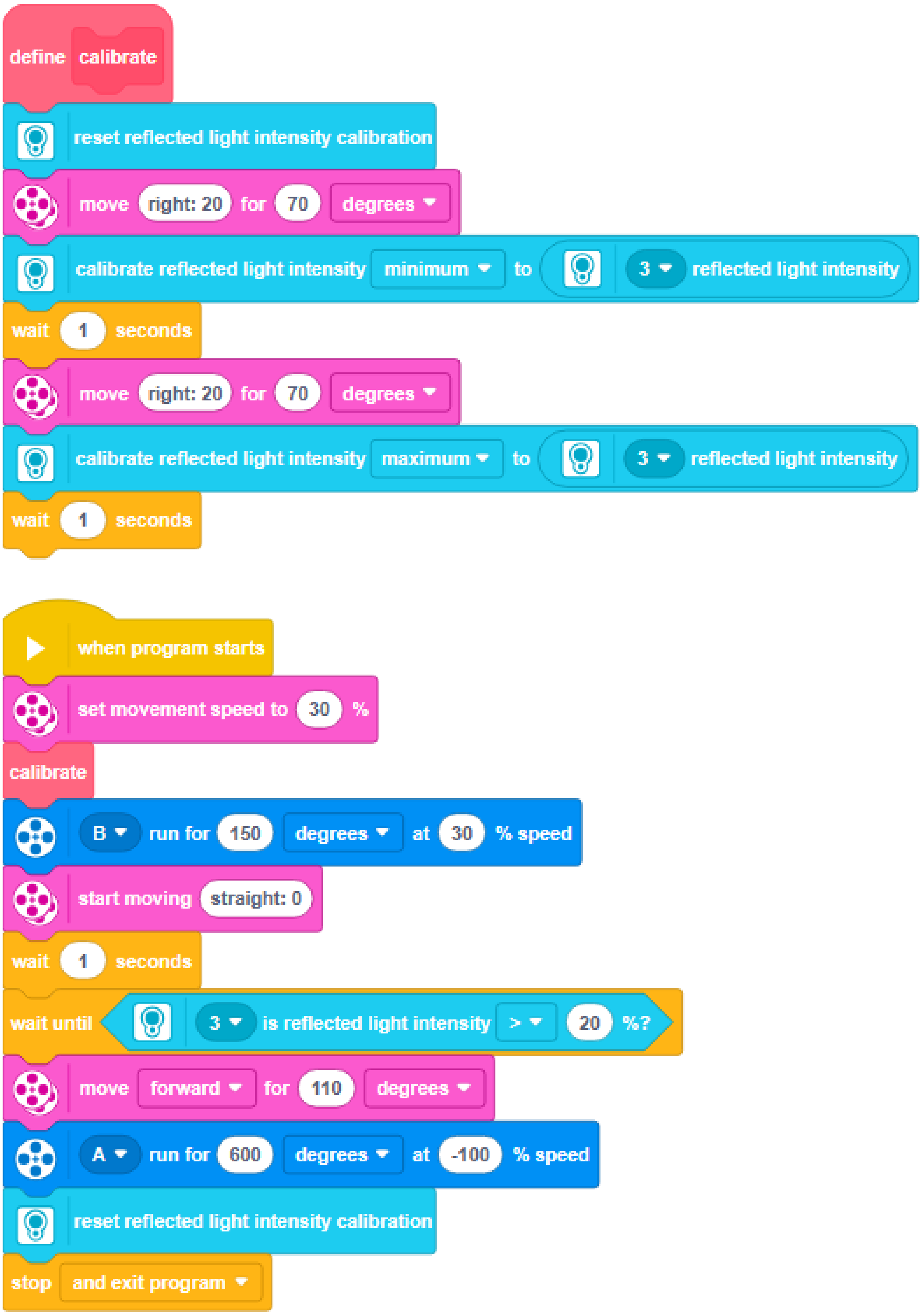
Reset the *Rocket* , *Launcher* , and *Mars Outpost* . Place the example solution model in starting position "2" on the Challenge Mat and execute the mission. Make sure that the *Launcher Module* is positioned as shown in the video.

Mission Troubleshooting

Use the Color Sensor in Reflected Light Intensity Mode to detect the "Earth" on the Challenge

Mat. For consistent results, start by calibrating the Color Sensor using the black and white lines that are just outside the base area.

Coding tips



differentiation

Simplify this course by:

Working side-by-side with your students to help them figure out how to hit the *Launcher* with enough force to launch the *Rocket* once their robot is in position

- Having your students complete the *Colors and Lines* lesson in the *Robot Trainer* unit before attempting this mission
- Encouraging peer-to-peer learning and coaching

Take this course to the next level with:

- Limiting the amount of time the students have to solve the mission
- Challenging the students to use a Color Sensor to solve this mission

Adding design constraints by limiting the number of LEGO ® elements available or assigning a “price” to each type of LEGO element and a maximum “cost” per robot

Evaluate opportunities

Teacher Observation Checklist

Create a scale that fits your needs, such as:

1、 partially completed

2、 Fully completed

3、 Overachieved

Use the following success criteria to evaluate student progress:

Students designed a robot that meets the requirements of the mission.

Students came up with creative solutions and considered multiple solutions.

Students worked together as a team to complete the mission.

Achievement Badges

Award an achievement badge based on how well the team solved the challenge mission.

✧ Bronze: The team launched the *Rocket* as planned but no part of it reached Mars.

✧ Silver: The team launched the *Rocket* and it reached Mars but they didn't succeed in activating the outpost.

✧ Gold: The team launched the *Rocket* and the outpost is activated.

✧ Platinum: The team launched the *Rocket* and the outpost is activated. They also went beyond the mission requirements by adding features to their design.

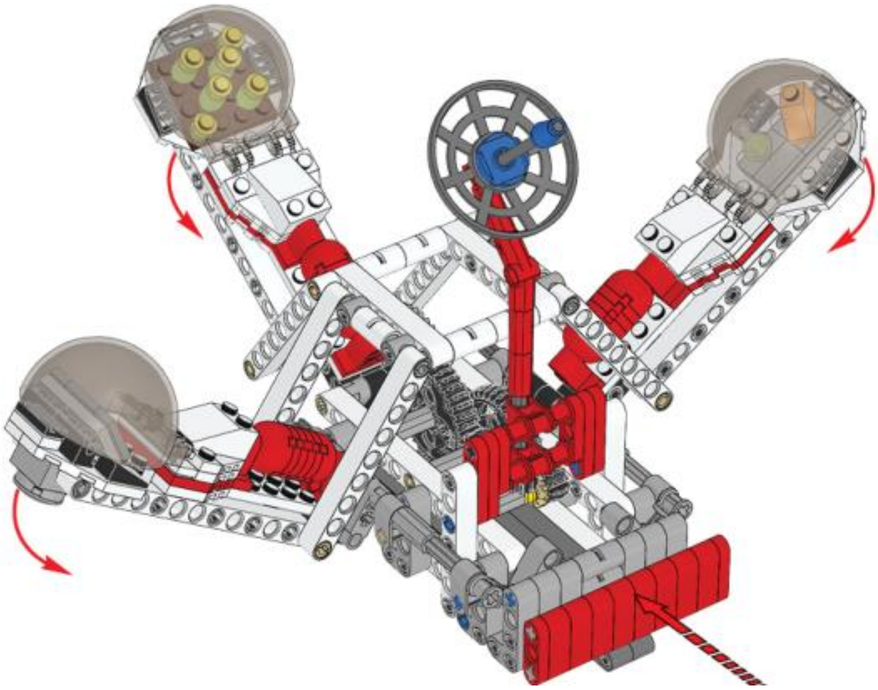
Self-Assessment

Have each student choose the achievement badge that they feel best represents their performance.

✧ Bronze: We did the best we could under difficult circumstances.

✧ Silver: We had a few accidents along the way but we still battled on to the end of the mission.

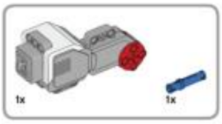
- ✧ Gold: We've accomplished the mission with excellent results.
- ✧ Platinum: We've not only completed the mission but also added original and effective features to our design.



Construction steps and Programming instructions

This section provides a detailed description of each step and method of building each module, including basic driver construction, gyroscope construction, color driver construction, and includes programming instructions to assist students in understanding the construction methods and programming skills

1. Drive base Building instructions



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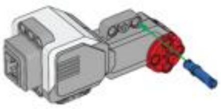

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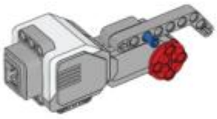

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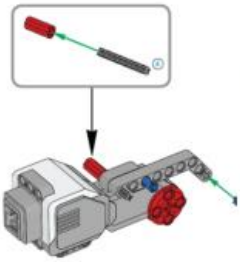

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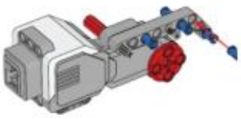

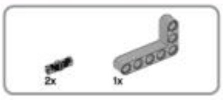

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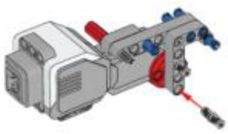

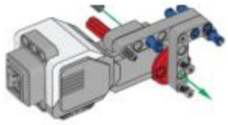

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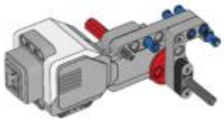

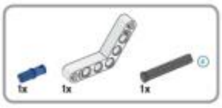

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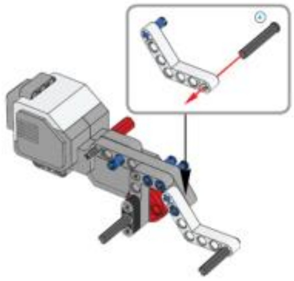

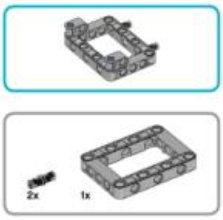

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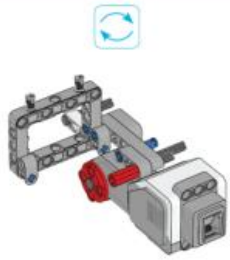

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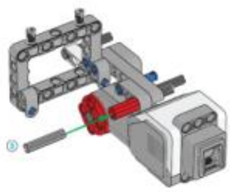

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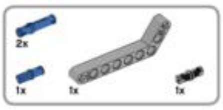

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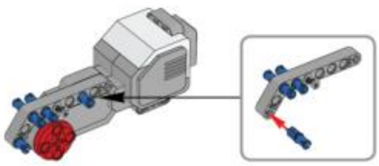

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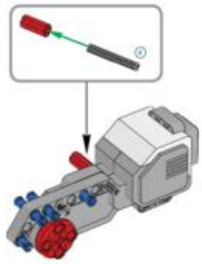

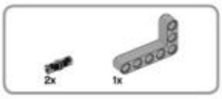

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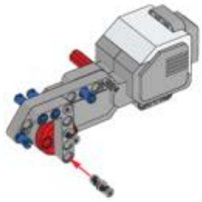

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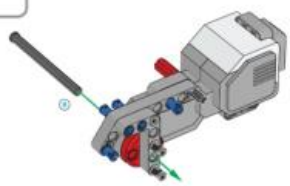

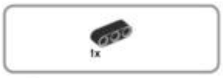

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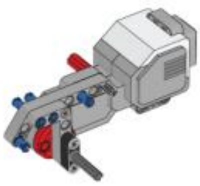

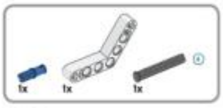

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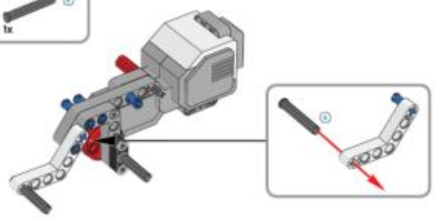

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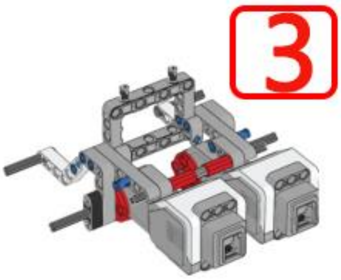

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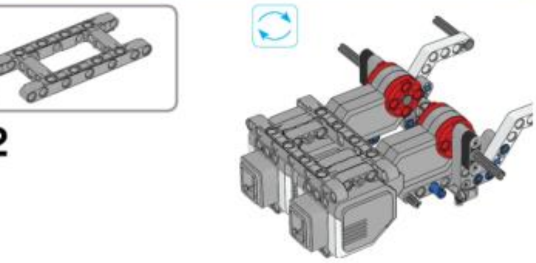

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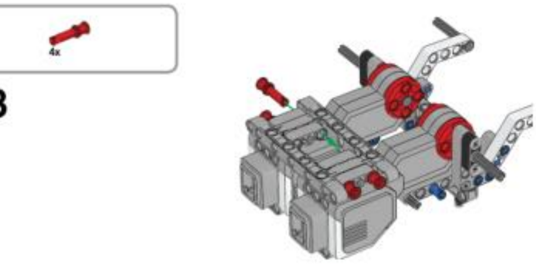

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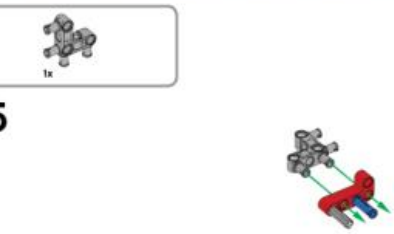

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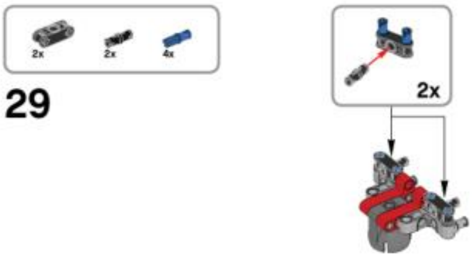

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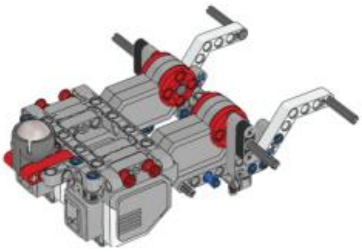

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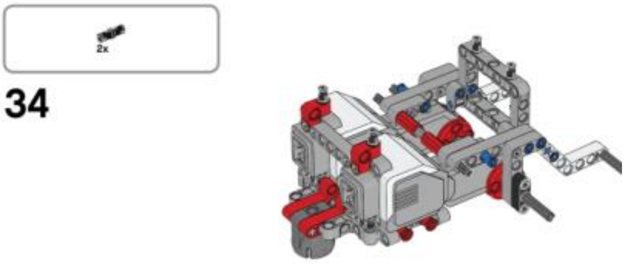

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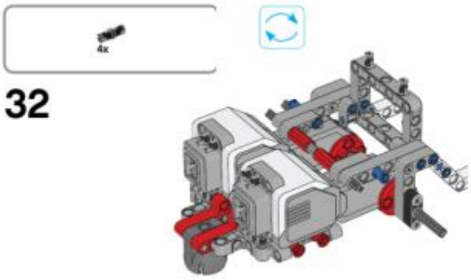

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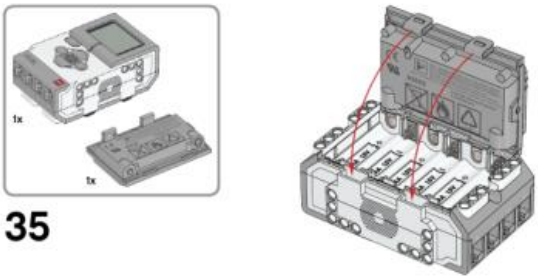

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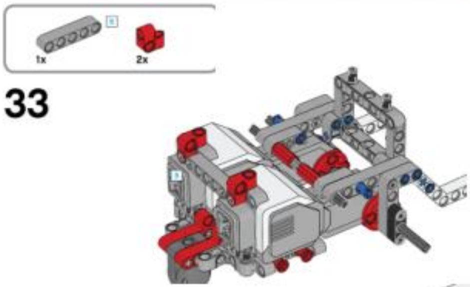

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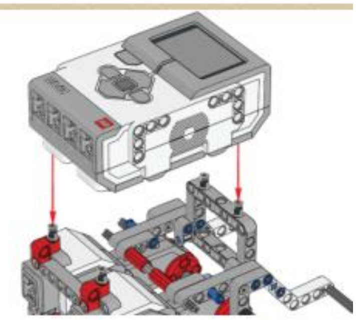

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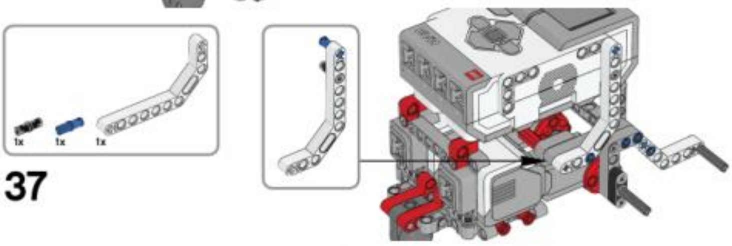

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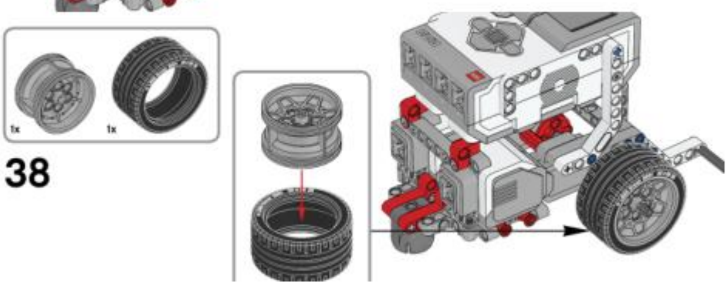

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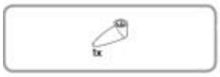

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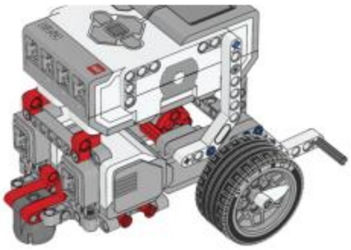

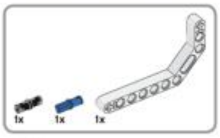

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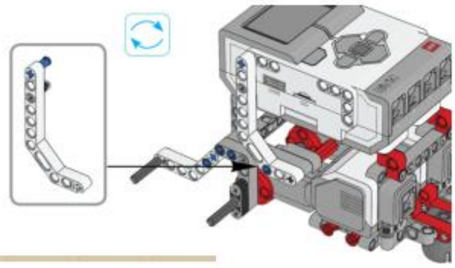

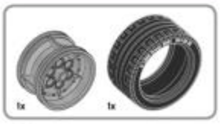

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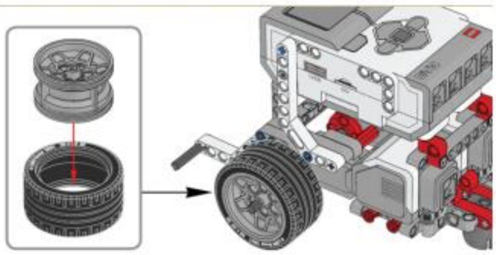

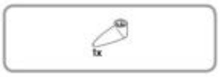

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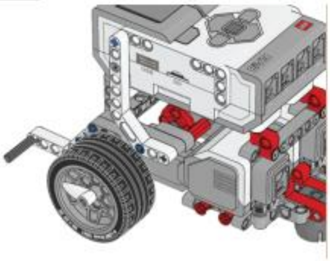

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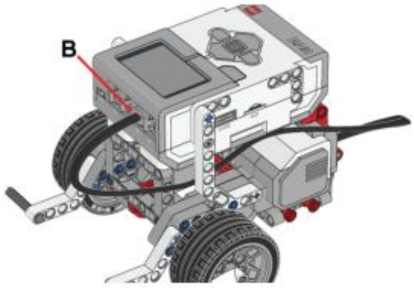

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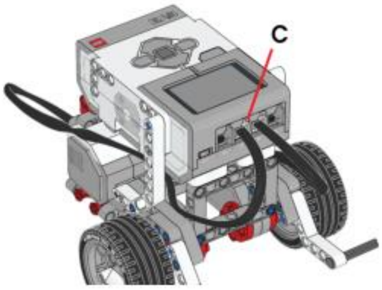

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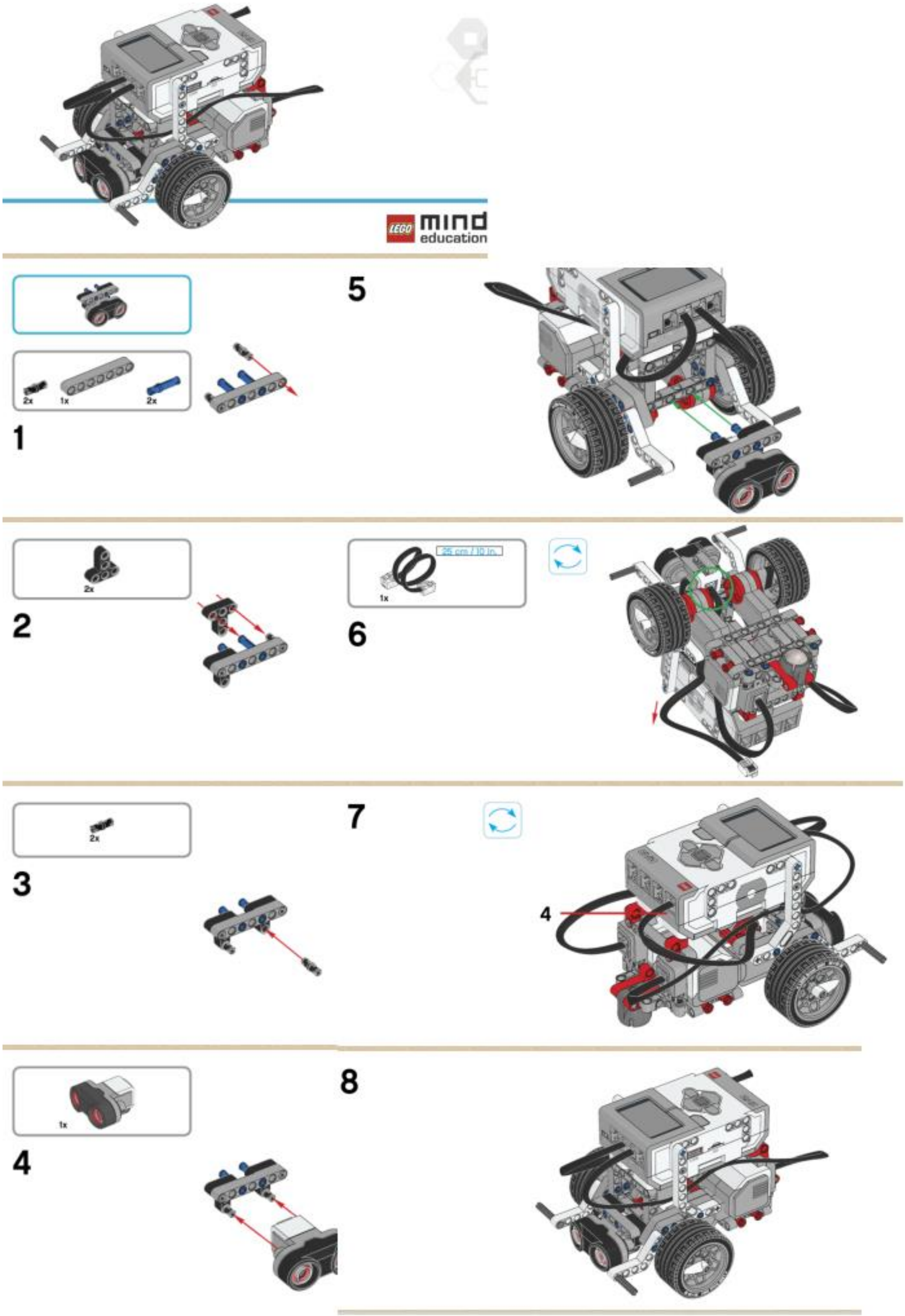
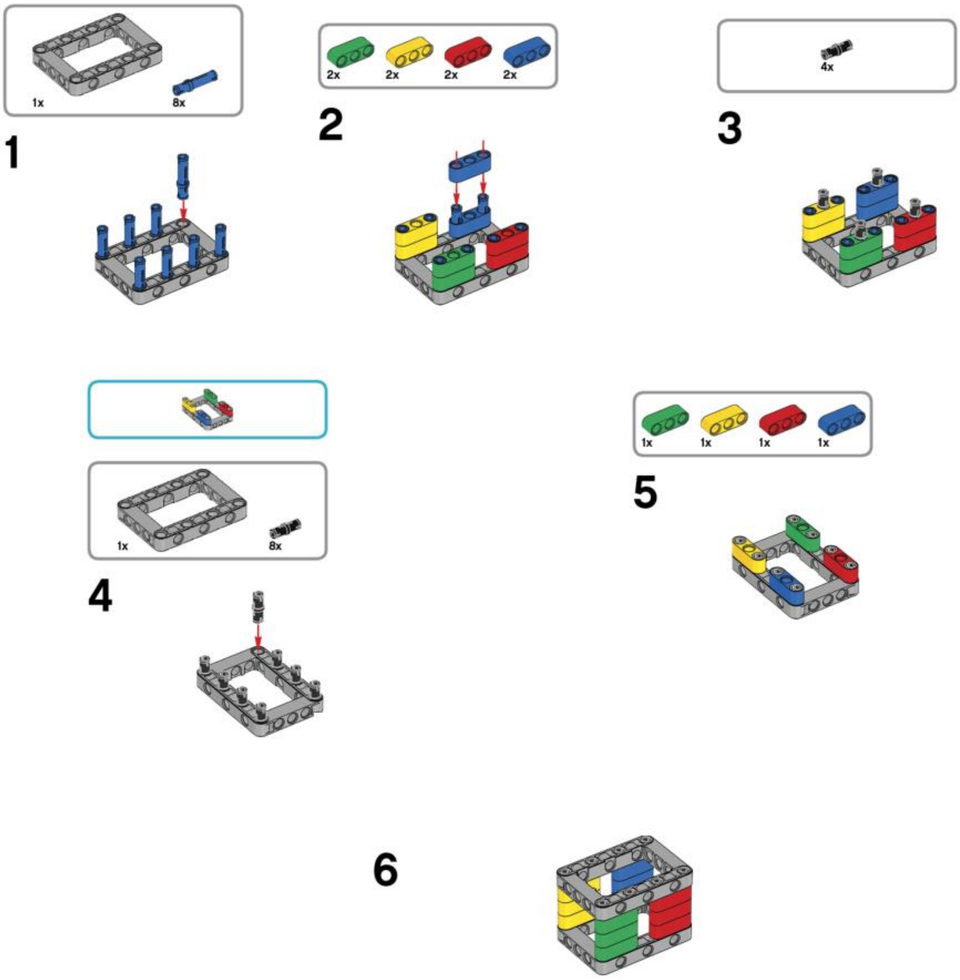
2. ltrasonic Sensor – Driving Base



3. Cuboid

Кубовидный



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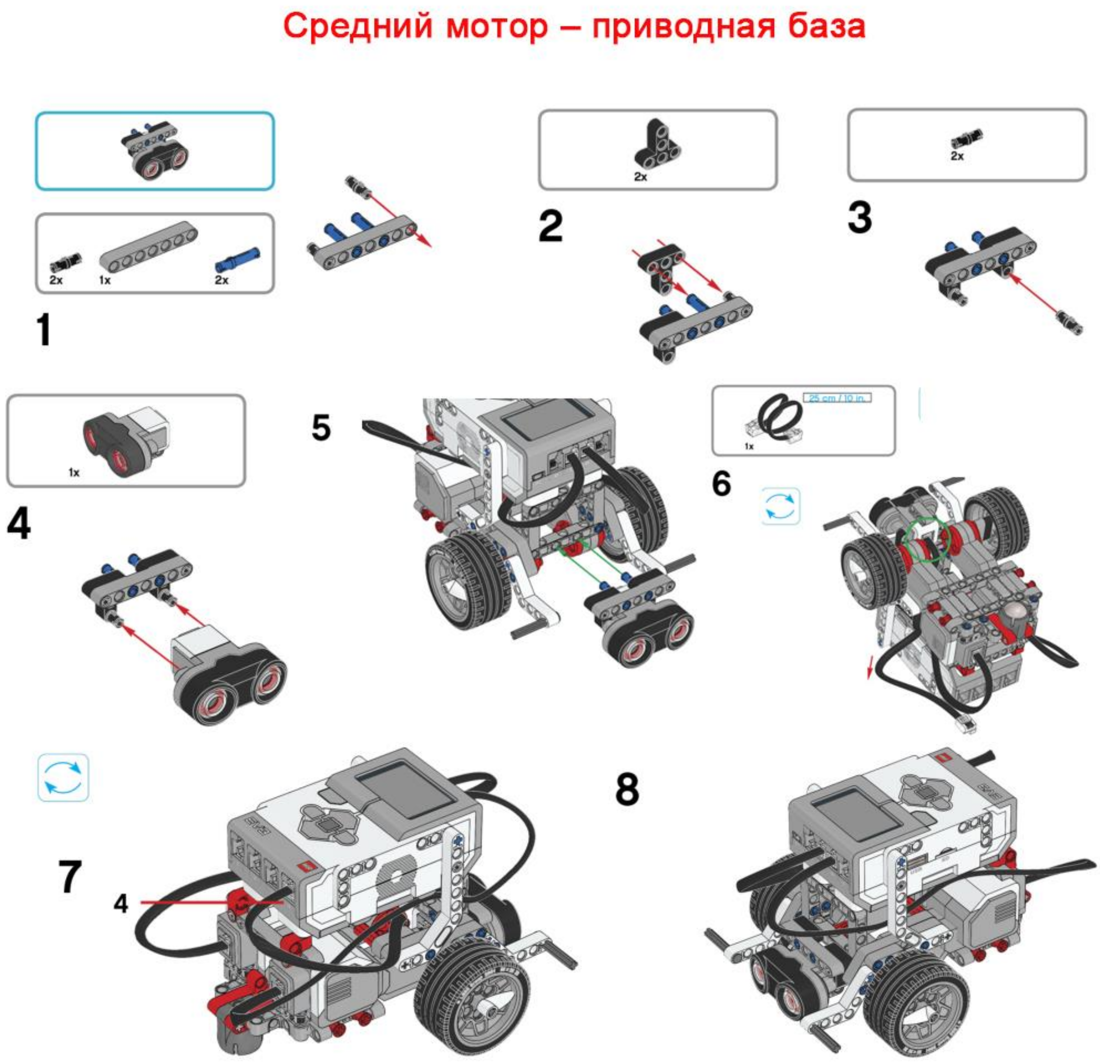
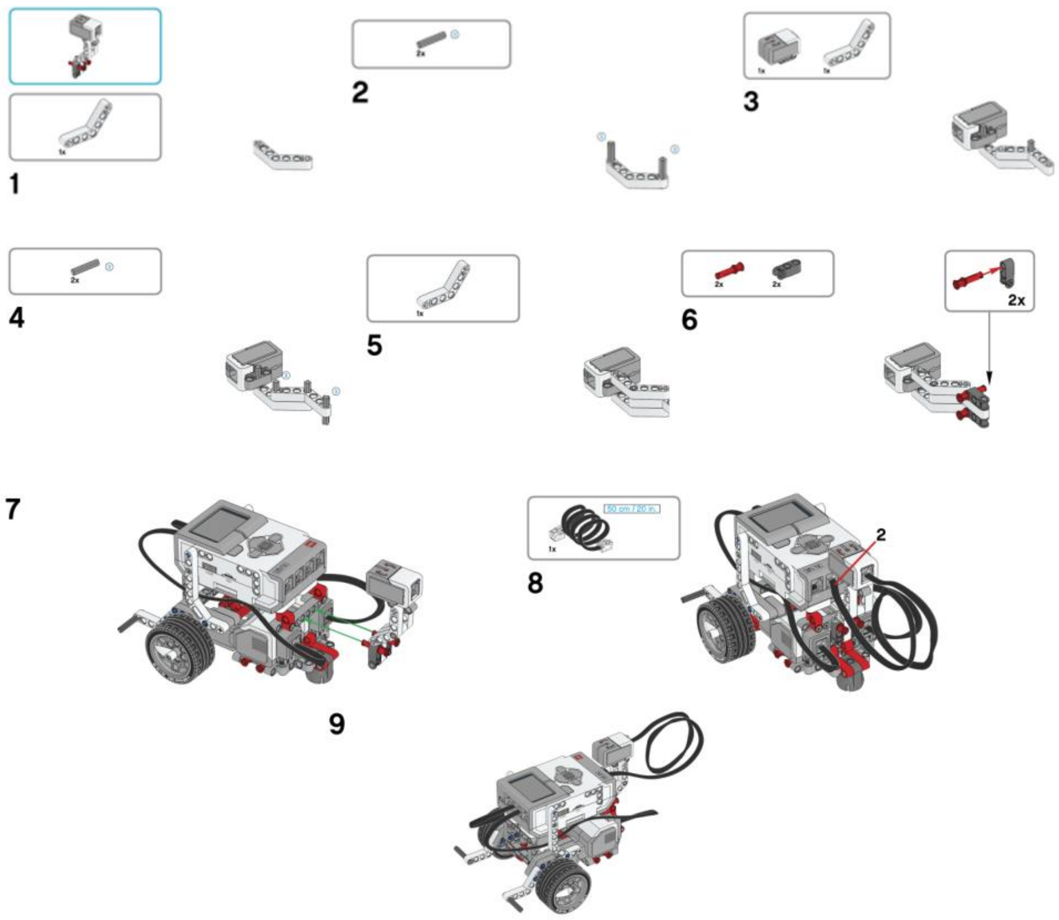


5. Color driven construction

6. Gyroscope construction steps

Gyro Sensor – Driving Base



7. Transmission module construction

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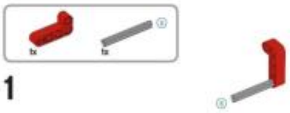

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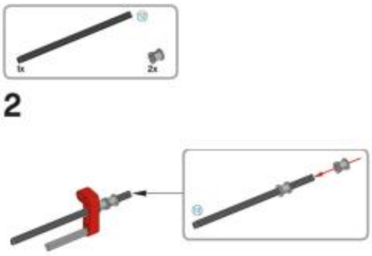

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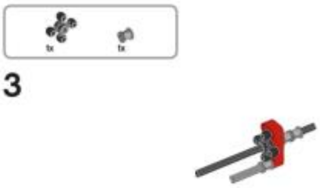

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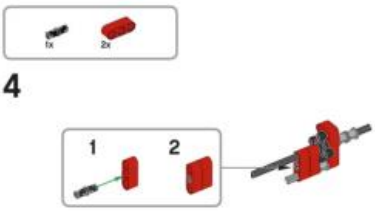

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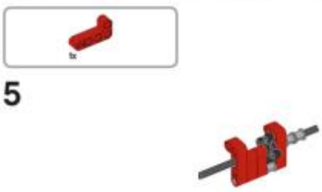

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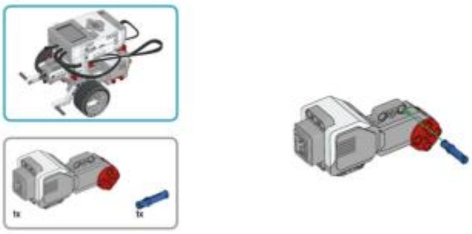
8. Space drive construction



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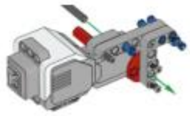

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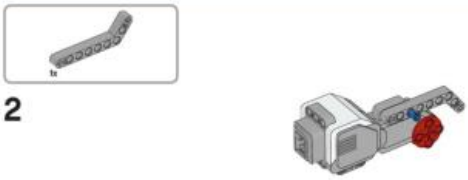

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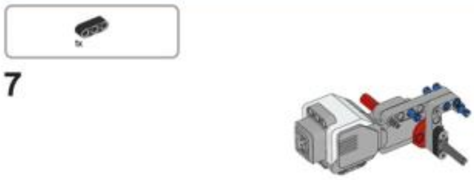

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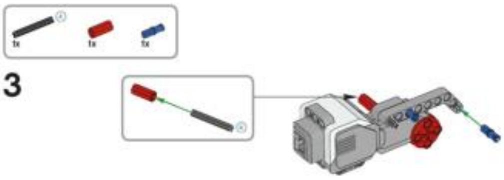

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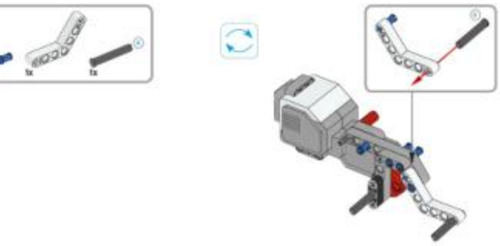

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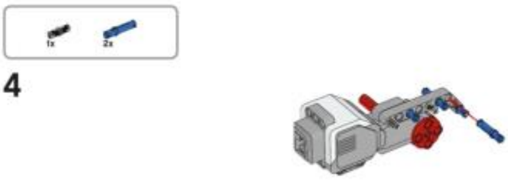

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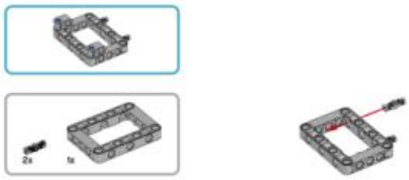

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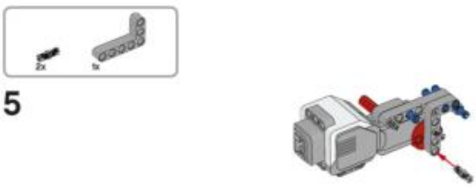

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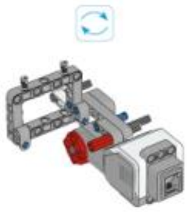

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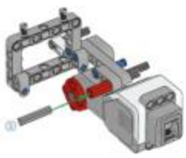

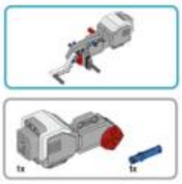

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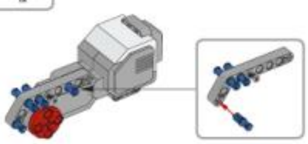

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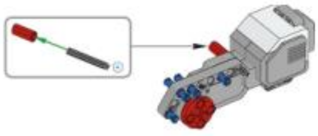

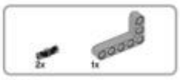

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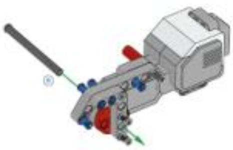

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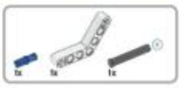

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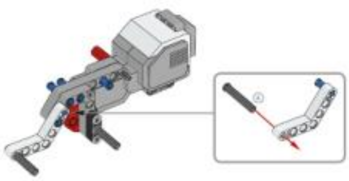

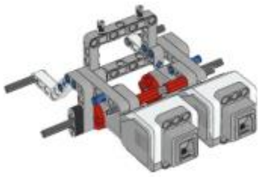

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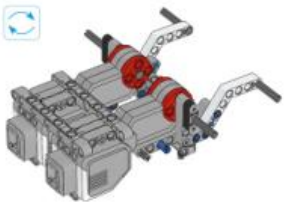

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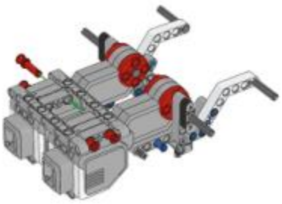

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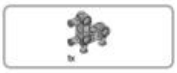

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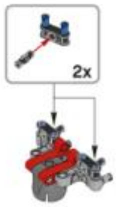

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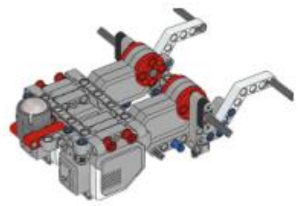

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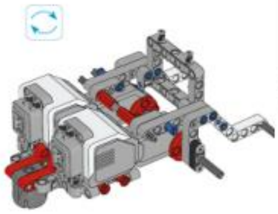

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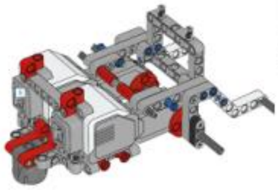

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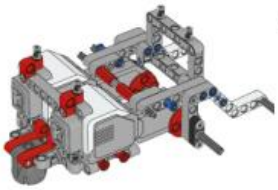

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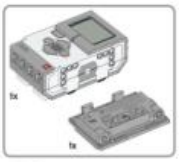

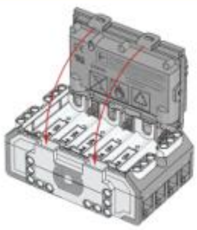

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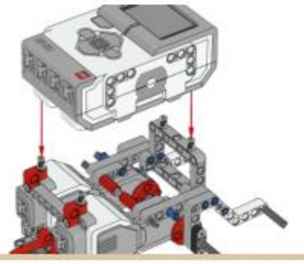

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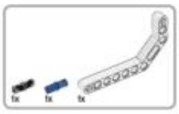

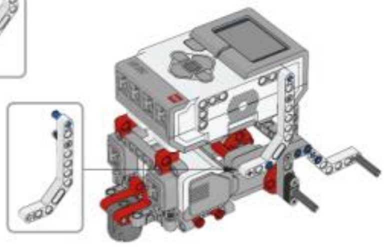

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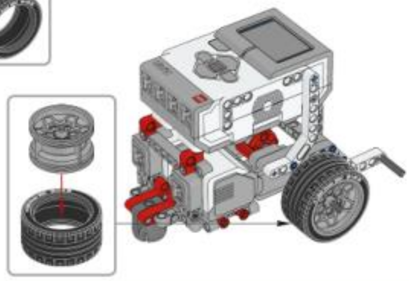

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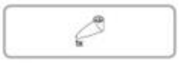

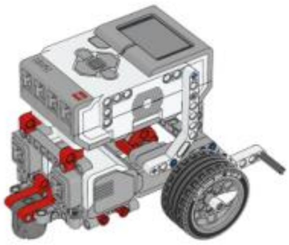

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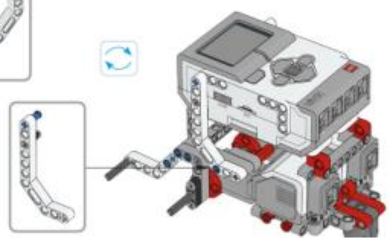

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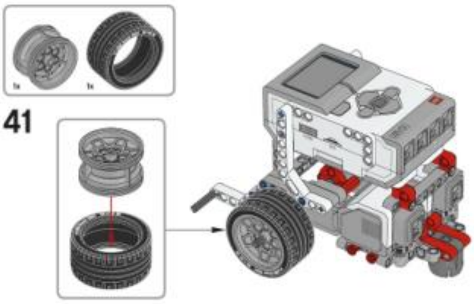

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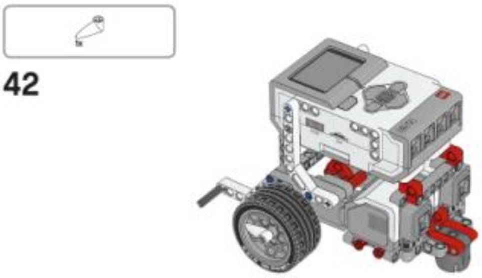

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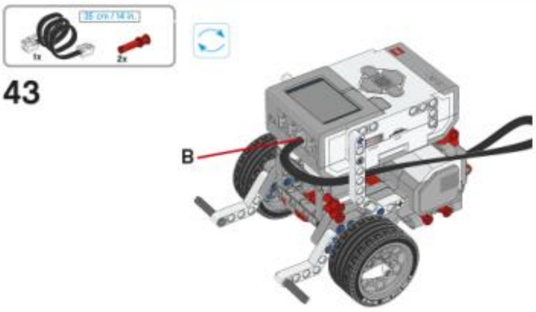

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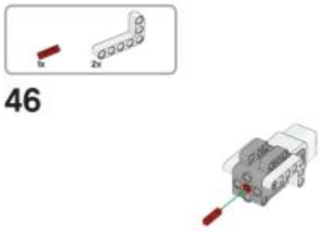

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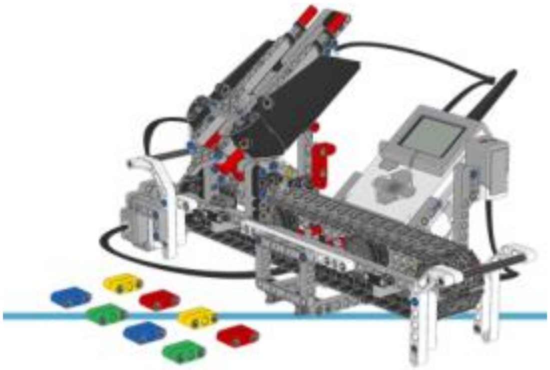
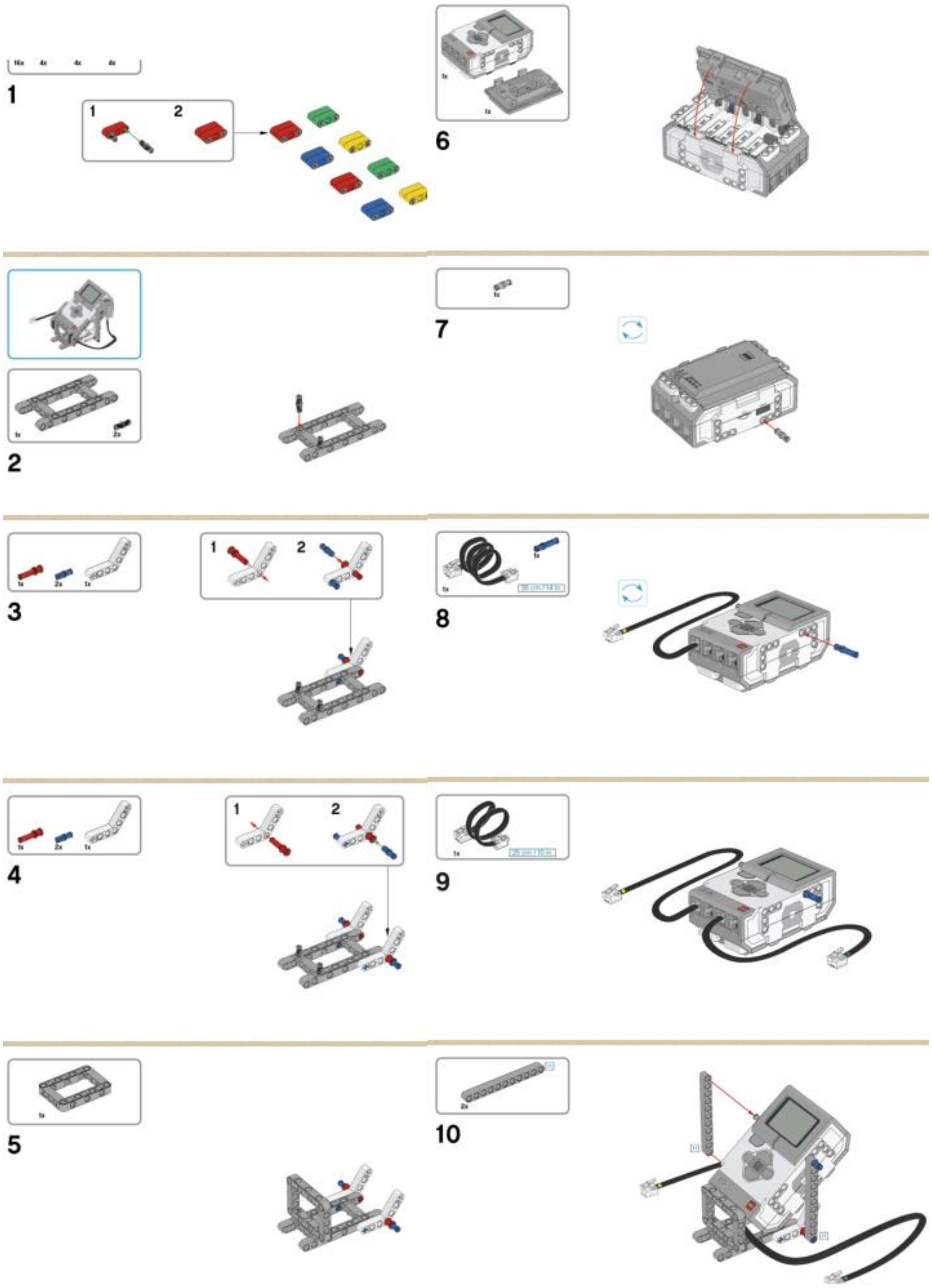
9. Color robot construction

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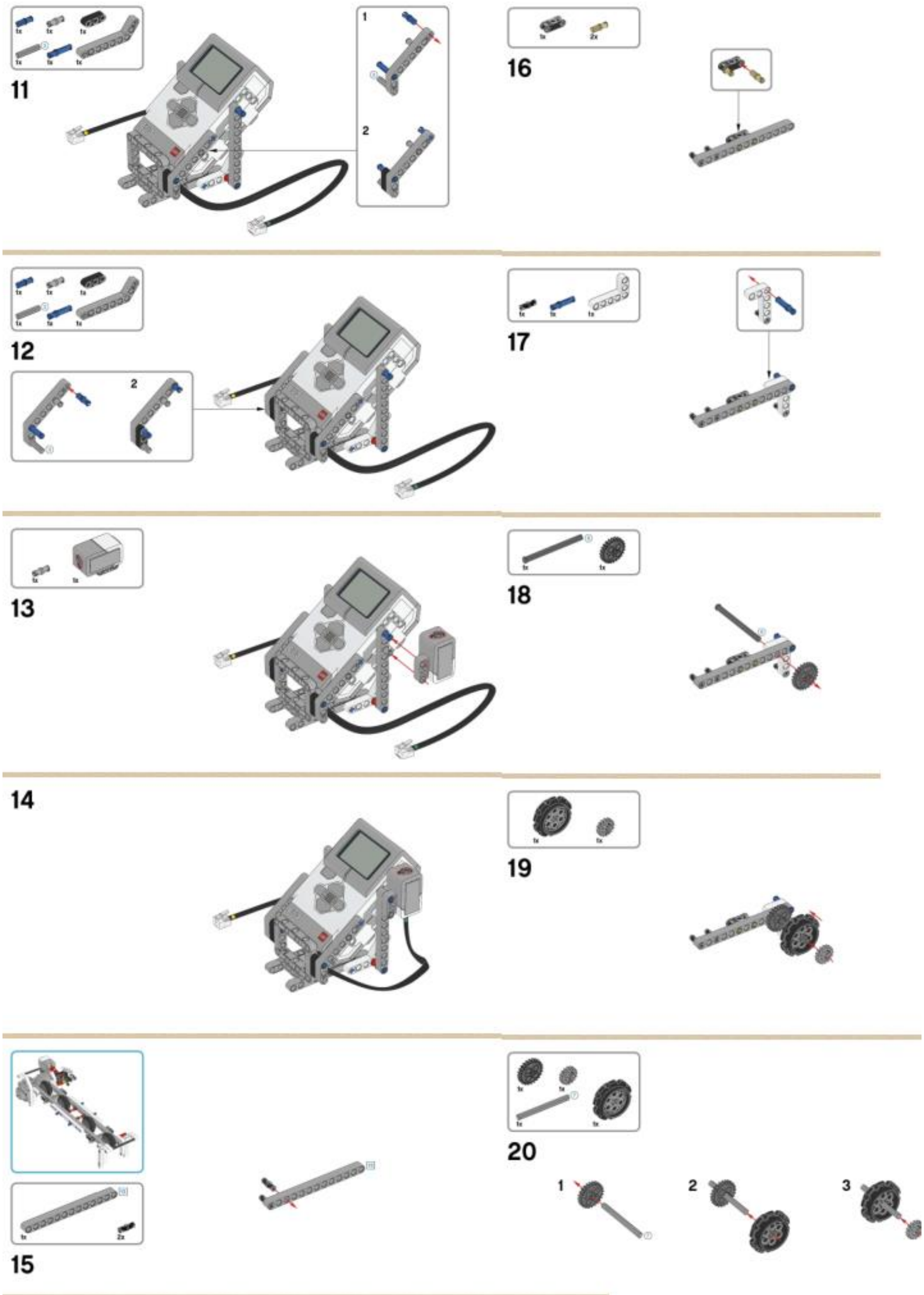
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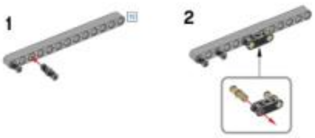

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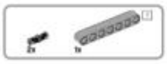

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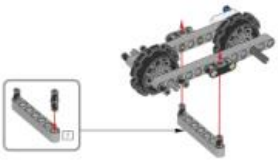

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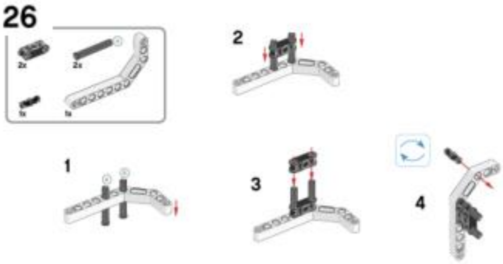

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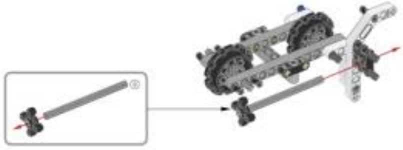

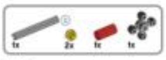

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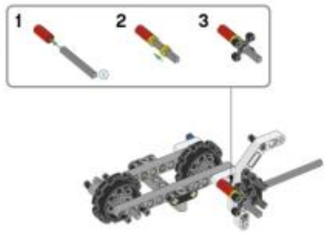

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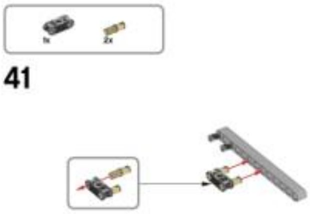
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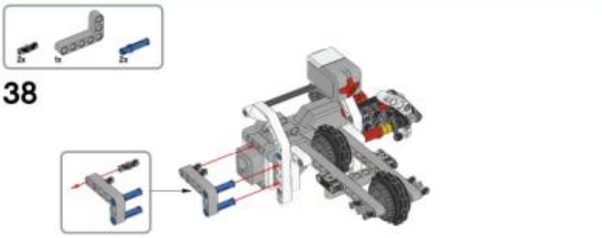
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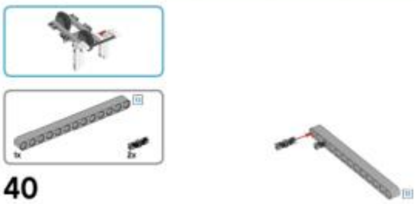
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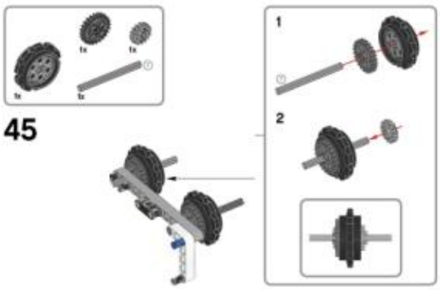
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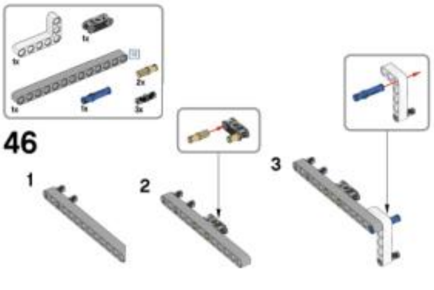
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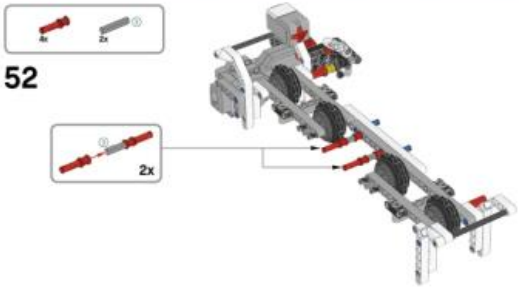
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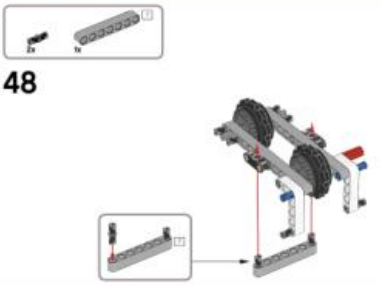
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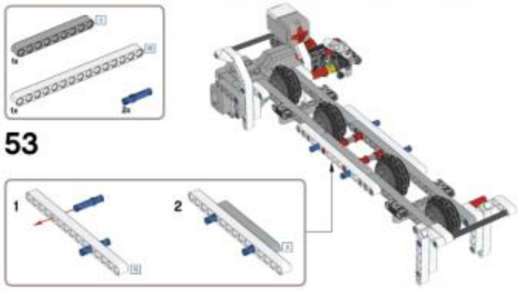
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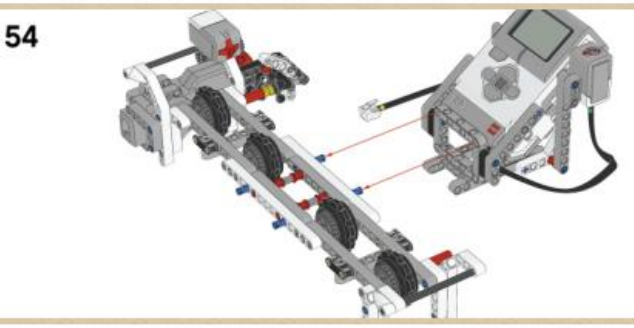
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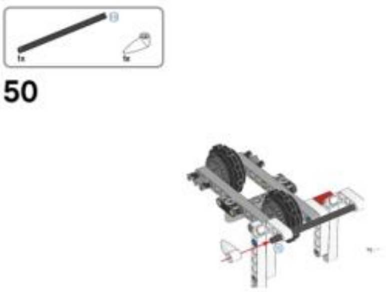
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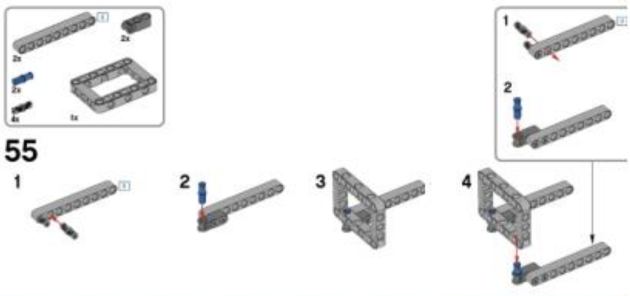
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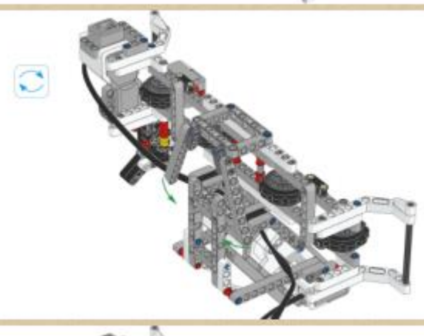

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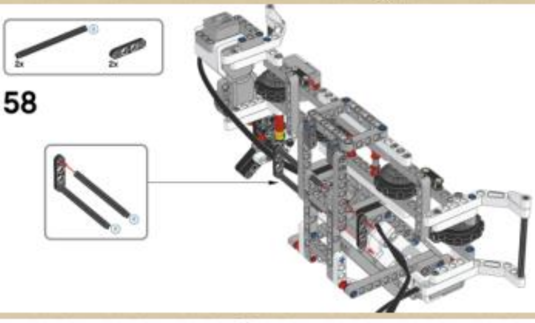

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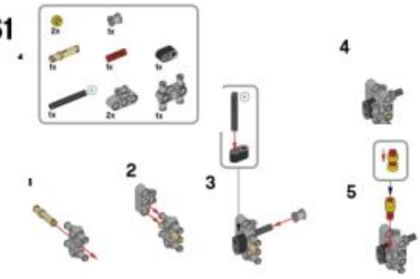

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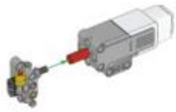

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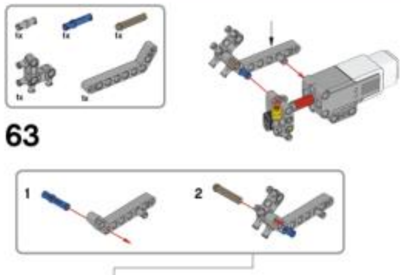

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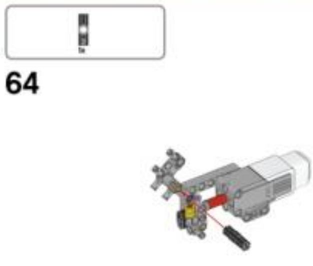

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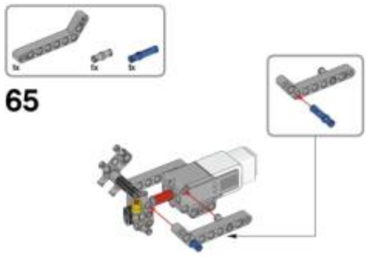

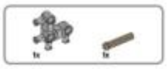

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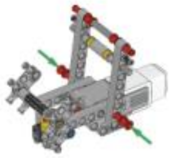

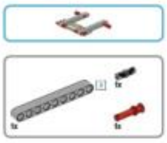

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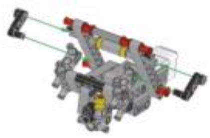

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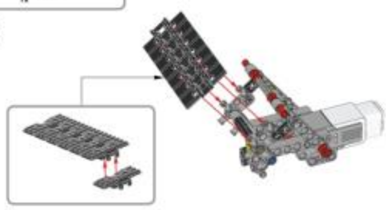

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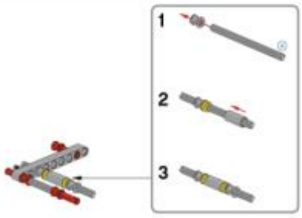

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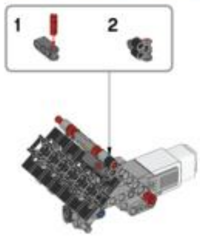

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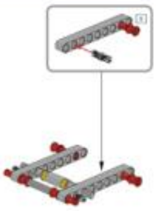

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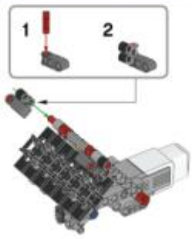

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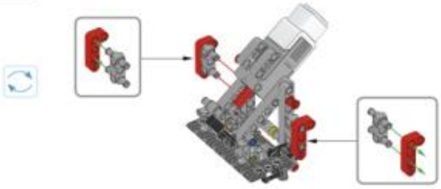

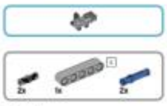

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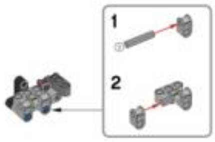

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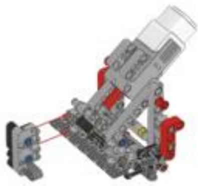

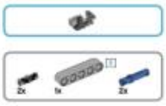

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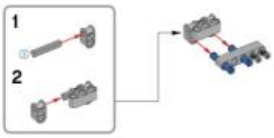

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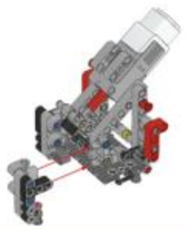

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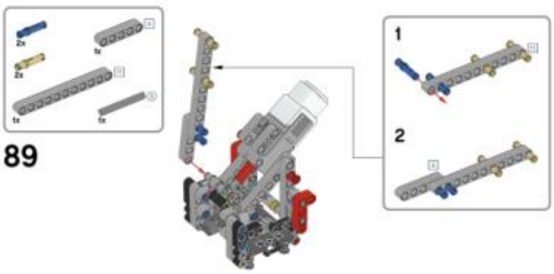

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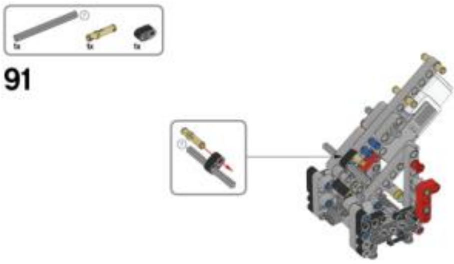

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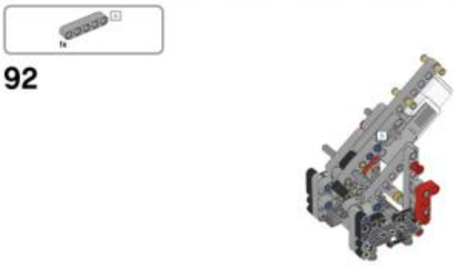

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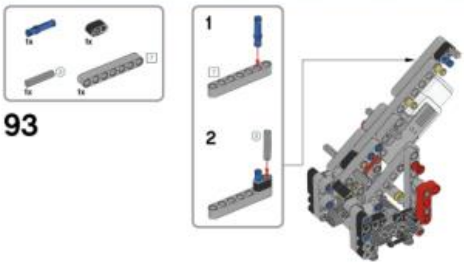

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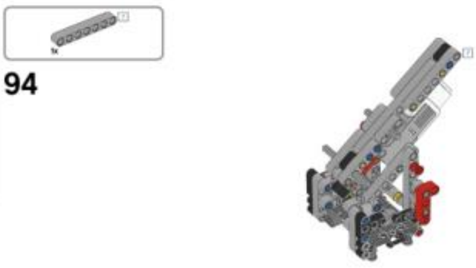

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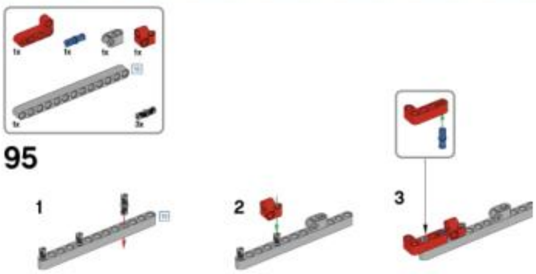

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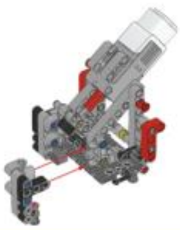

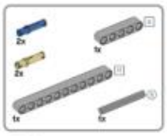

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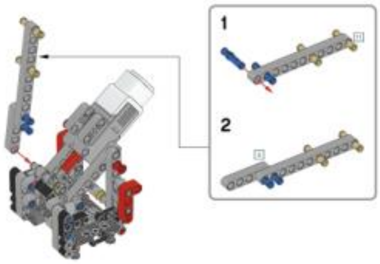

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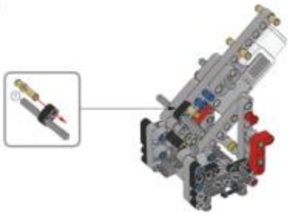

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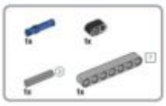

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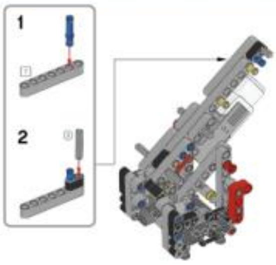

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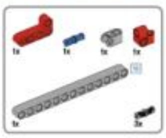

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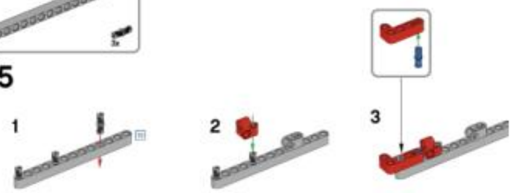

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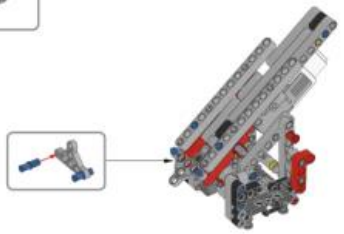

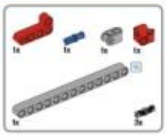

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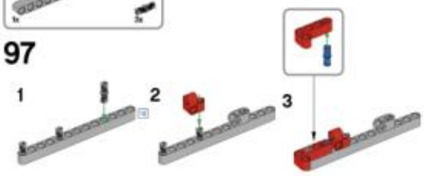

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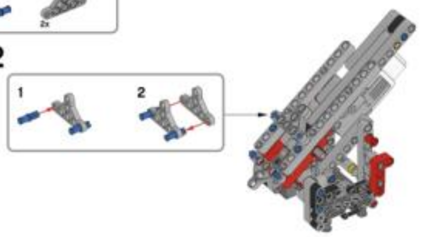

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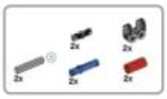

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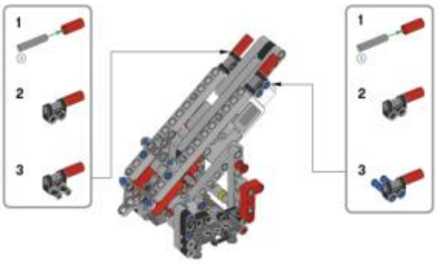

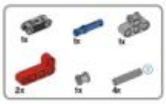

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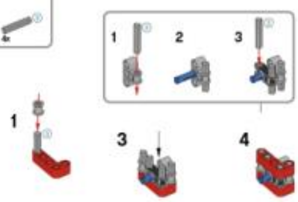

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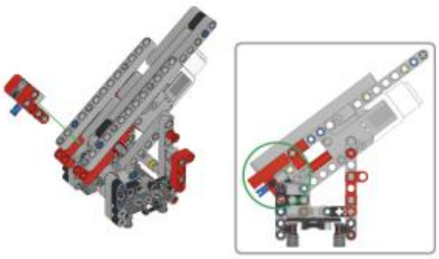

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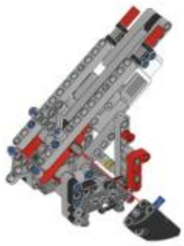

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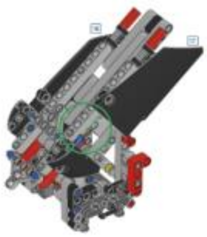

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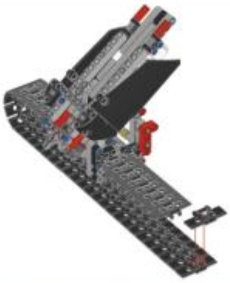

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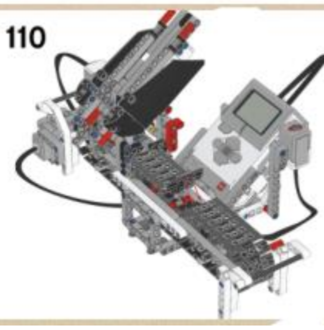

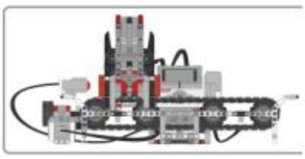

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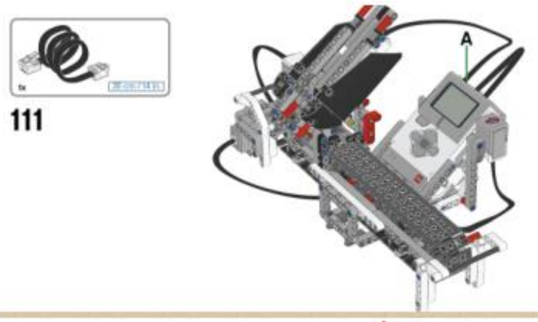

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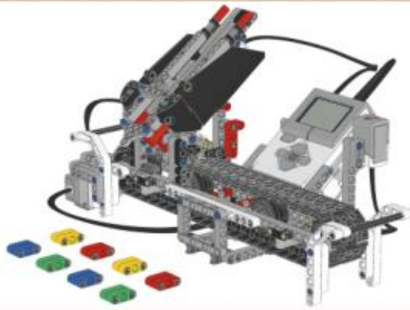
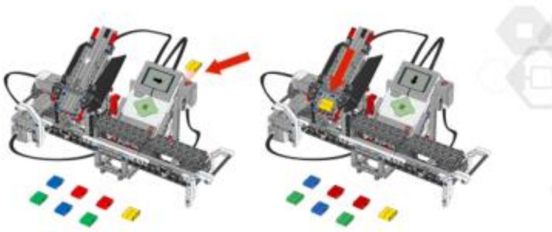
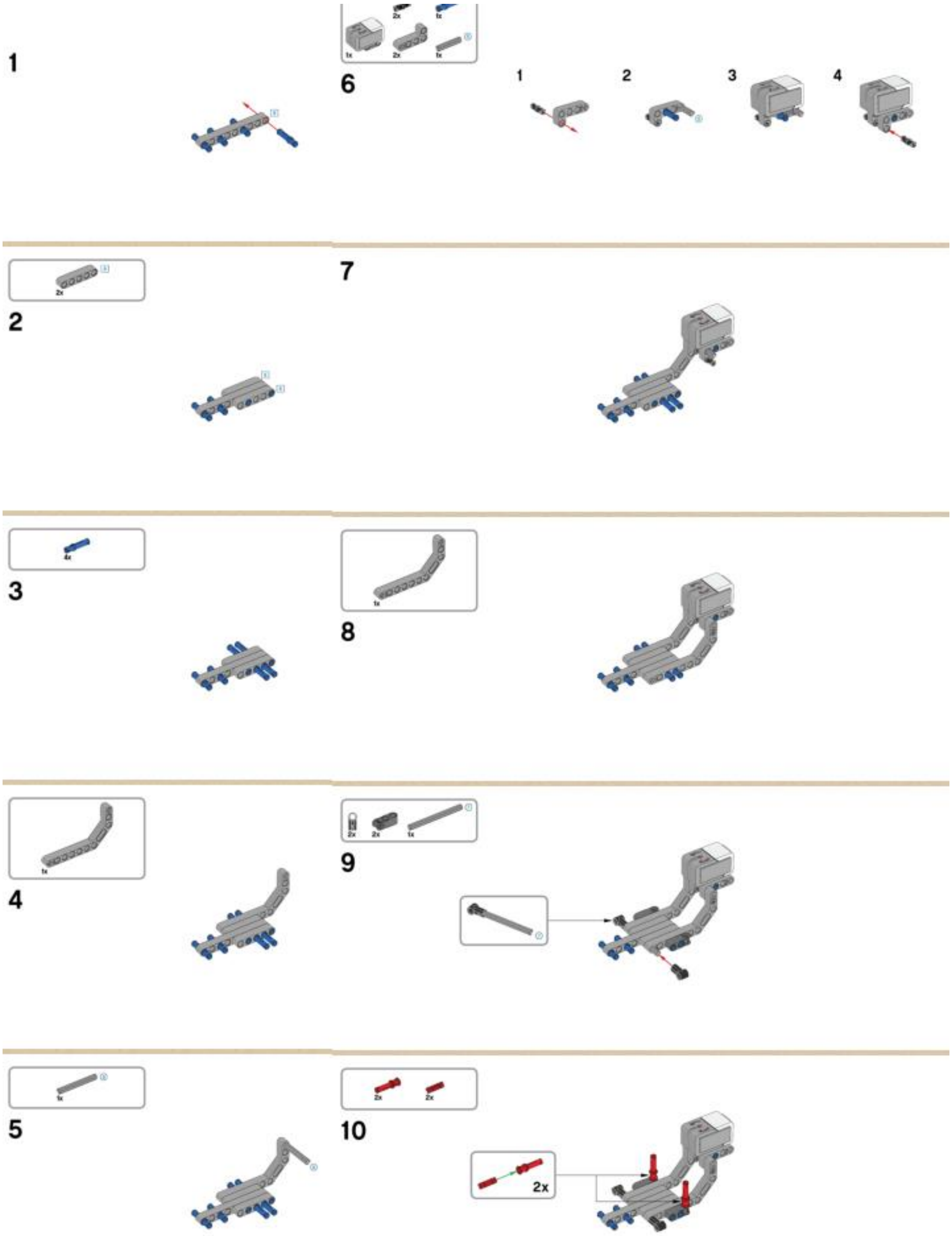




10. Строительство танковых роботов.



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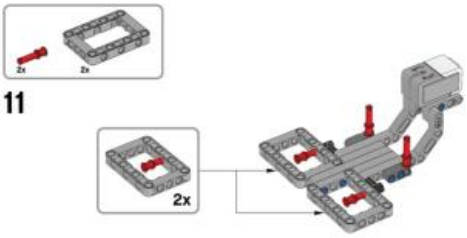

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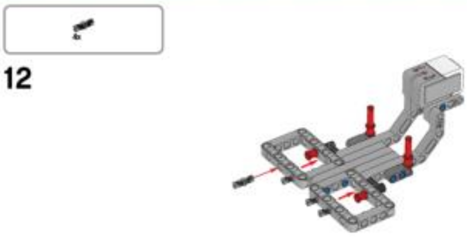

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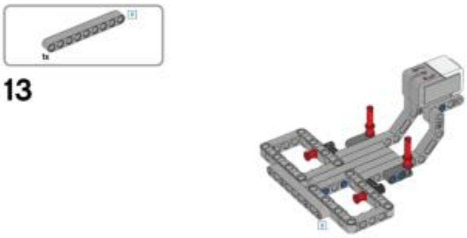

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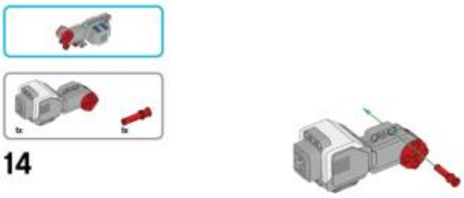

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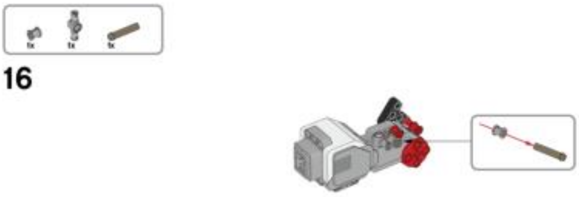

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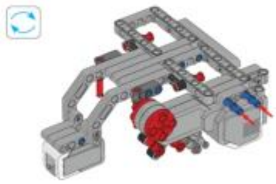

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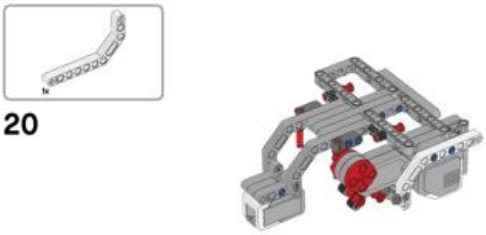

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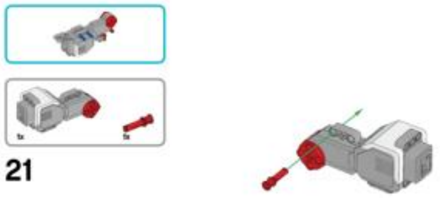

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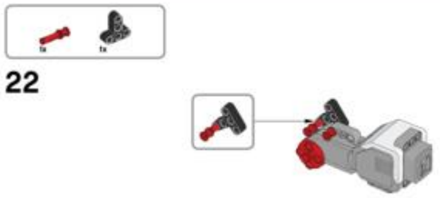

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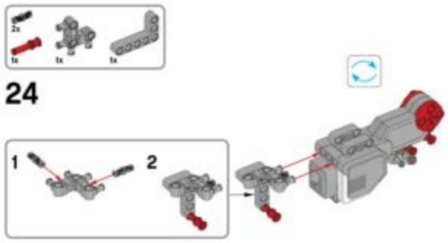

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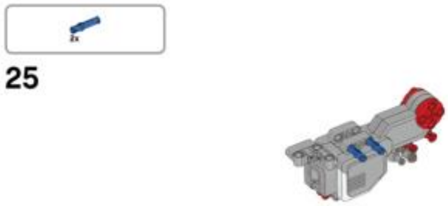

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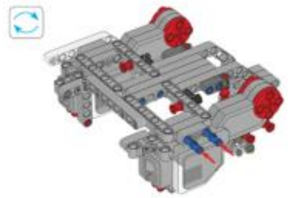

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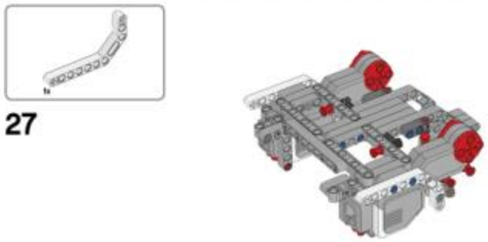

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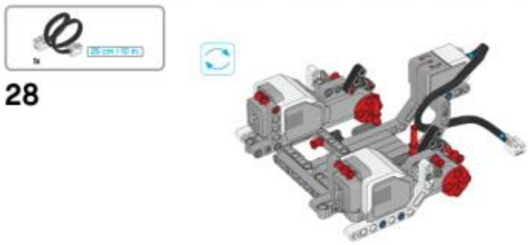

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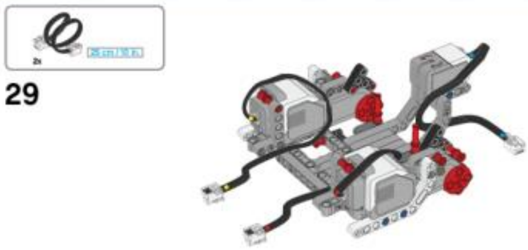

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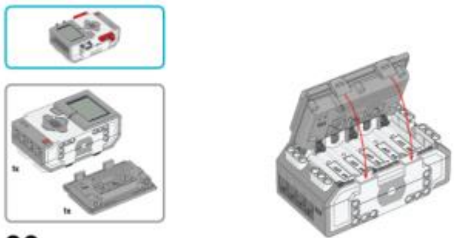

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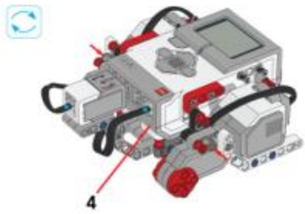

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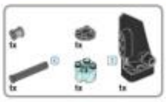

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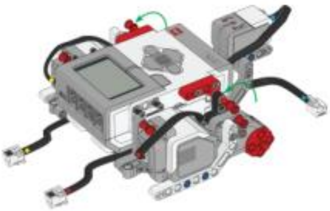

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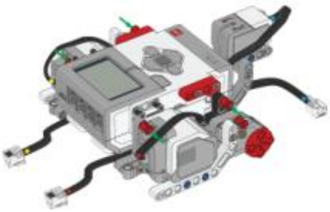

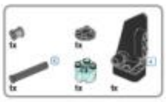

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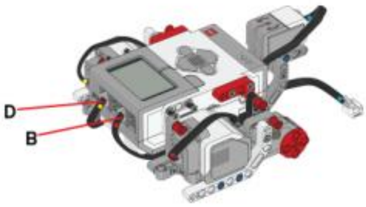

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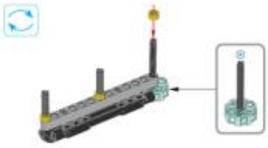

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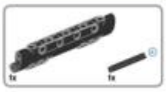

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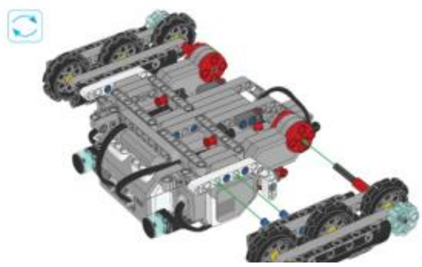

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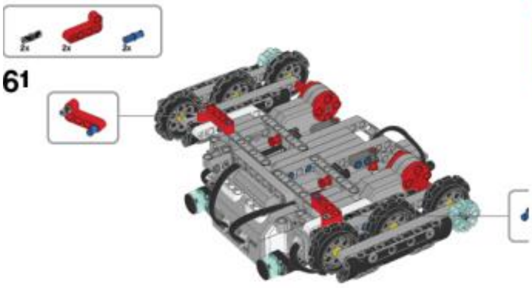

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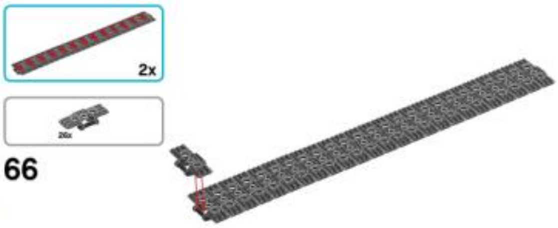

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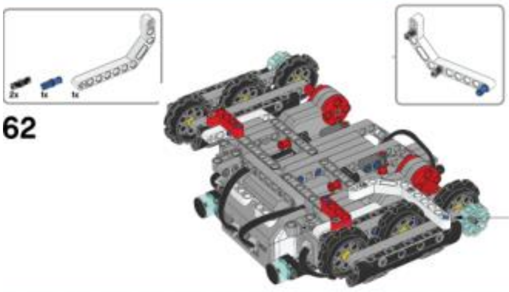

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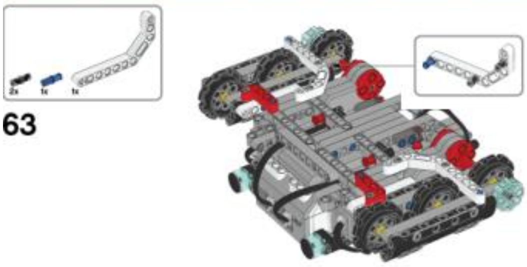

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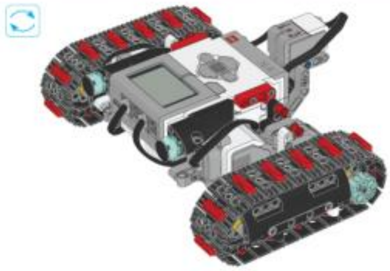

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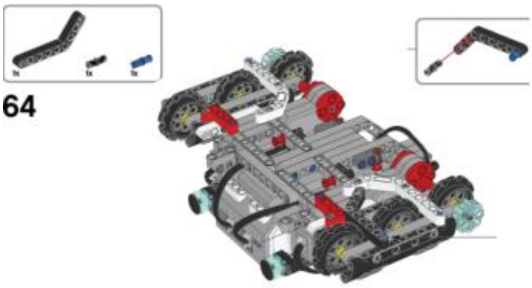

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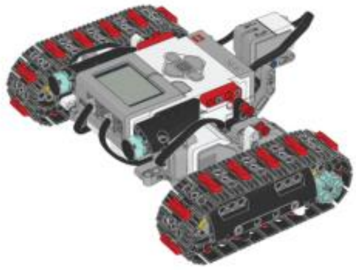

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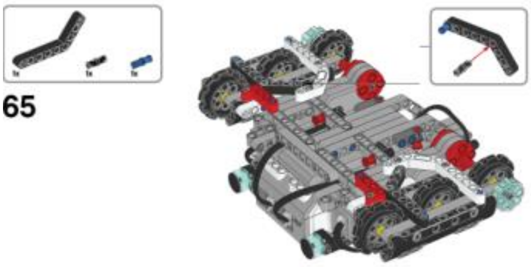

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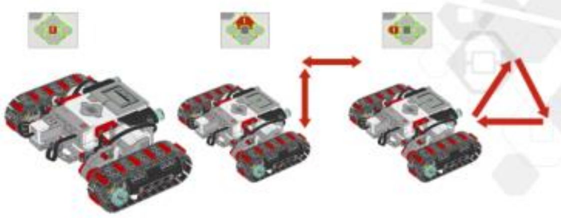
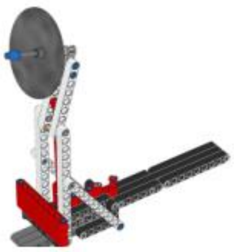
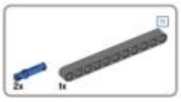


11. Construction of space communication stations





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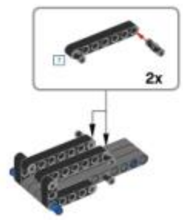

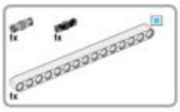

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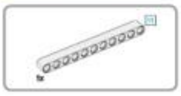

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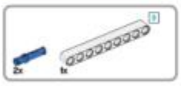

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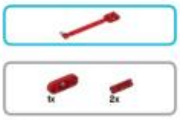
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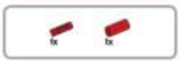
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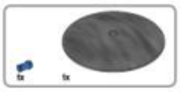

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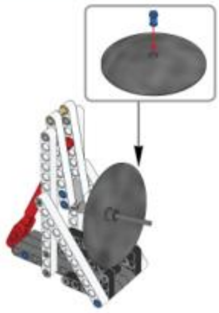

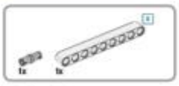

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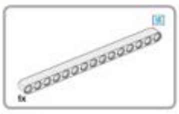

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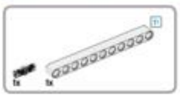

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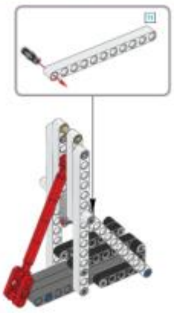

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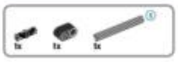

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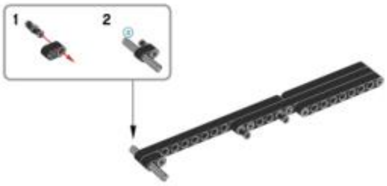

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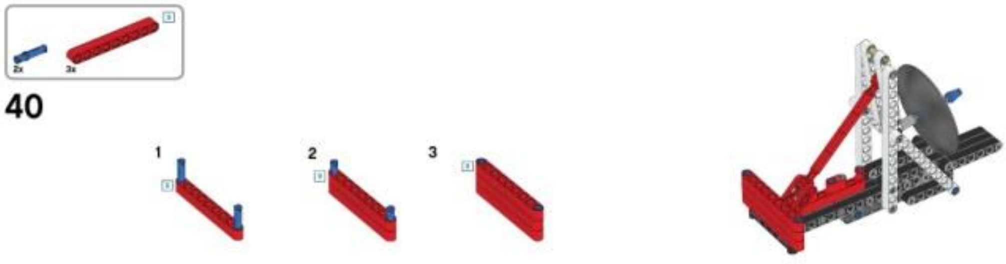

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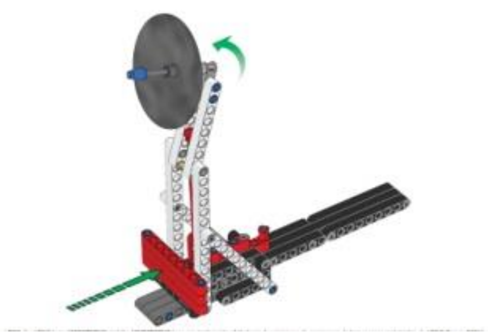

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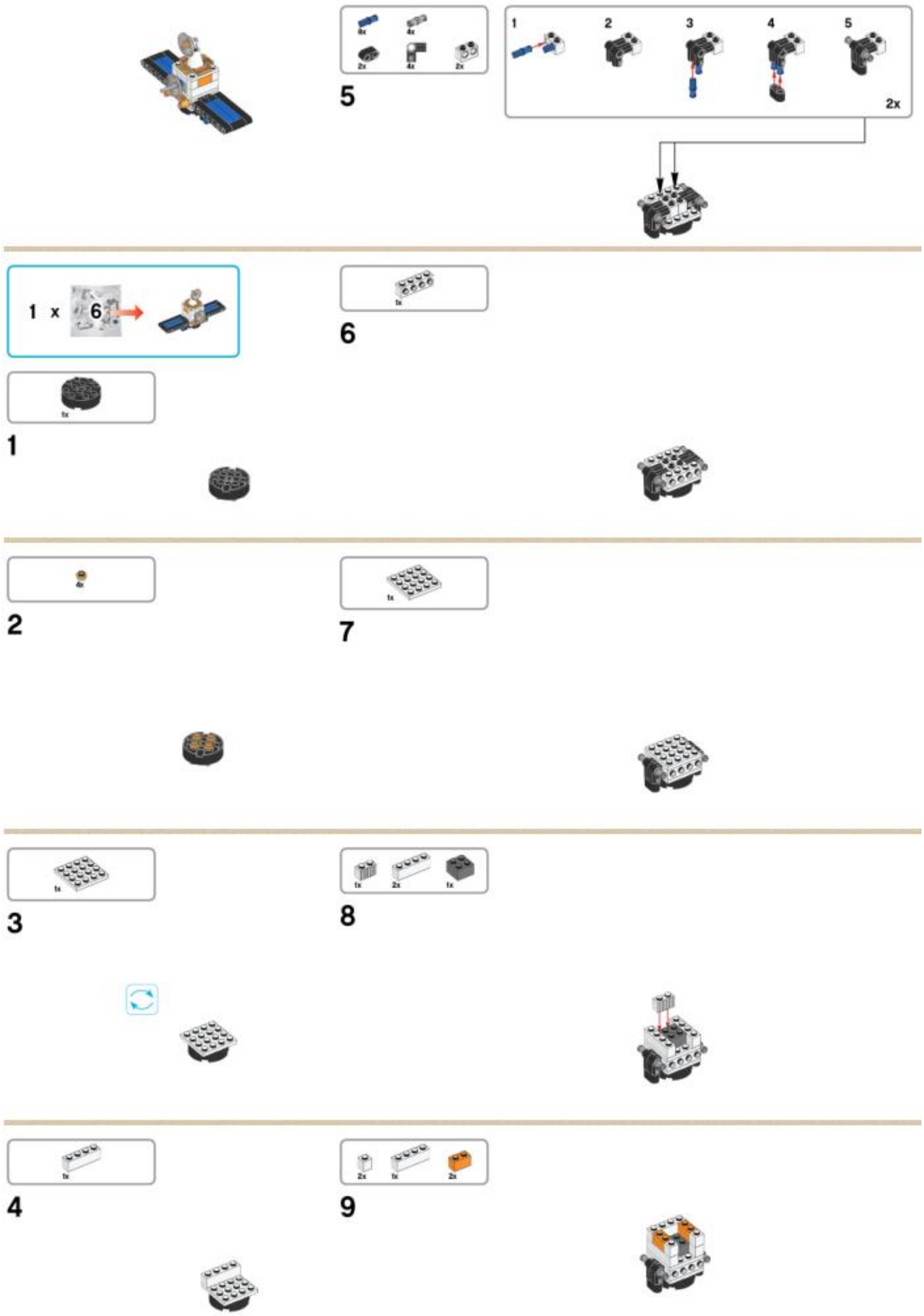

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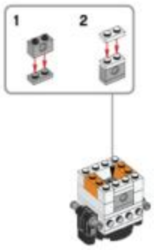

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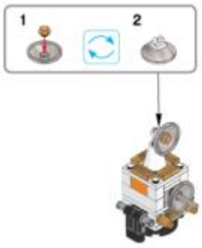

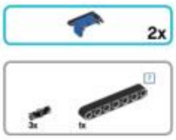

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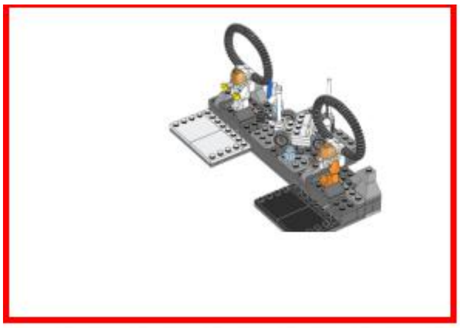
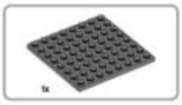
13. Unit construction





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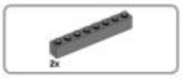

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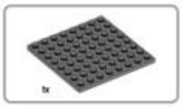

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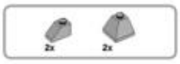

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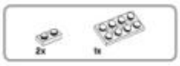

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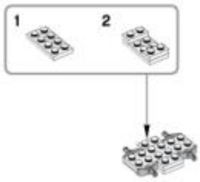

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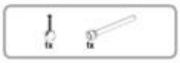

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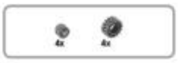

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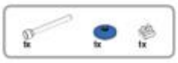

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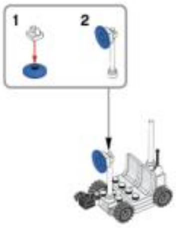

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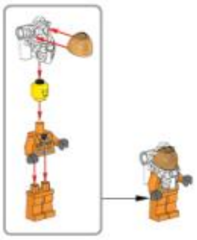

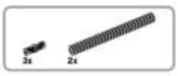

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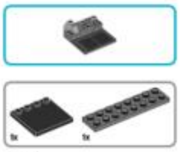

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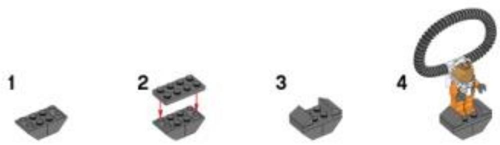

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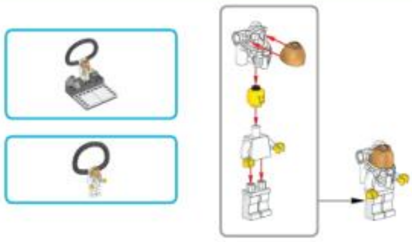

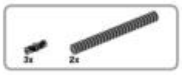

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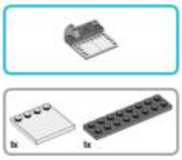

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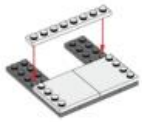

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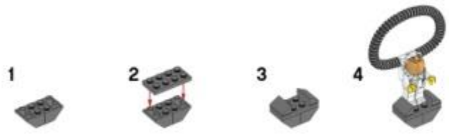

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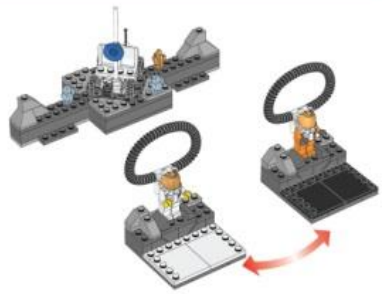

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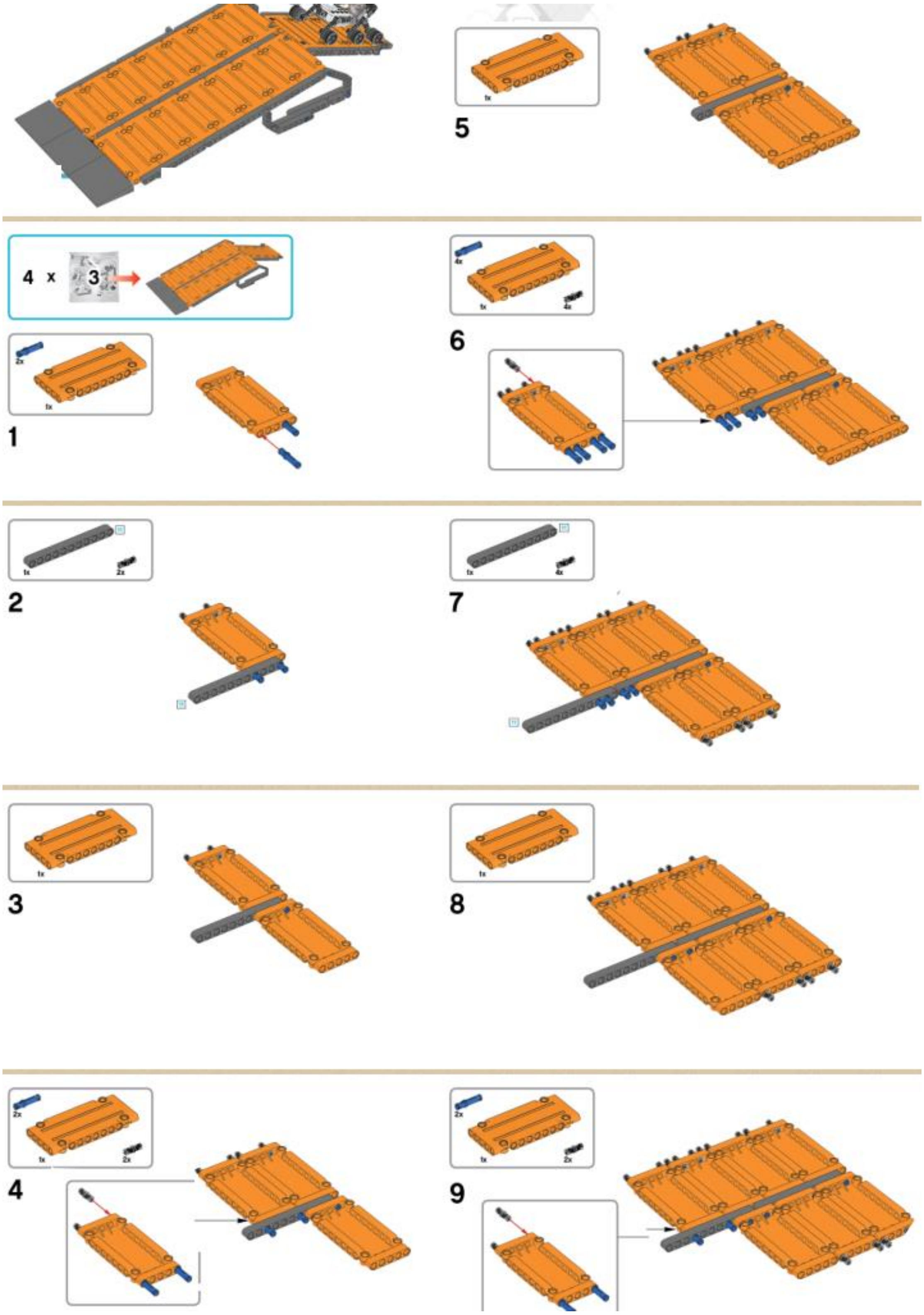
14. Volcano Crater and MSL Construction



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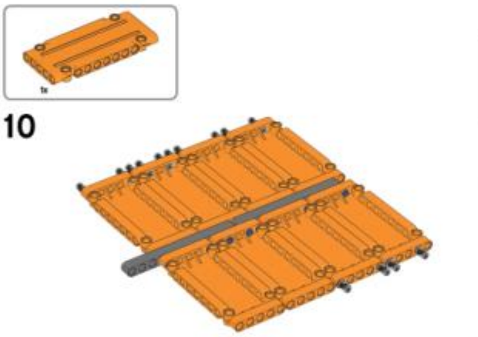

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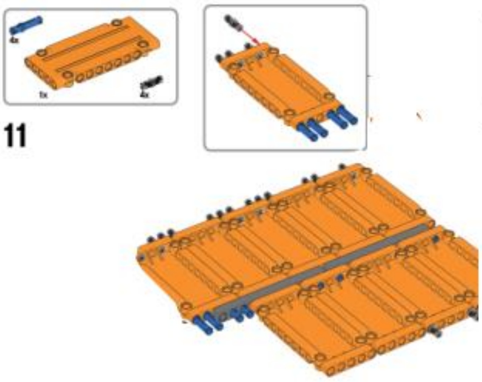

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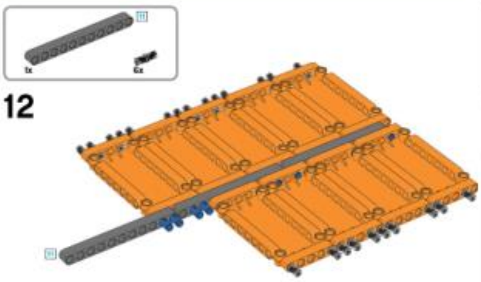

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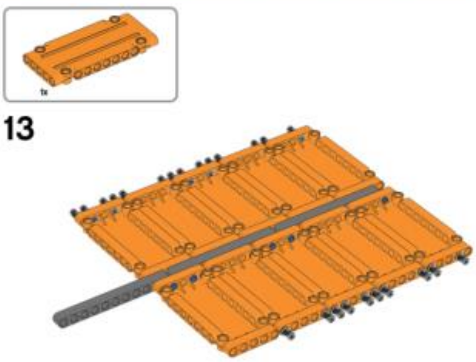

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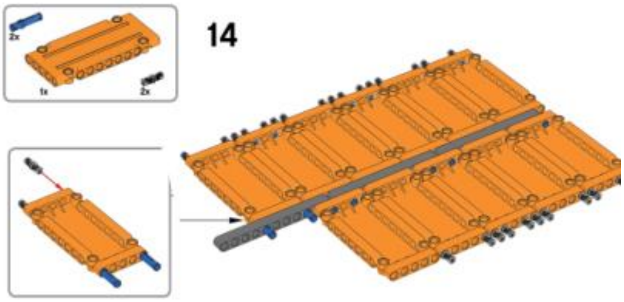

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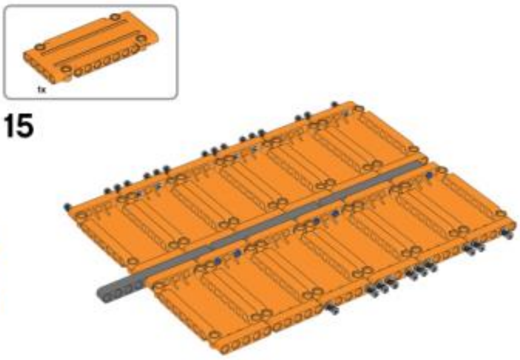

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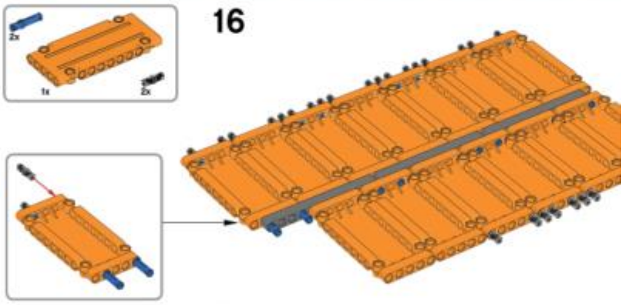

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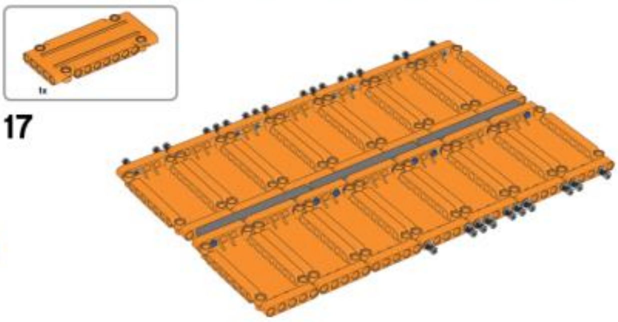

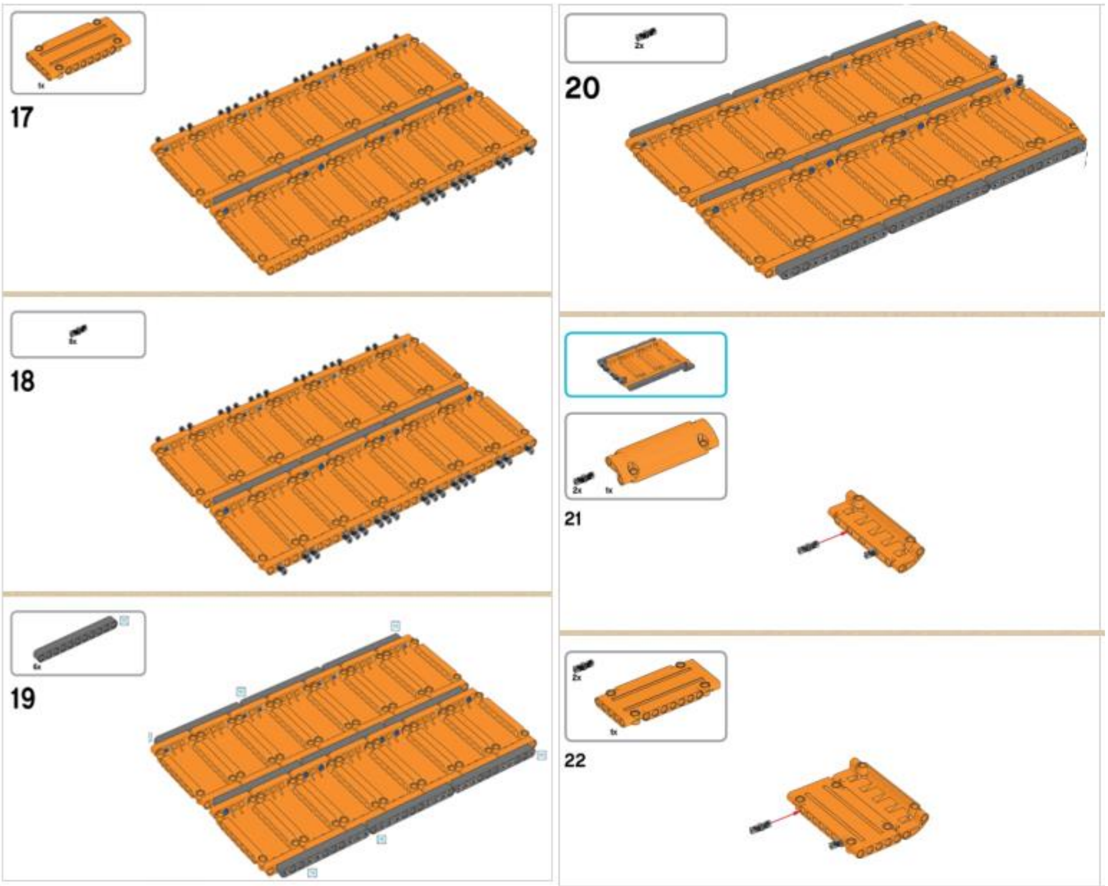
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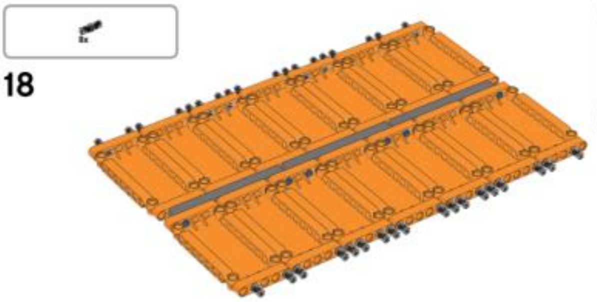

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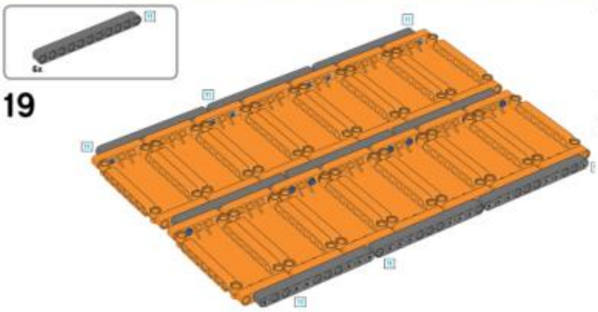

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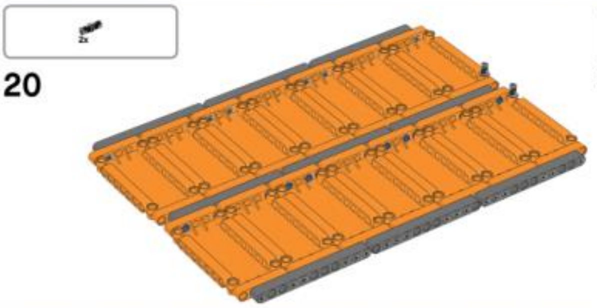

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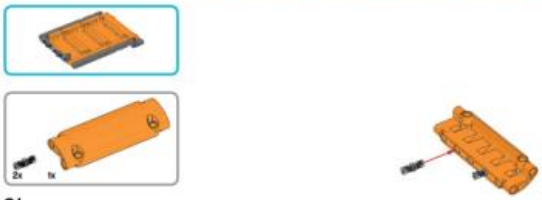

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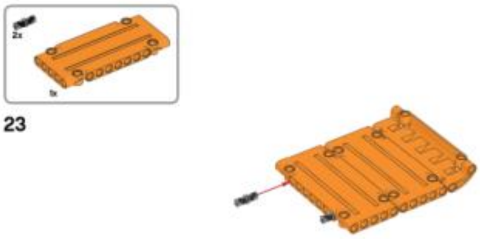

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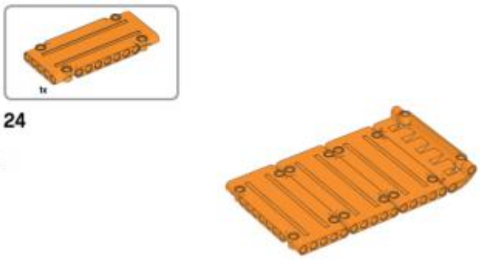

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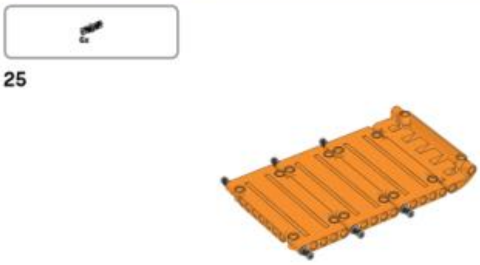

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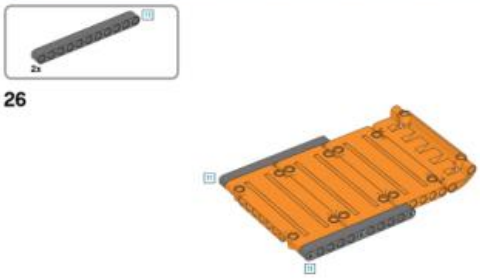

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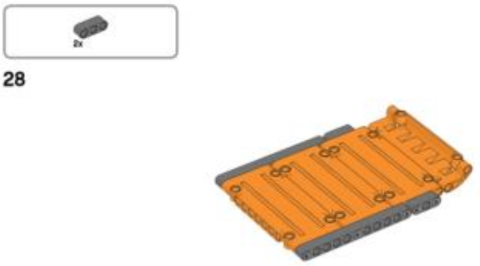

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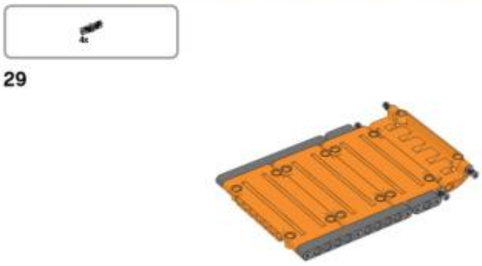

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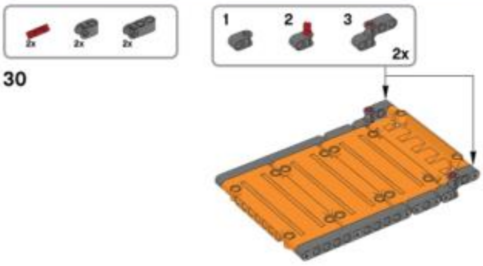

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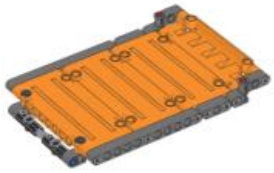

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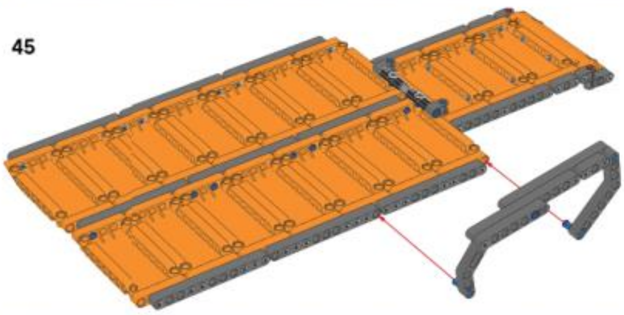

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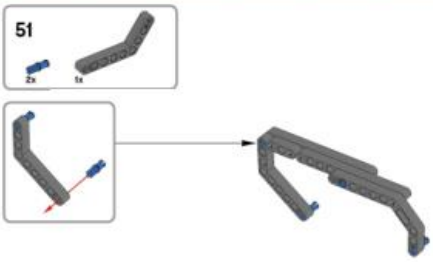

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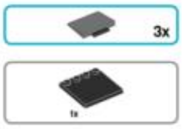

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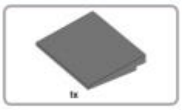

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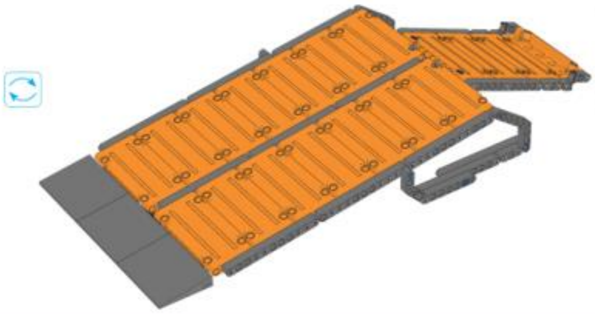

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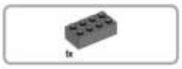

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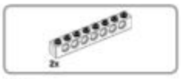

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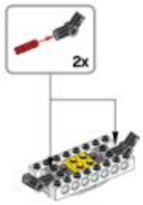

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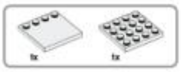

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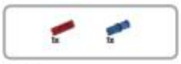

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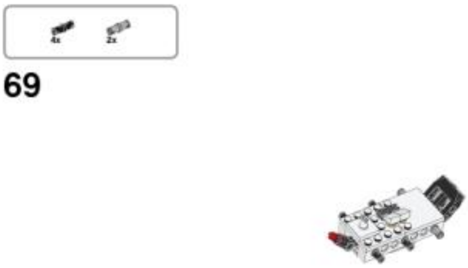

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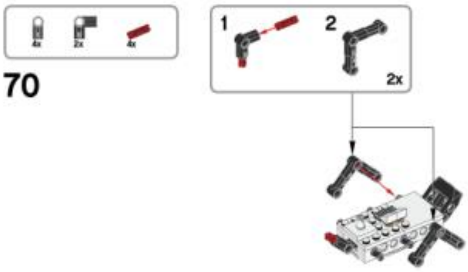

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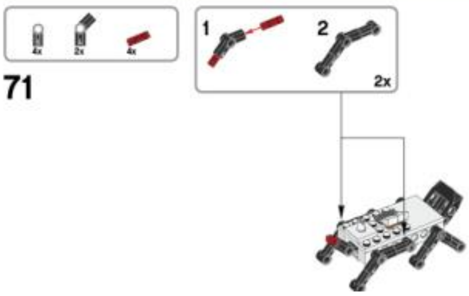

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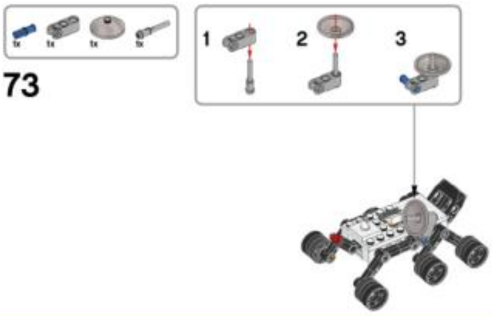

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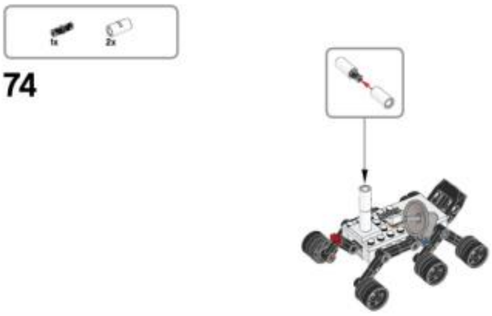

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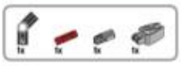

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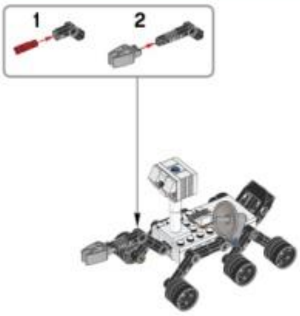

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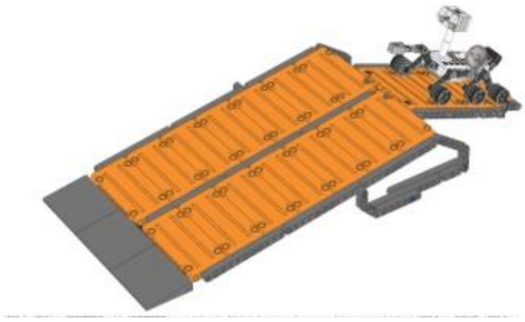
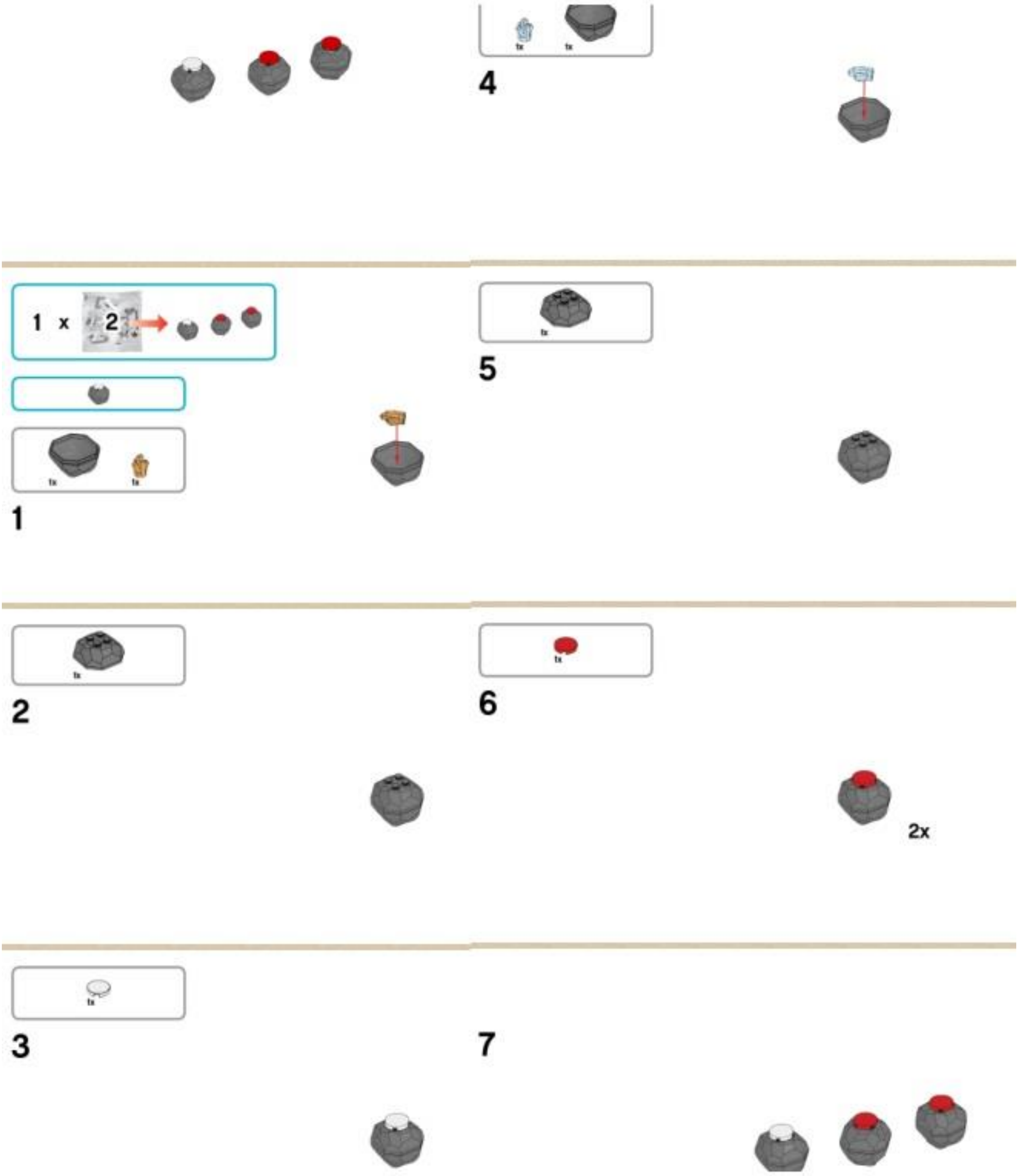


15. Difficulty in rock samples



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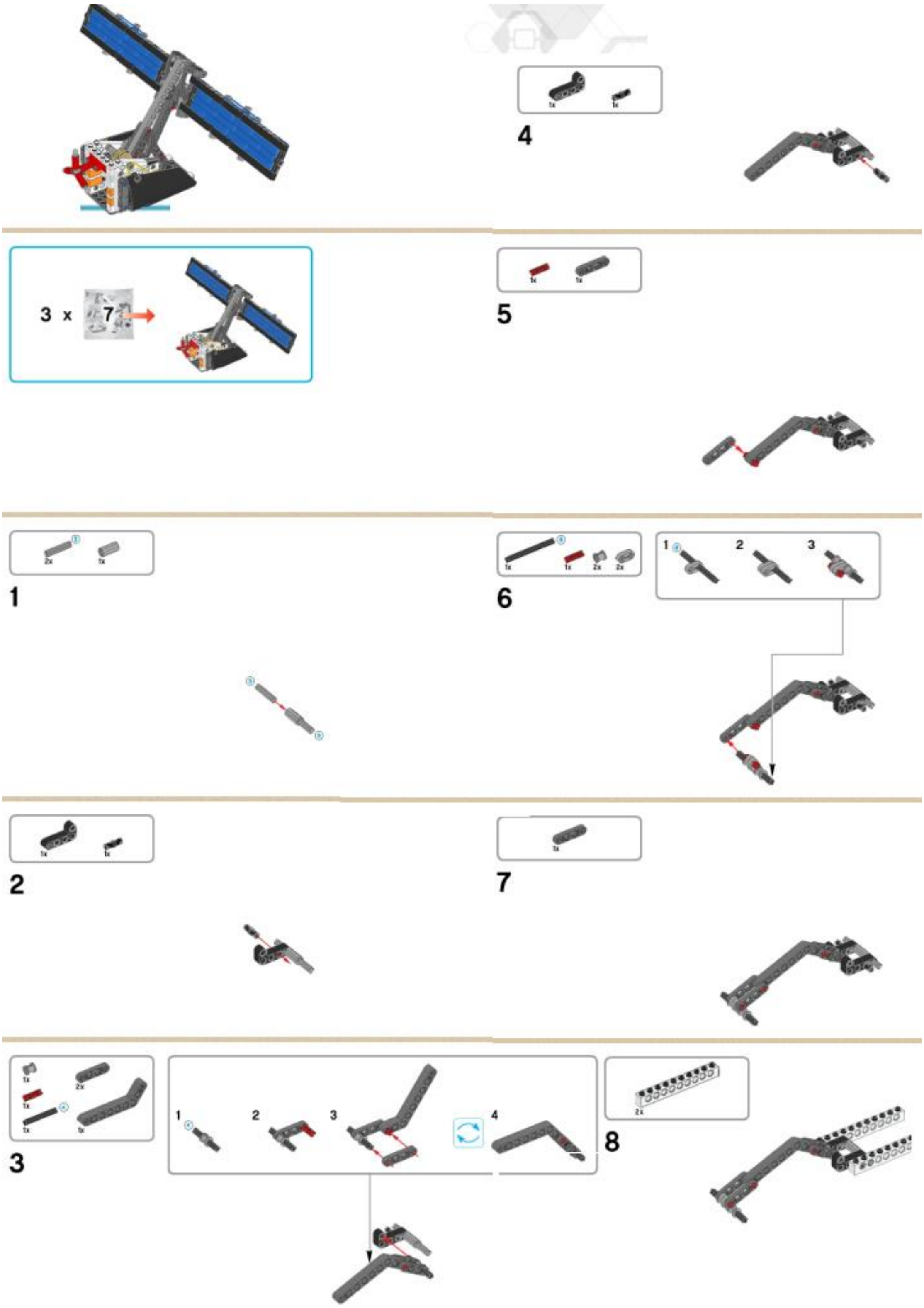

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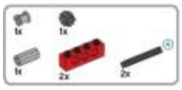

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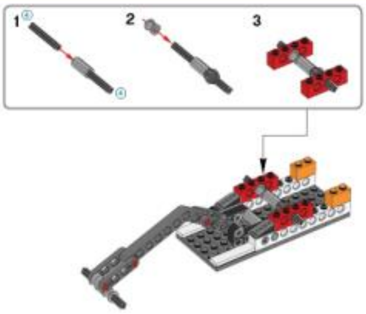

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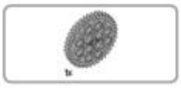

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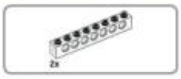

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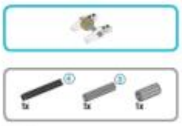

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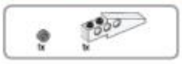

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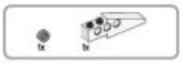

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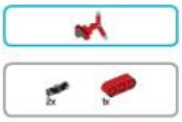

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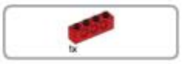

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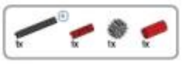

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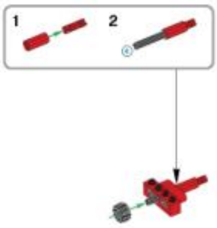

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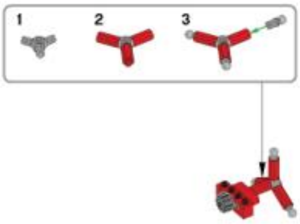

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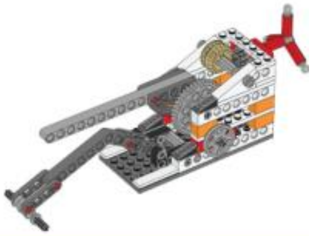

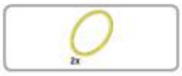

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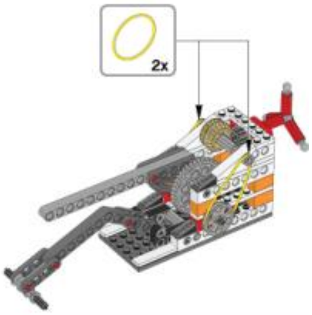

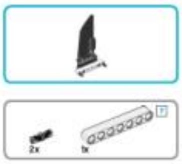

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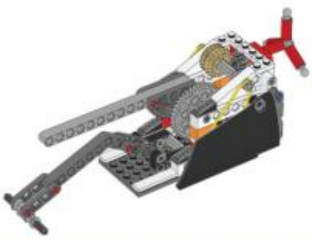

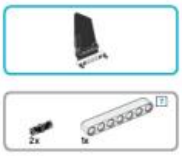

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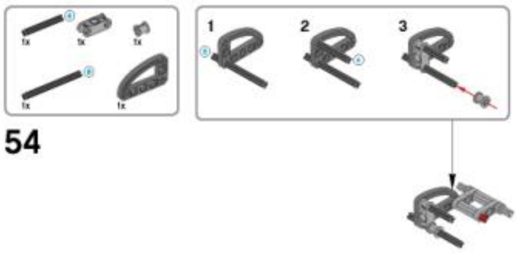

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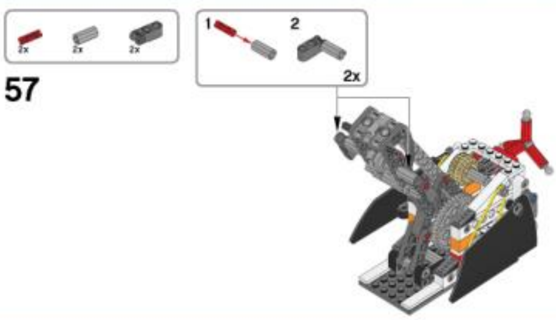

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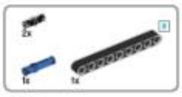

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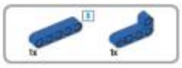

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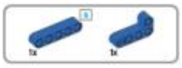

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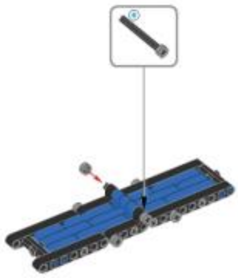

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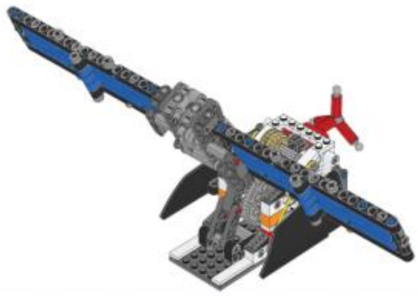

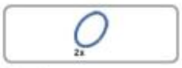

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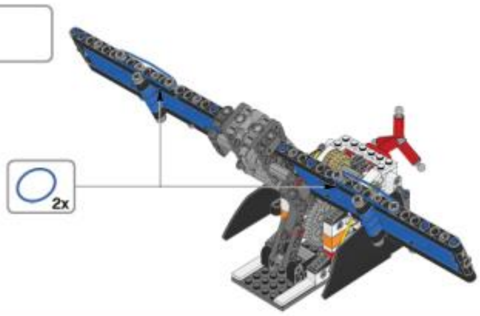

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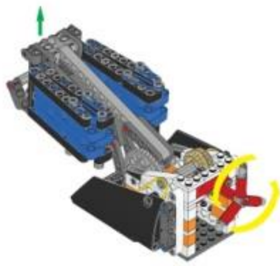

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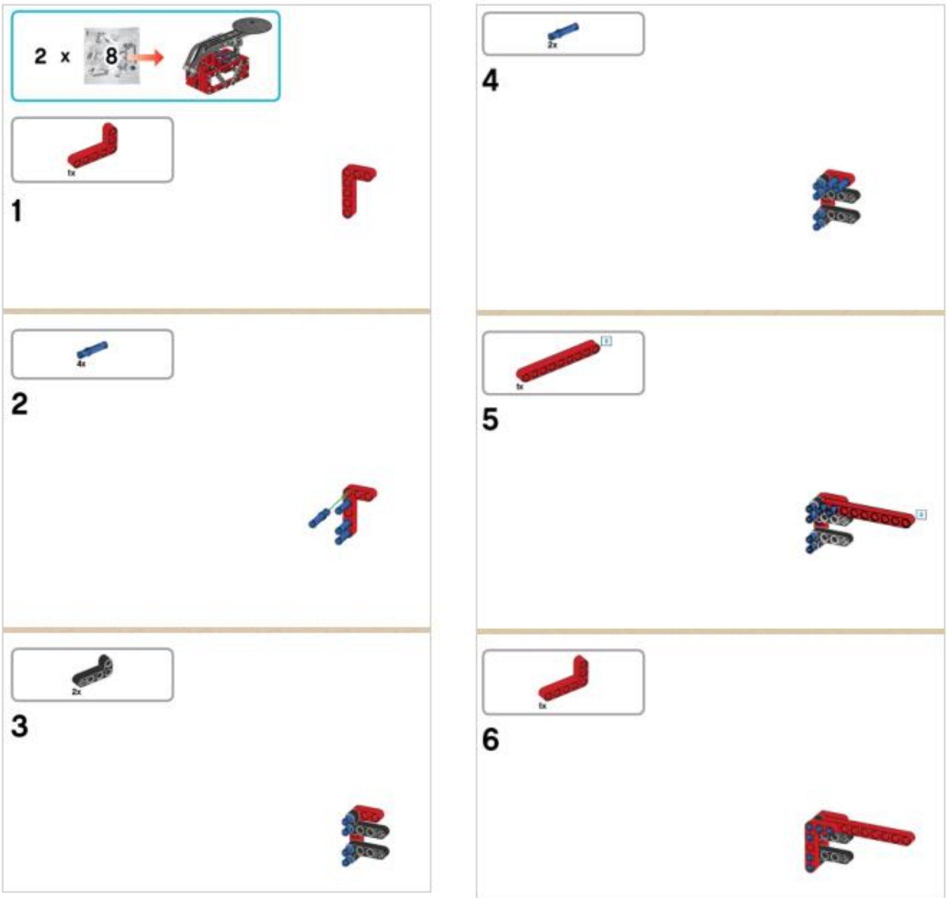
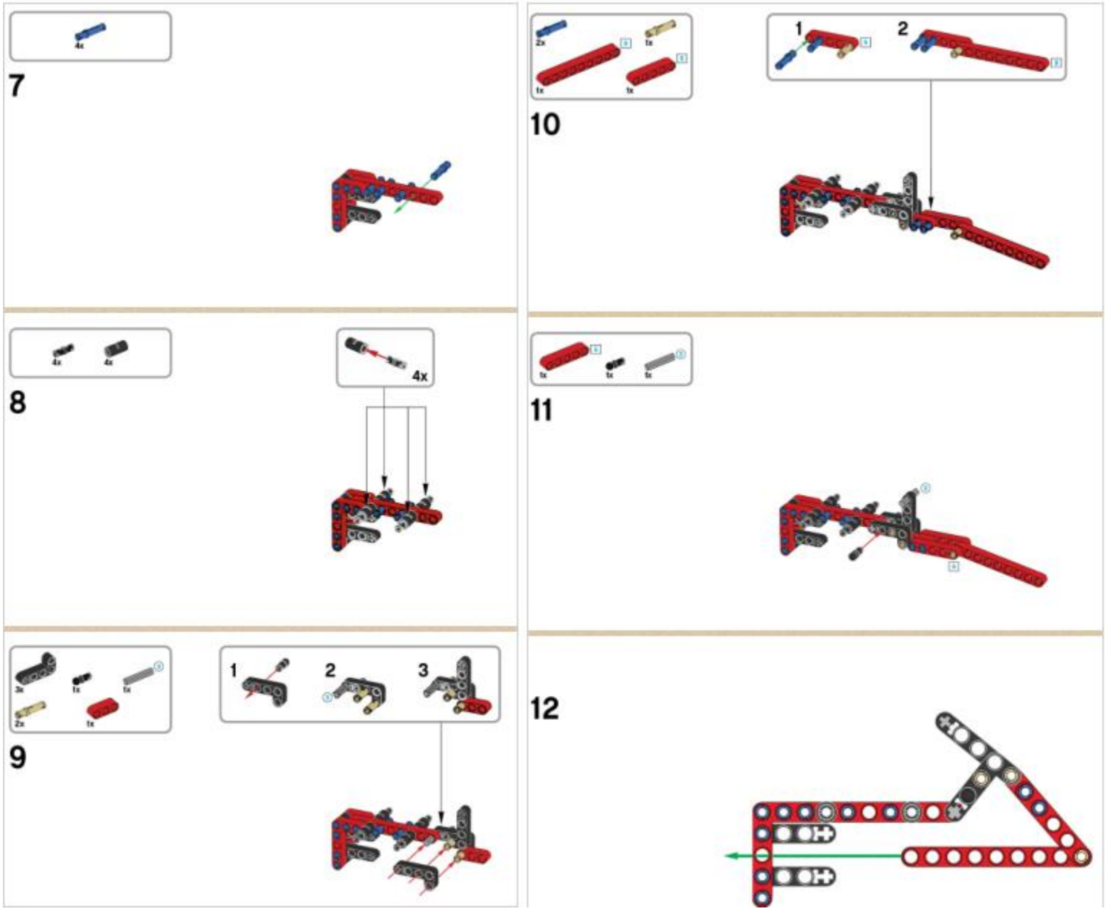
17. Missiles and launchers

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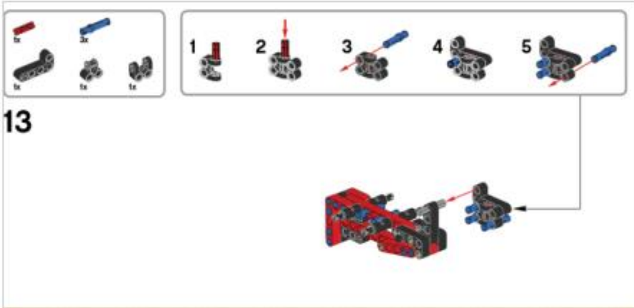

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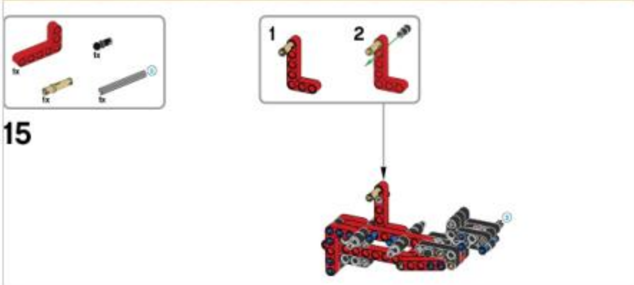

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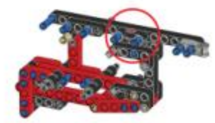

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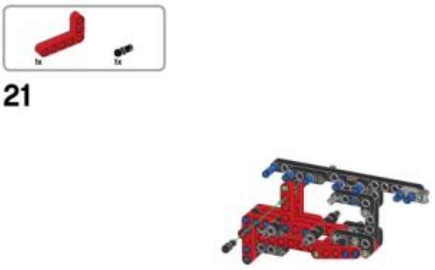

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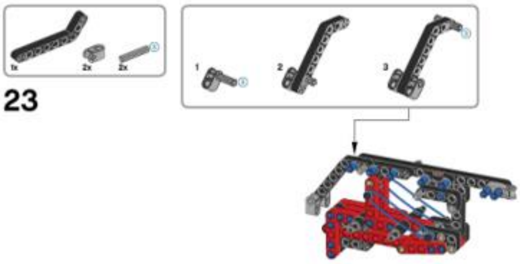

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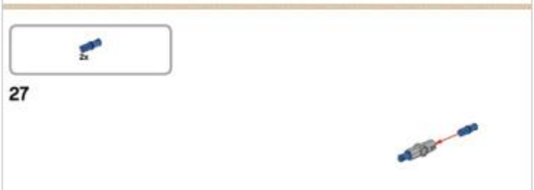
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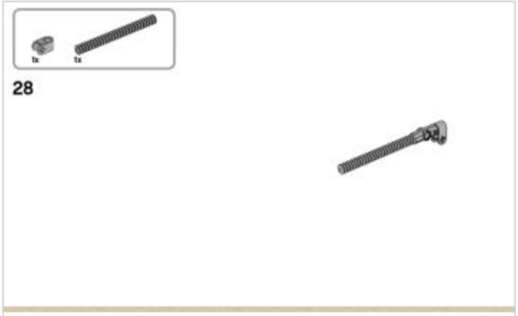
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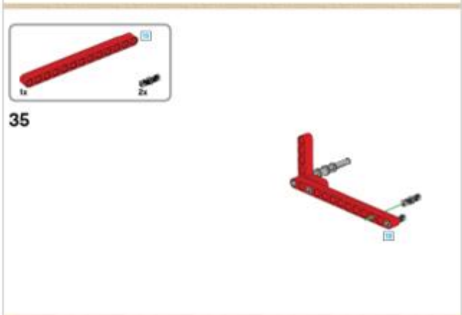
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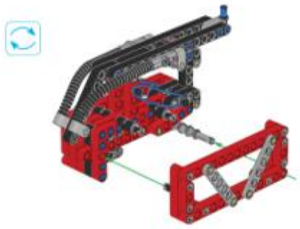

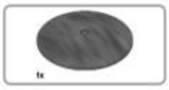

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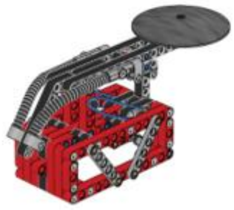

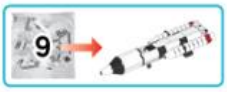

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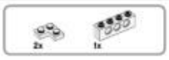

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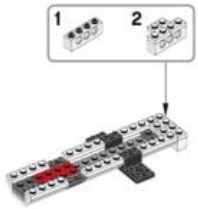

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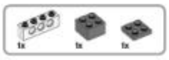

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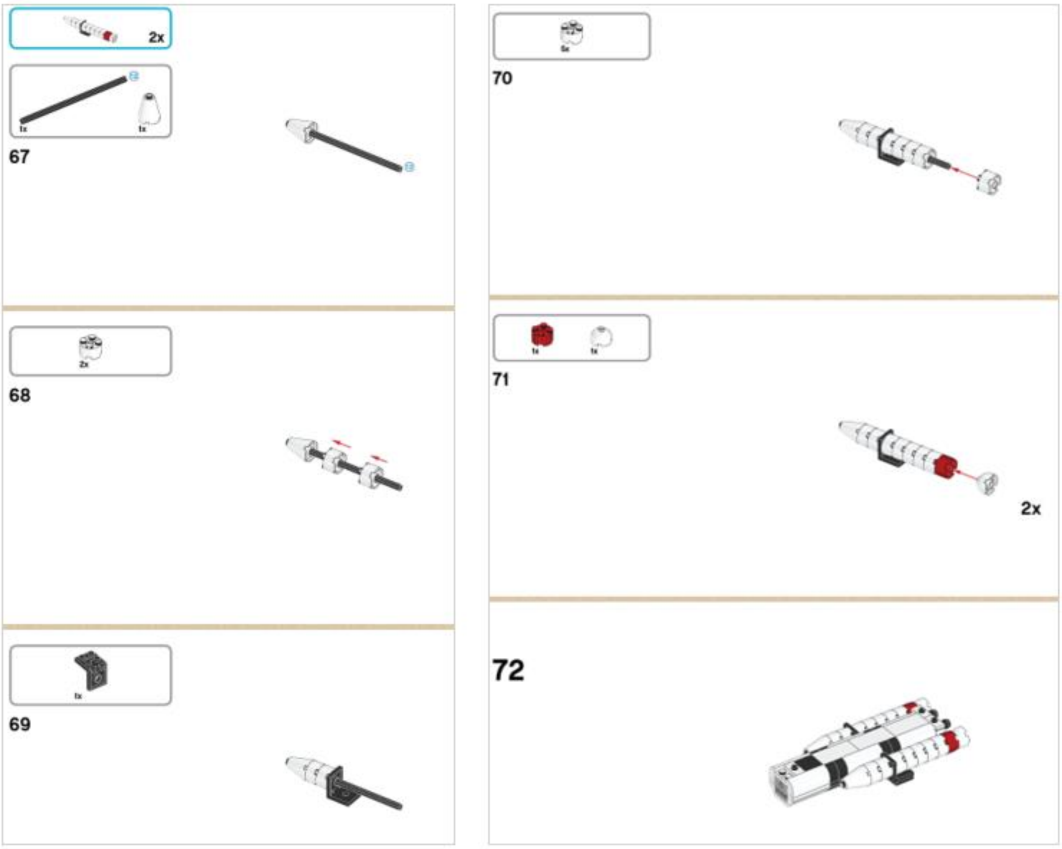
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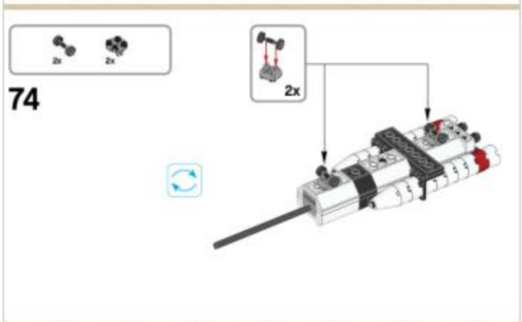
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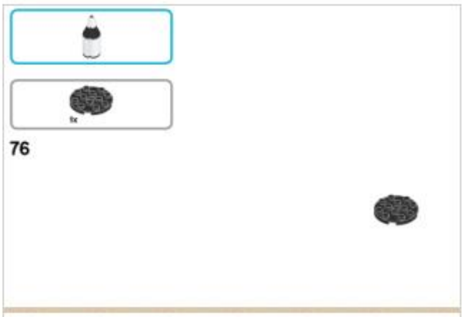
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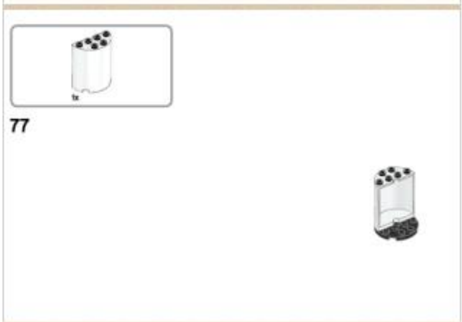
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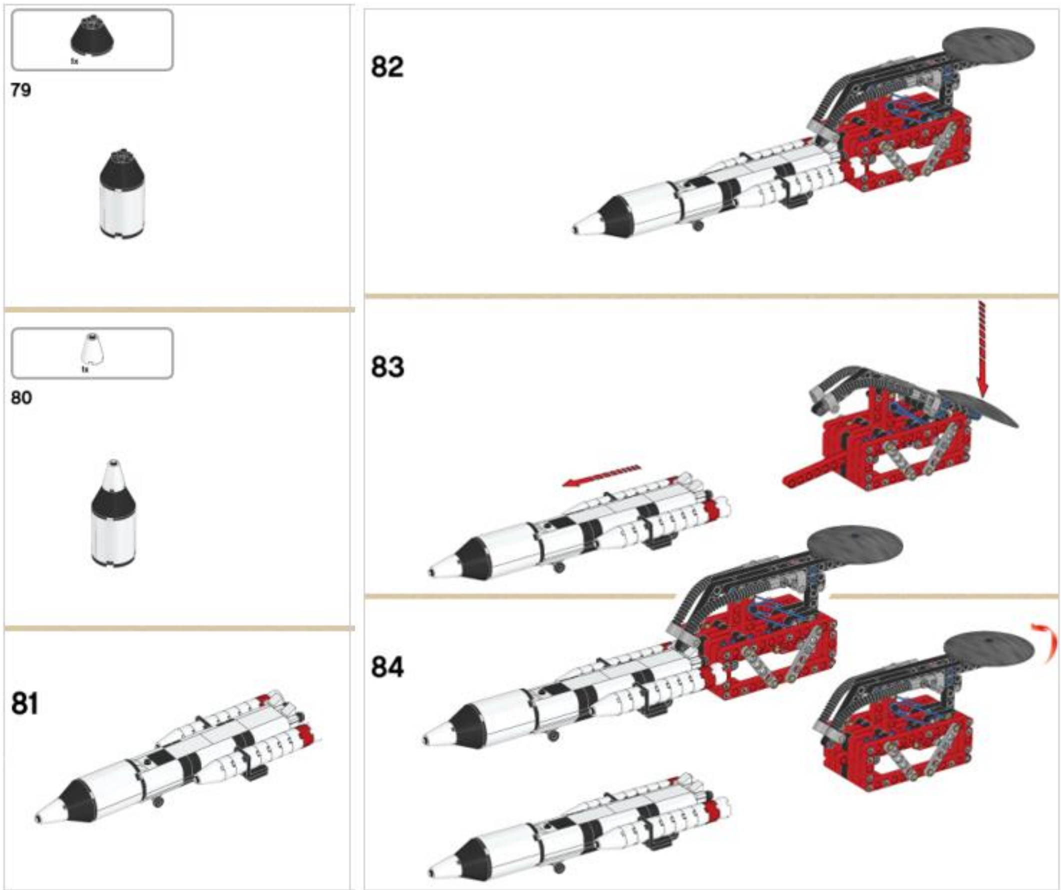
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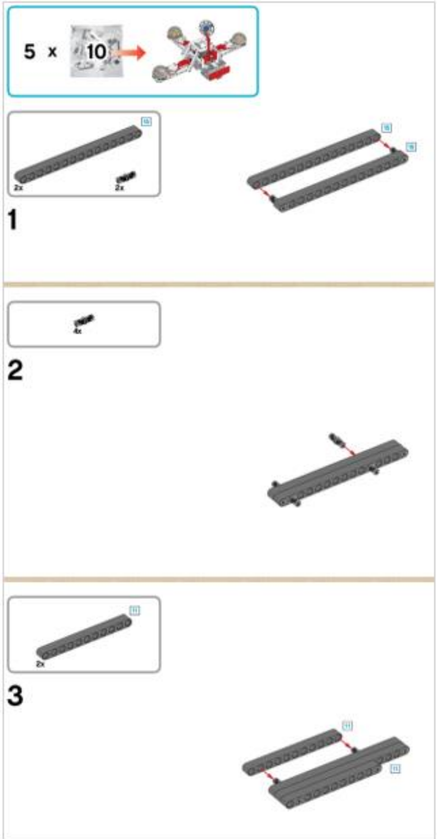
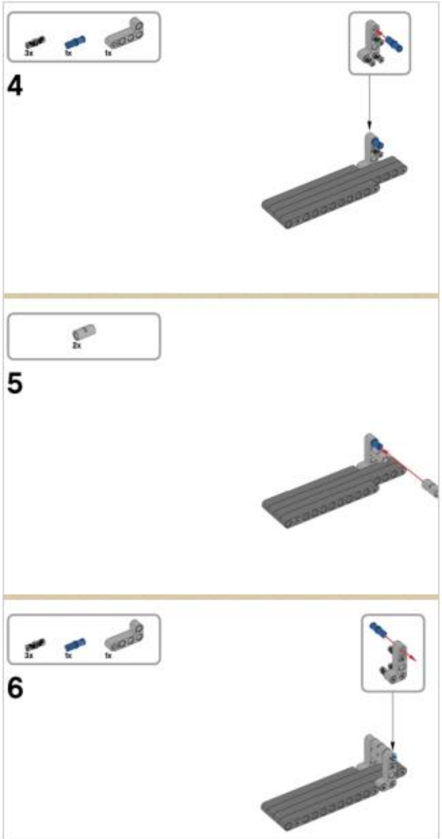
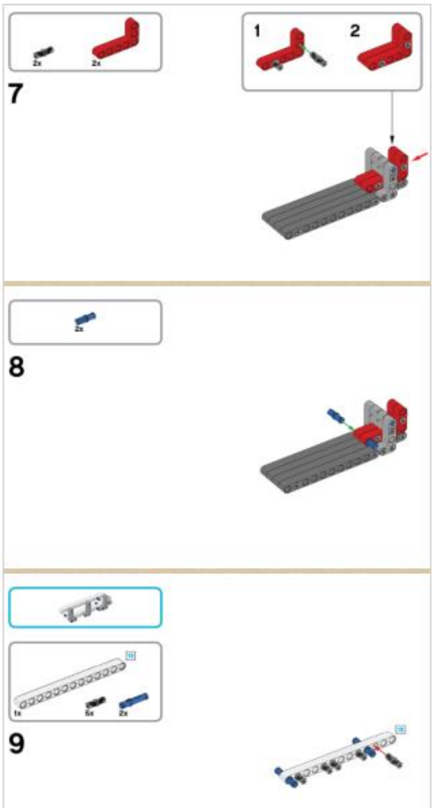
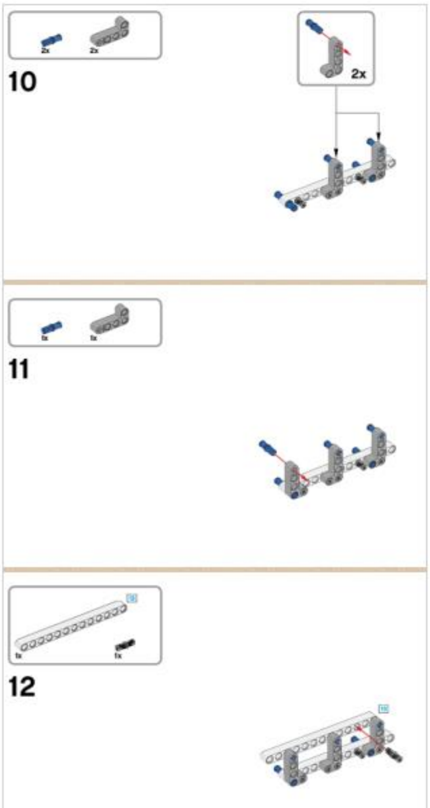
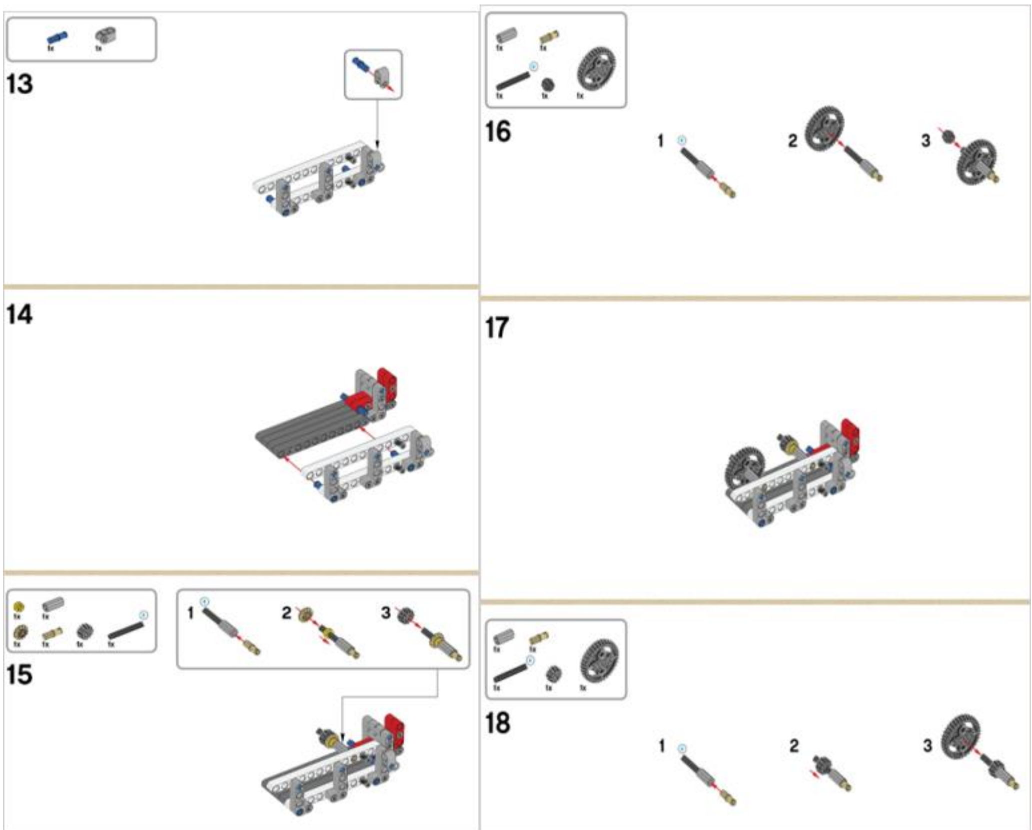
18. Mars outpost







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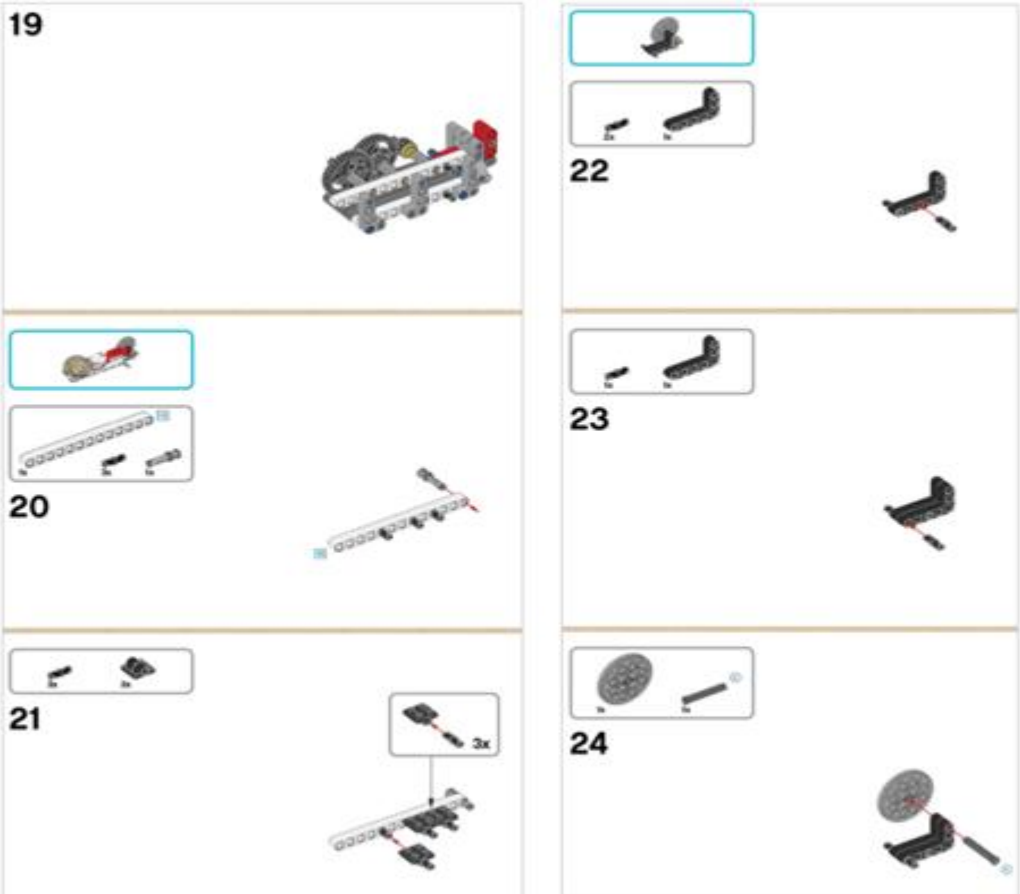
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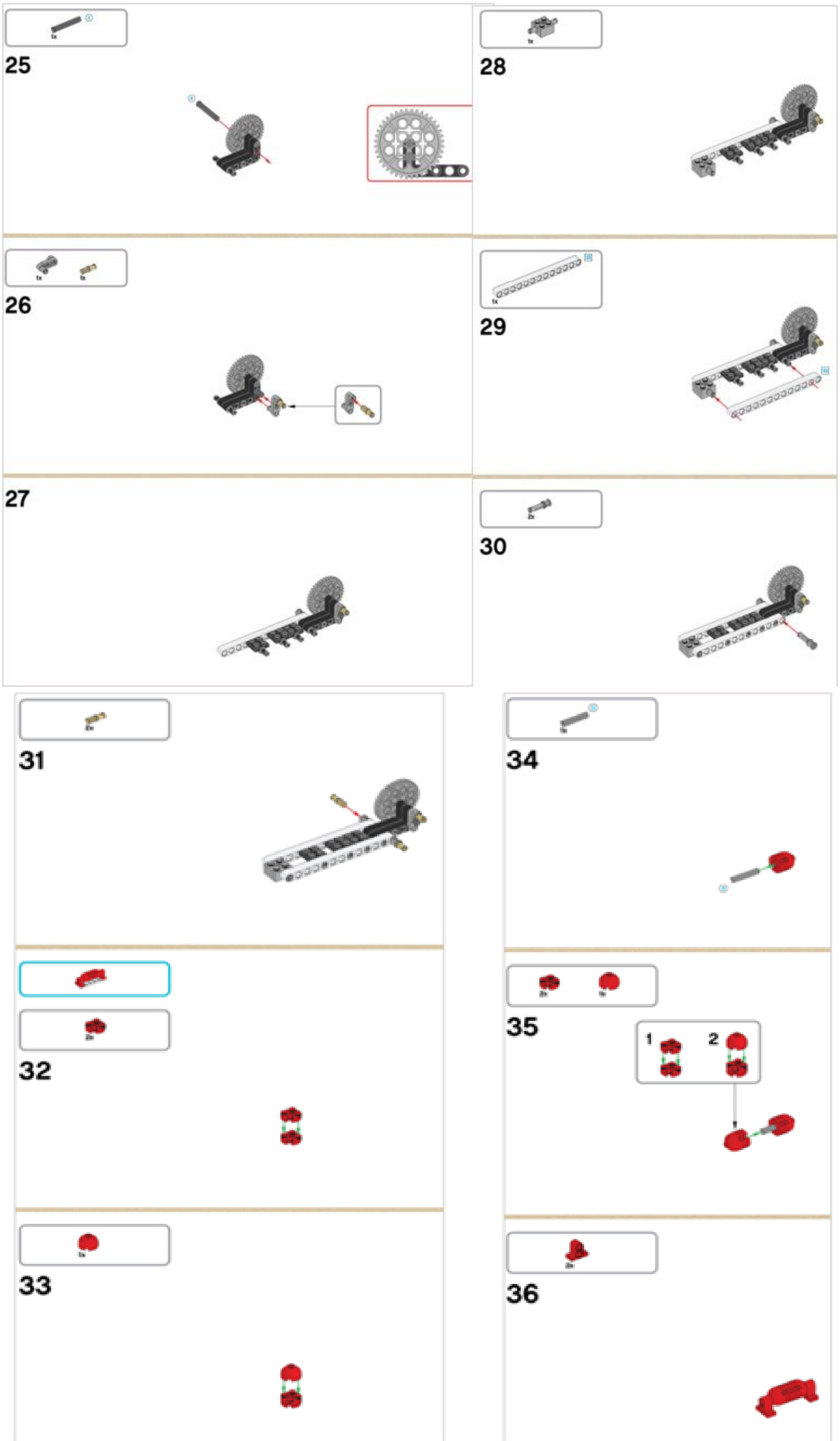
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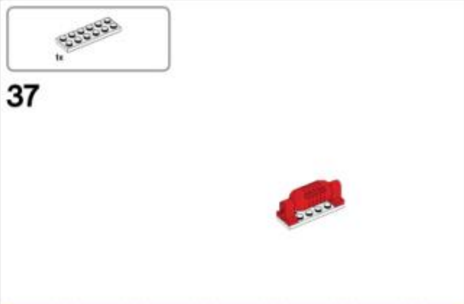

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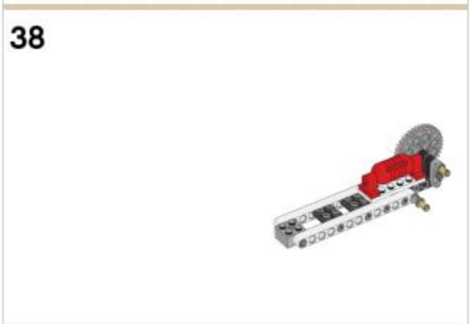

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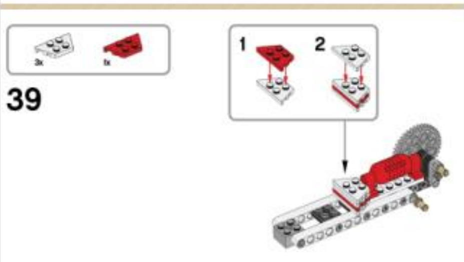

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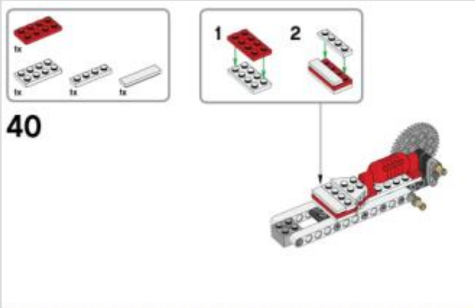

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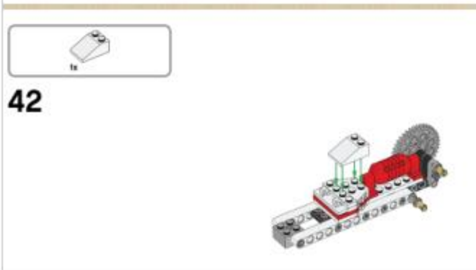

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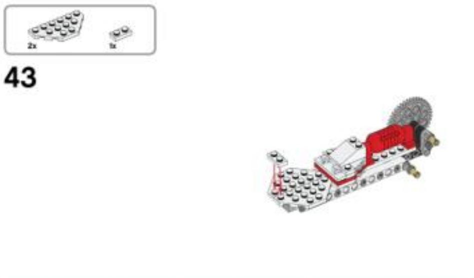

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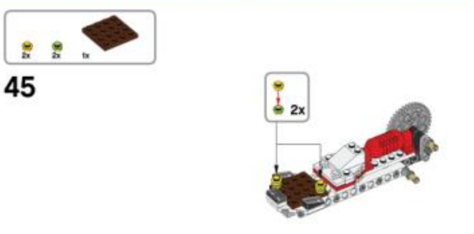

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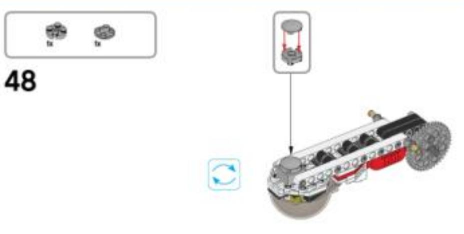

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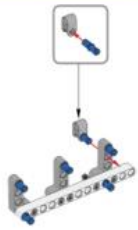

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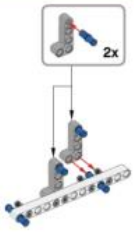

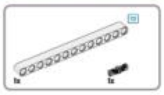

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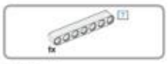

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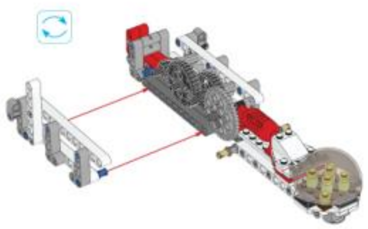

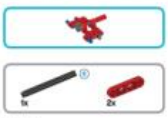

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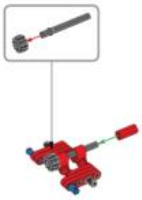

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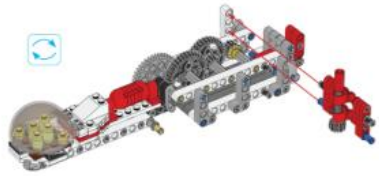

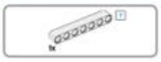

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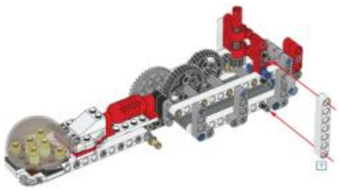

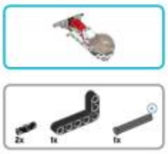

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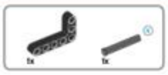

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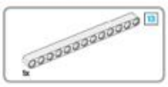

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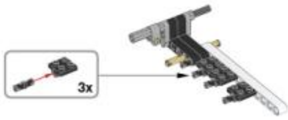

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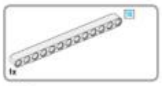

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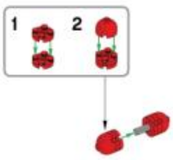

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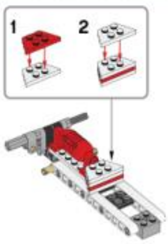

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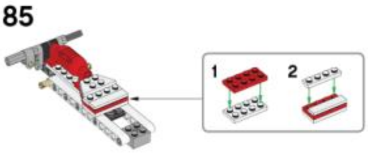

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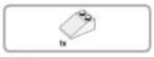

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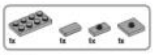

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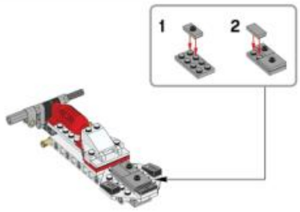

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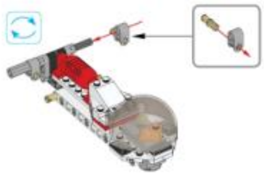

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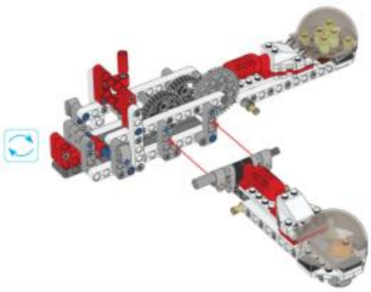

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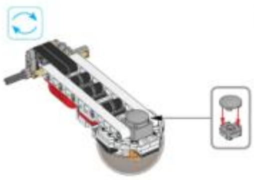

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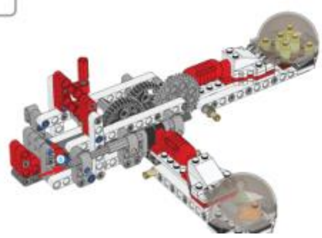

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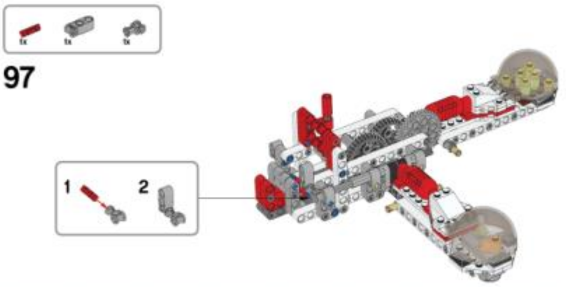

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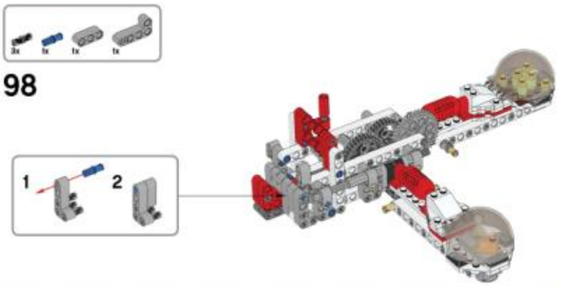

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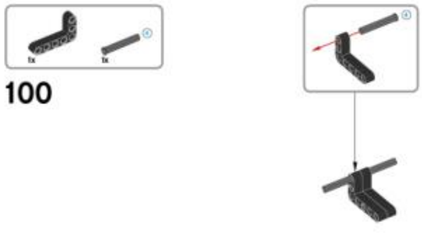

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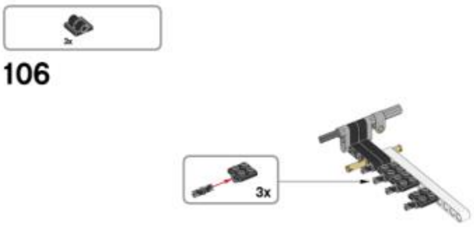

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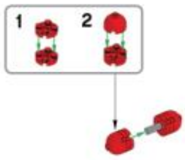

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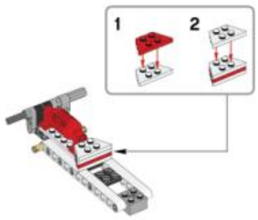

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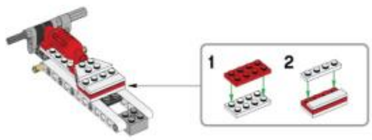

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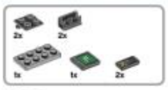

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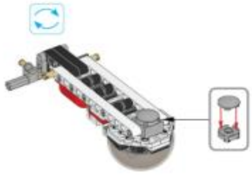

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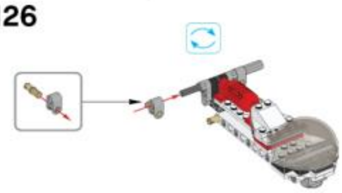

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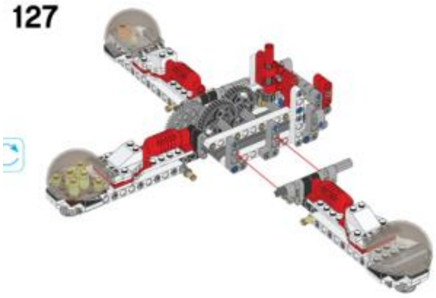

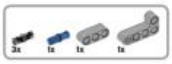

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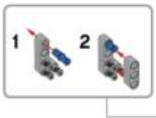

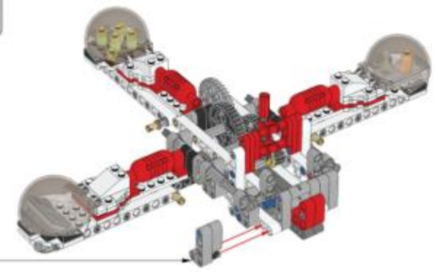

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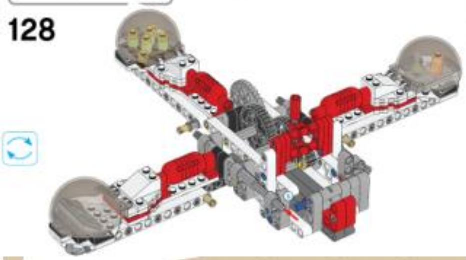

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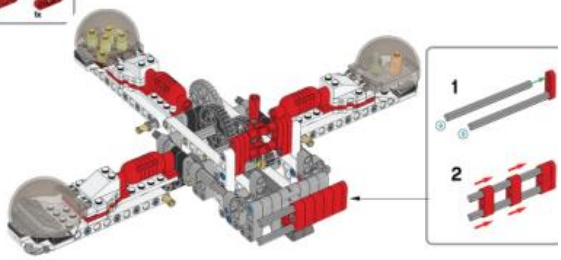

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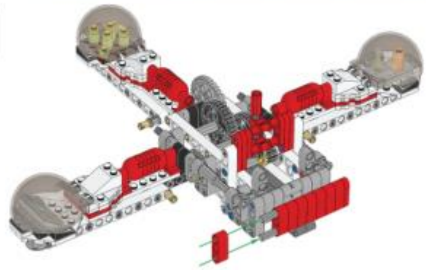

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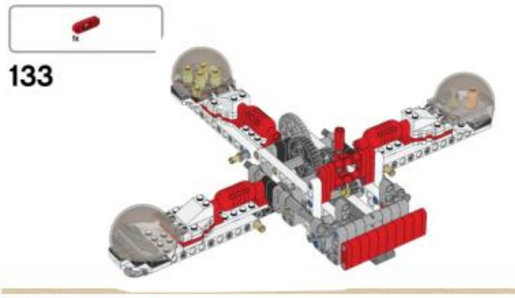

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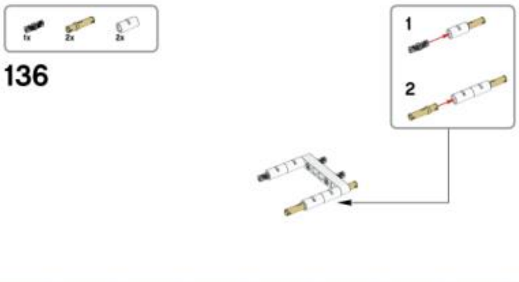

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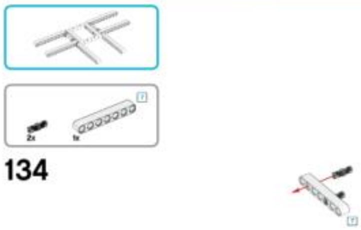

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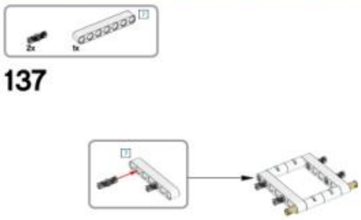

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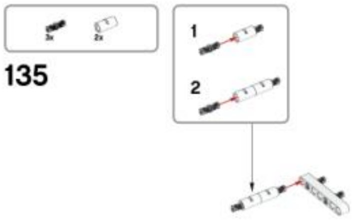

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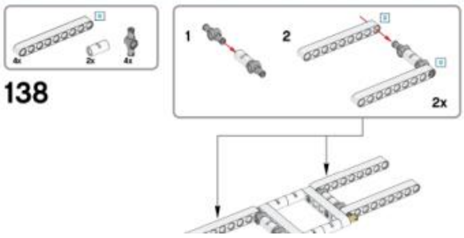

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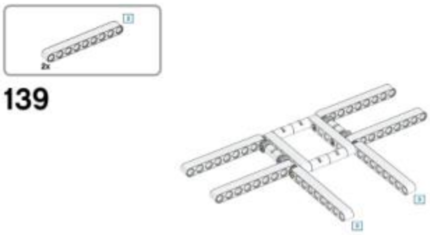

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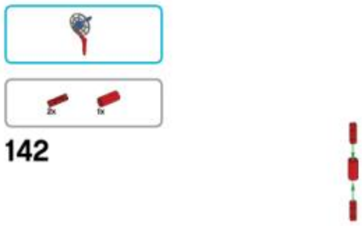

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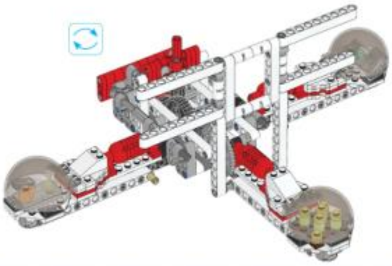

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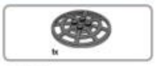

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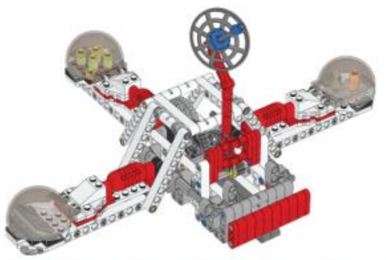

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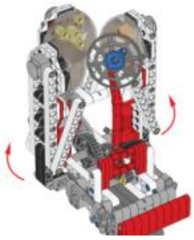

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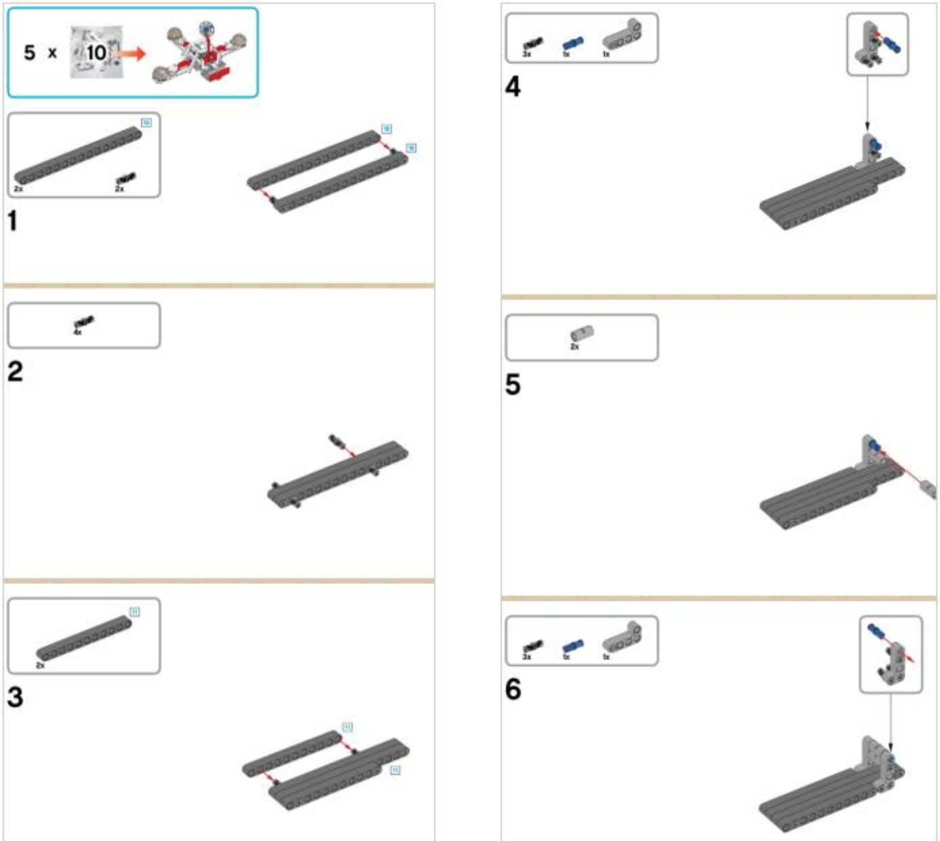
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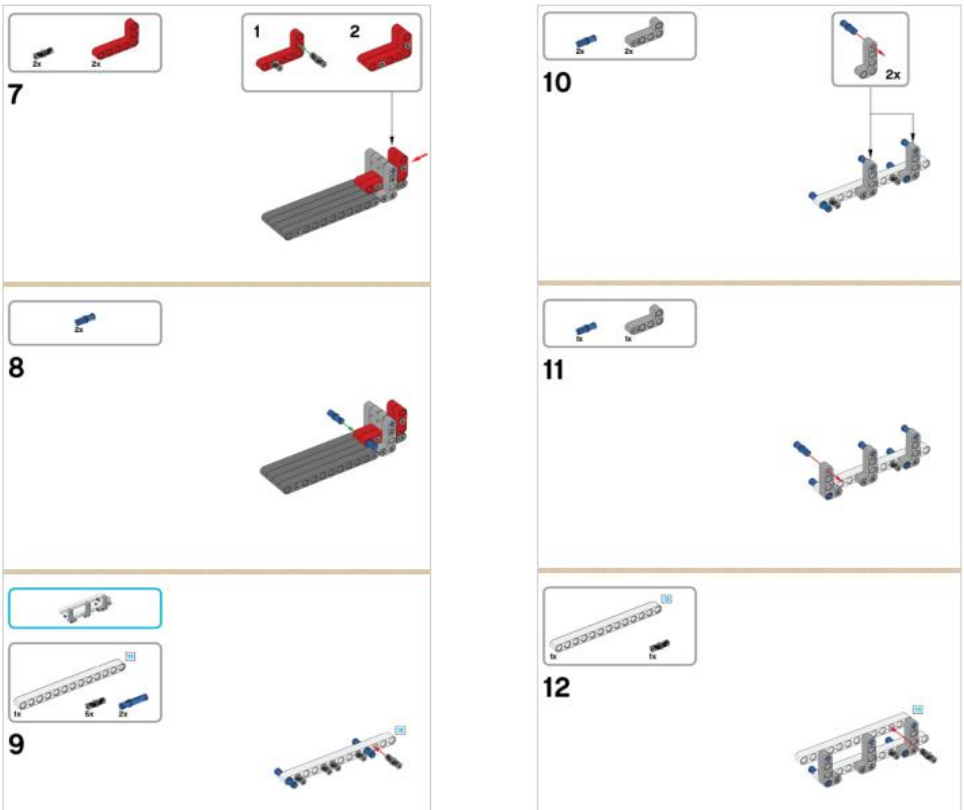
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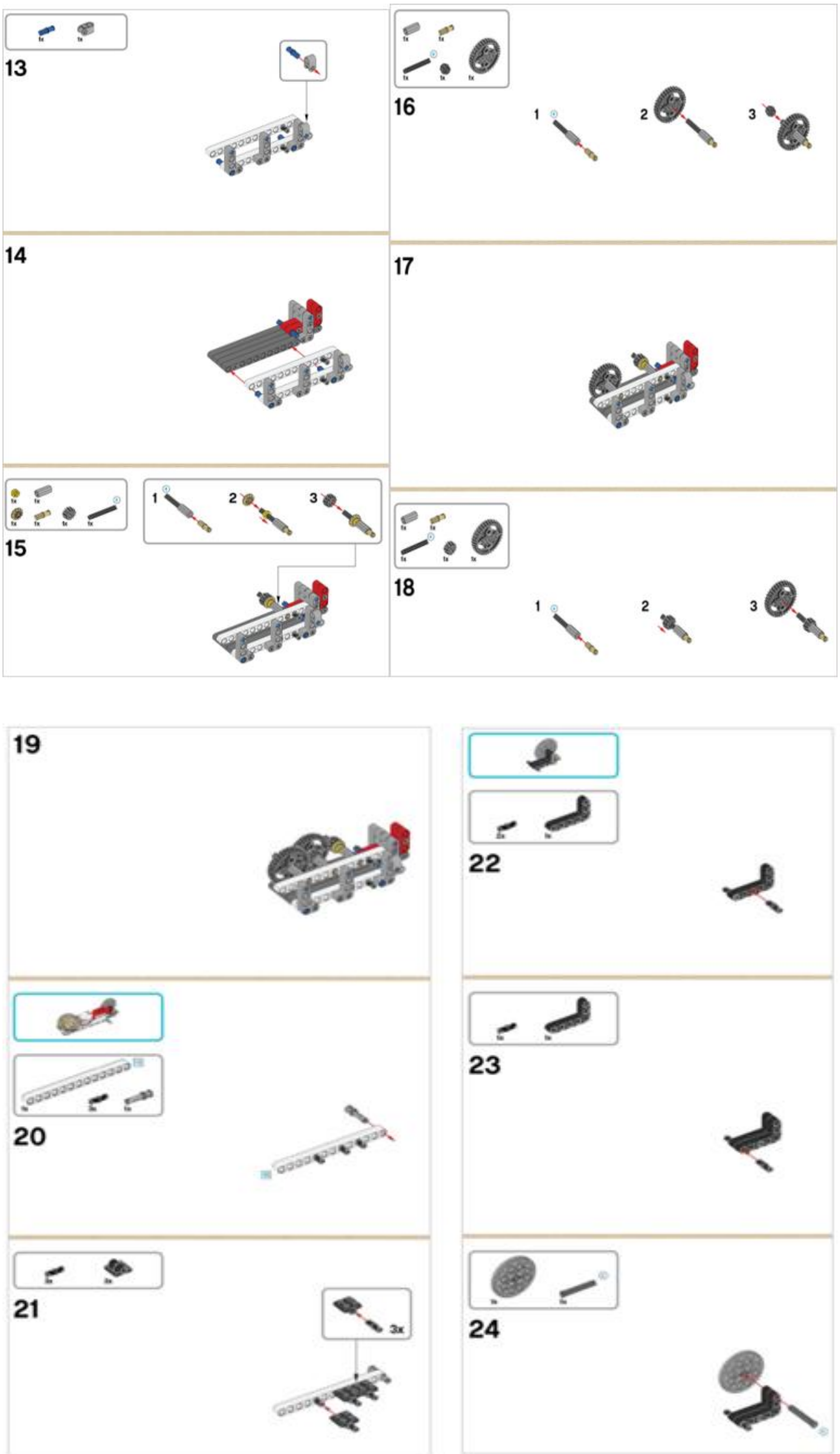
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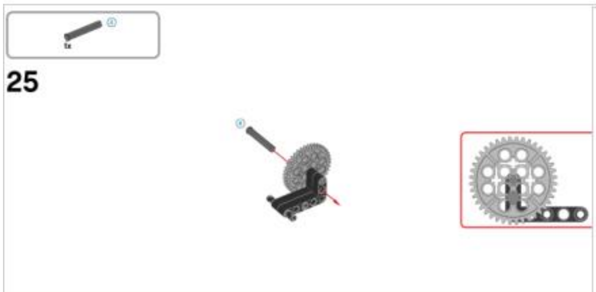

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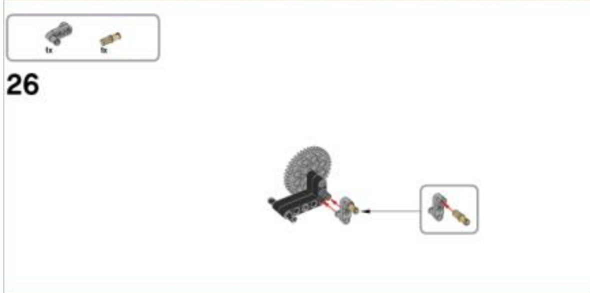

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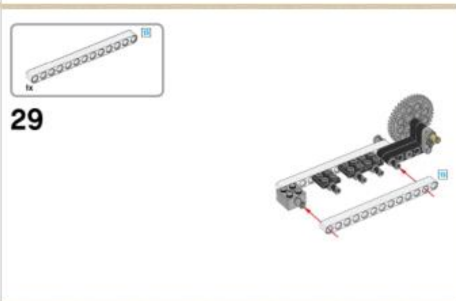

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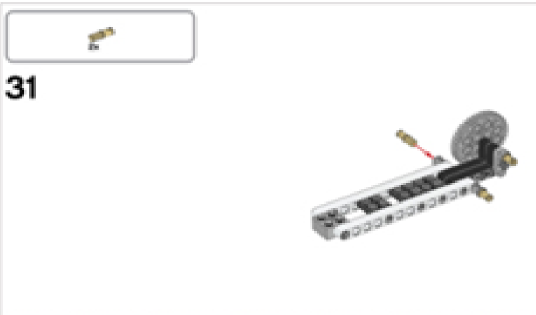

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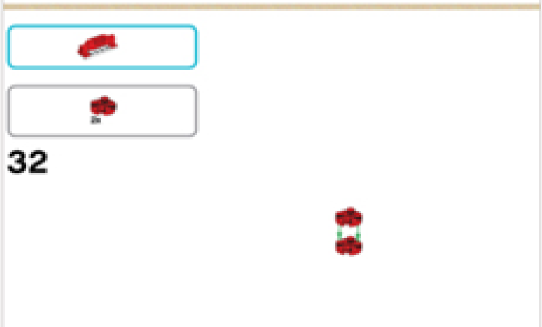

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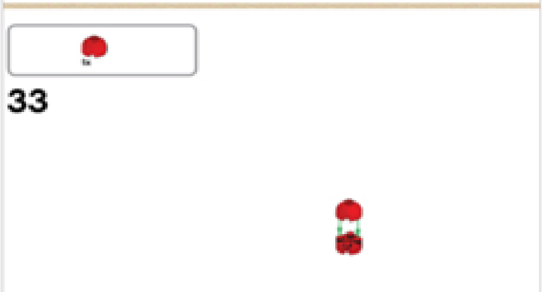

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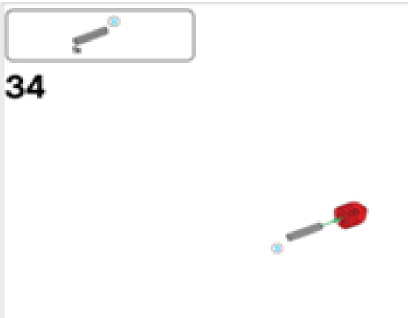

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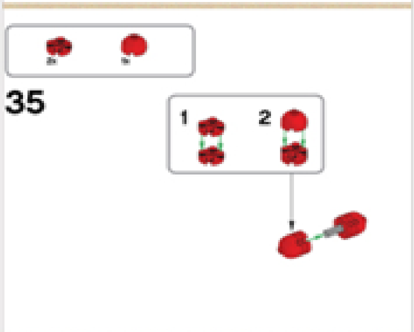

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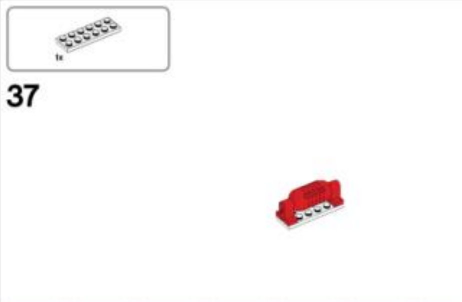

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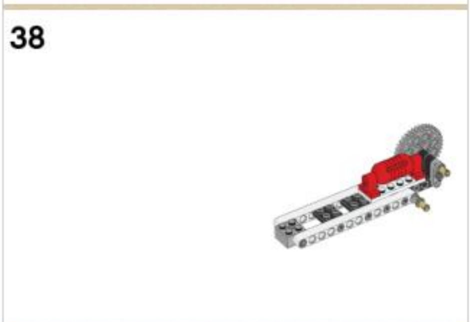

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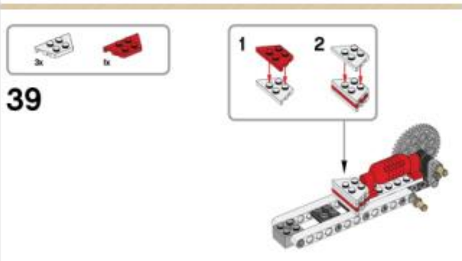

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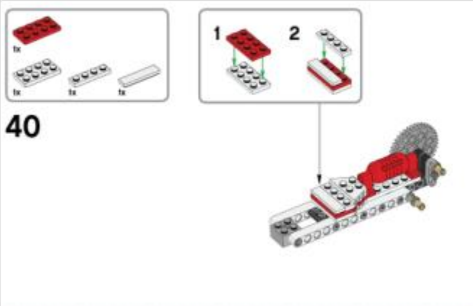

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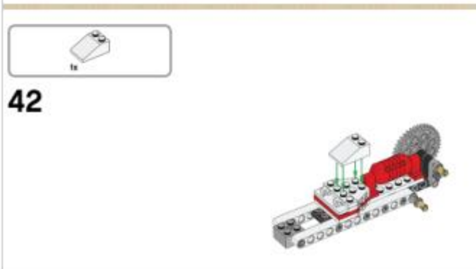

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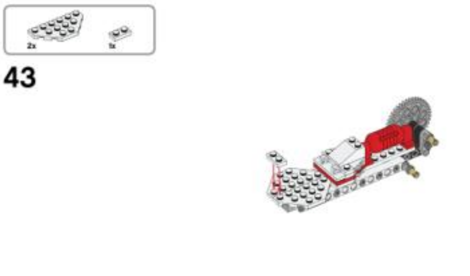

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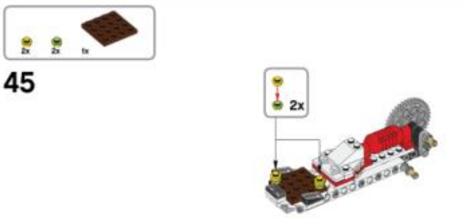

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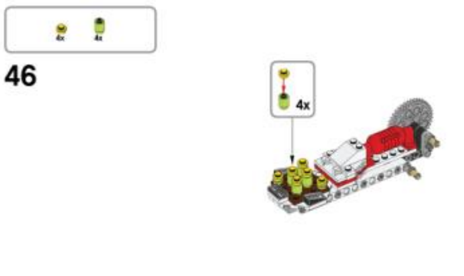

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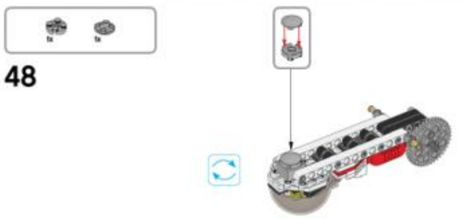

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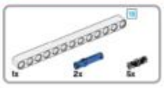

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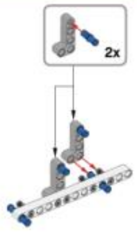

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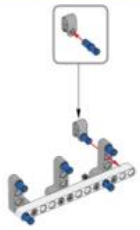

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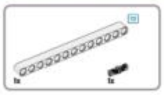

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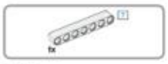

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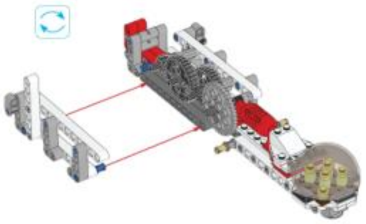

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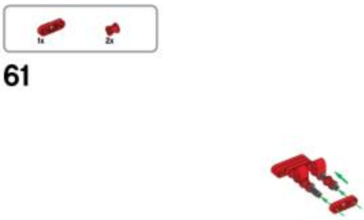

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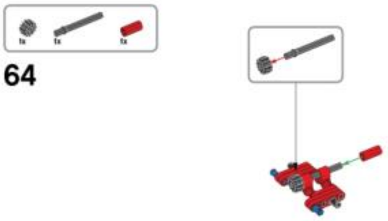

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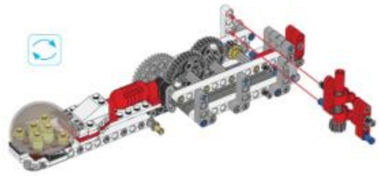

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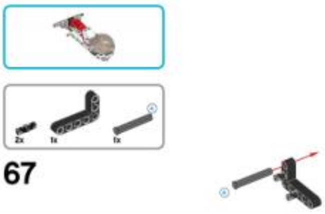

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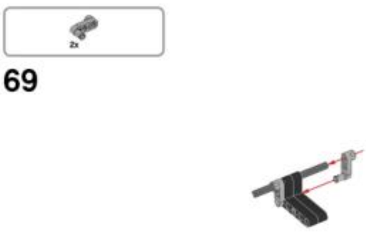

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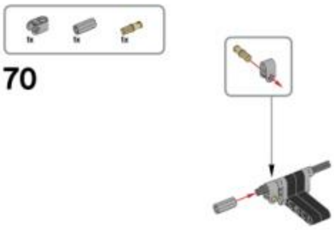

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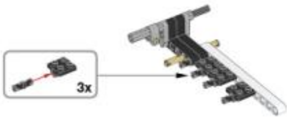

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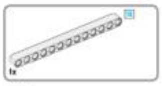

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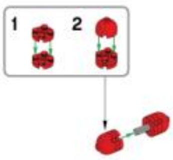

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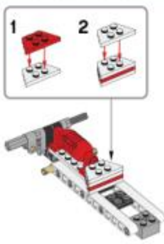

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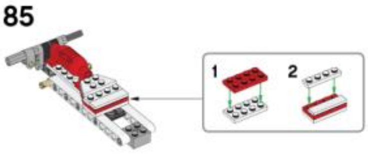

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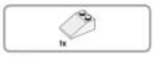

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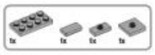

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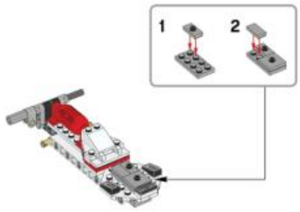

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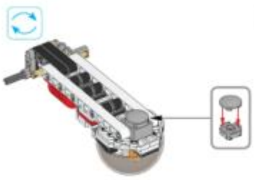

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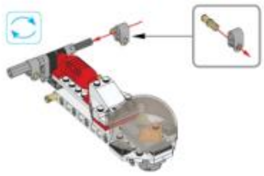

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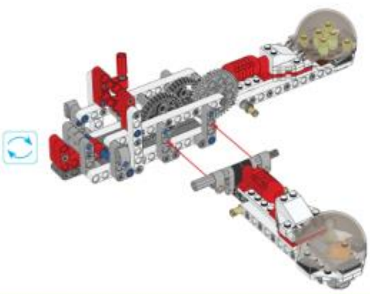

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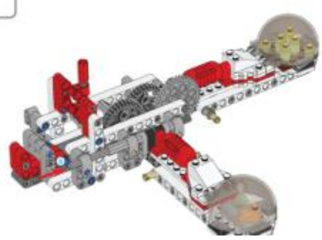

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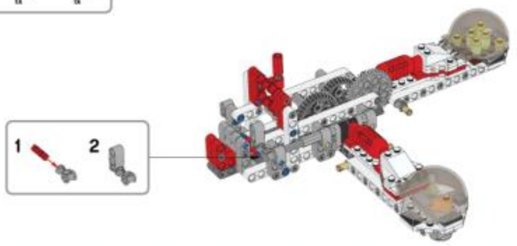

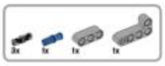

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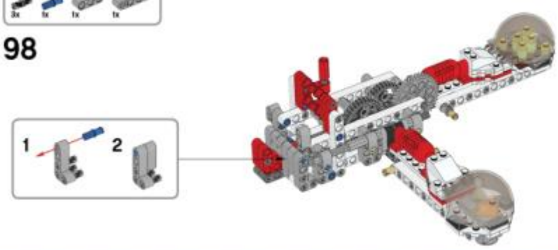

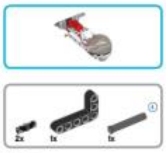

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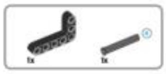

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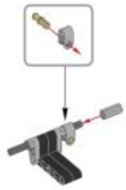

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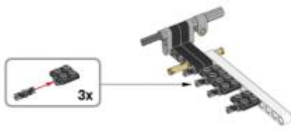

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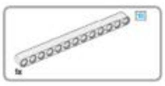

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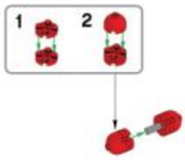

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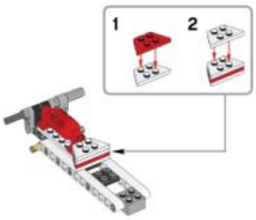

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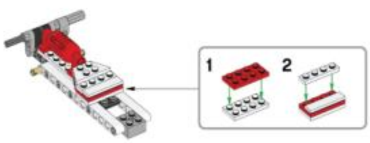

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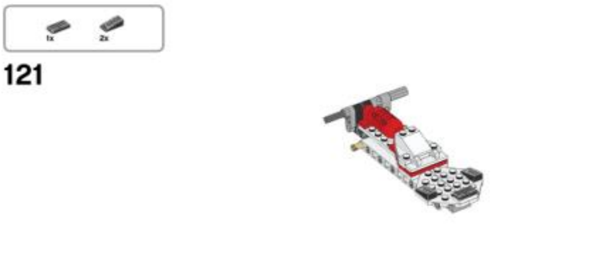

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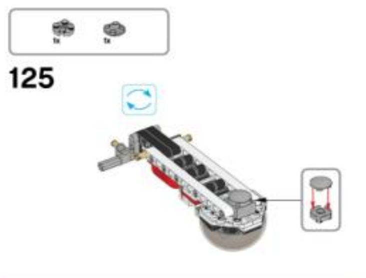

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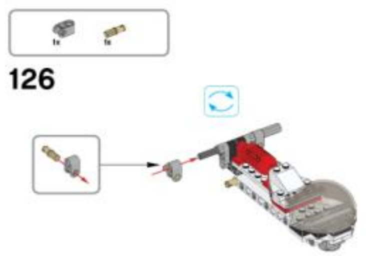

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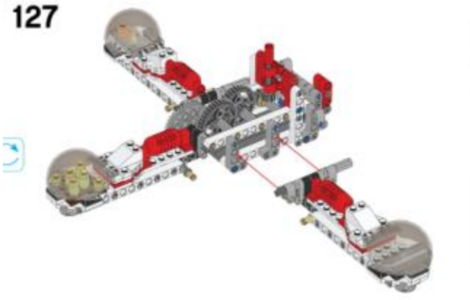

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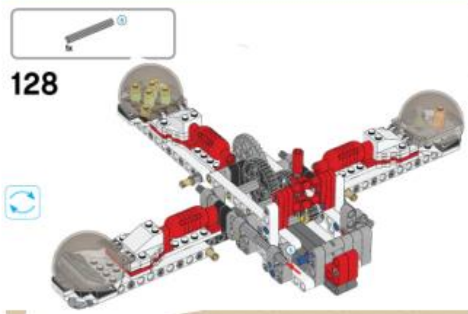

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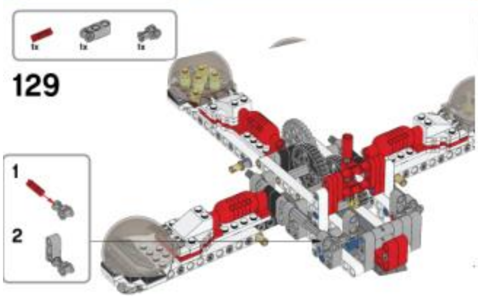

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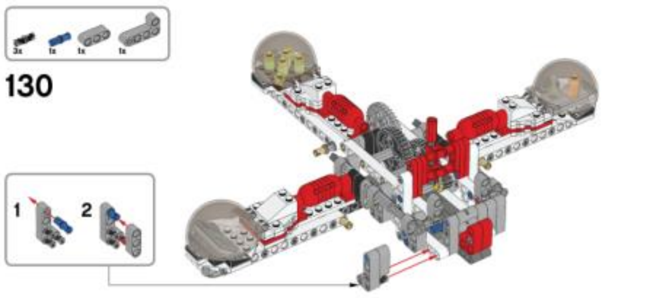

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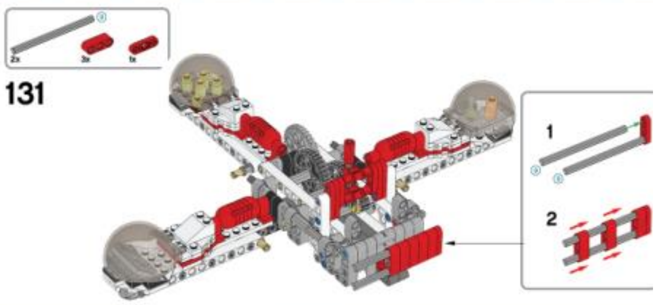

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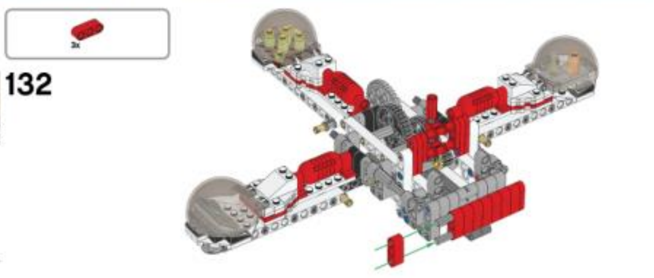

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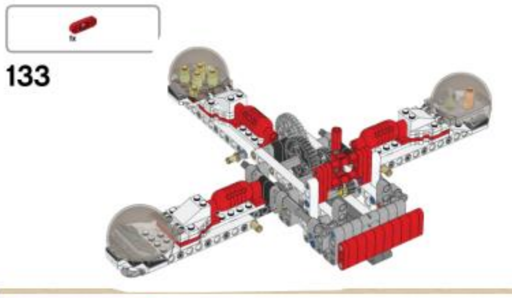

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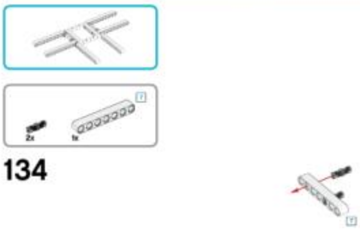

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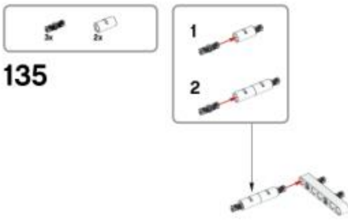

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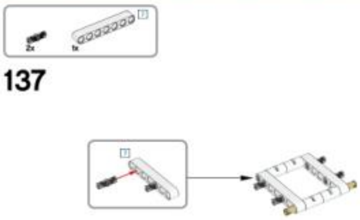

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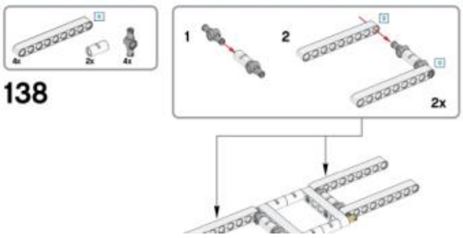

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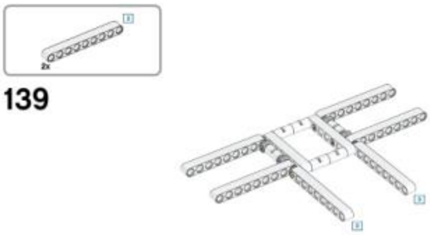

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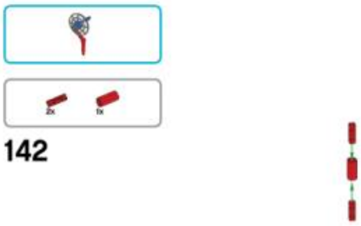

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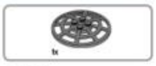

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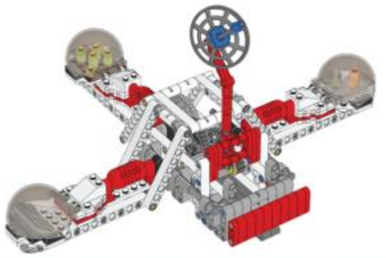

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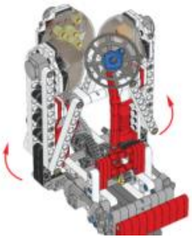

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