the LEGO satellite spotter

Thousands of human-made satellites orbit the earth. You can see some of them in the early morning or early evening, when light from the sun reflects off the satellite's surface. But satellites move quickly, sometimes remaining in sight for less than a minute. In this chapter, you'll build a mechanical pointer that you can aim at the sky to figure out where a satellite will pass by. The LEGO Satellite Spotter accepts data about future satellite passings, points toward those satellites' tracks, and emits a tone when a satellite is about to come into sight.

getting satellite data

Predicting a satellite's position involves complex mathematics, well beyond the scope of this book. Fortunately, several websites use satellite data from space agencies to predict satellite overpasses. These sites include Heavens Above (*https://heavens-above.com/*); Spot the Station (*https://spotthestation.nasa.gov/*), NASA's Skywatch application; and Spaceweather.com (*https://spaceweather.com/*). If you input your location, a date, and a time, these websites should tell you the following information about the satellites passing overhead:

The identity of the satellite The easiest satellites to see are the International Space Station and Mayak. The *International Space Station* is fun to look at because people are onboard—be sure to wave. *Mayak*, which is Russian for *beacon*, launched in 2017 after a crowd-funded program to build the satellite. Mayak features a bright reflector that makes it visible from the ground.

The brightness of the satellite Most satellites reflect too little light for you to see them easily, but a few can be quite bright. We calculate the brightness of satellites by using a measure called *apparent magnitude*, which decreases as objects get brighter. The International Space Station can reach a magnitude of –6 (the brightest star in the sky is Sirius, with a magnitude of –1.5).

The start time The satellite will come into view at a particular time. You'll want to start looking in the appropriate direction just before this time.

The azimuth angle at the start time *Azimuth* is the angle to your left or right, as indicated by a compass. The satellite will come into view at this particular compass angle.

The elevation angle at the start time The satellite will come into view at a particular angle above the horizon.

Collect these values so you can input them to the program for the LEGO Satellite Spotter. Table 1 shows this data for an unusually active night. The International Space Station completes an orbit around the earth in about 90 minutes, so sometimes it can be seen more than once in an observing session.

TABLE 1: **Satellite Overpass Data for an Observing Session Planned for July 14, 2020**

SATELLITE ID	BRIGHTNESS (APPARENT MAGNITUDE)	START TIME (UTC)	START TIME (LOCAL)	START AZIMUTH (DEGREES)	START ELEVATION (DEGREES)
International Space Station	–3.5	01:30:03	21:30:03	202.5	10
Mayak	1	01:56:46	21:56:46	67.5	10
International Space Station	–1.1	03:07:29	23:07:29	270	10
Mayak	–0.4	03:30:02	23:30:02	0	10

The satellite prediction websites can help you find the best times for viewing satellites based on your location. More satellites will pass by on some nights or mornings than others.

building the LEGO satellite spotter

The LEGO Satellite Spotter (Figure 1) uses a pair of motors to point a Technic beam at the correct elevation and azimuth.

The beam has a light brick attached to the end, making the pointer easy to see in dark conditions. The LEGO Satellite Spotter also uses the Dexter Industries dGPS to measure the time, which it needs to keep track of the satellite's start time.

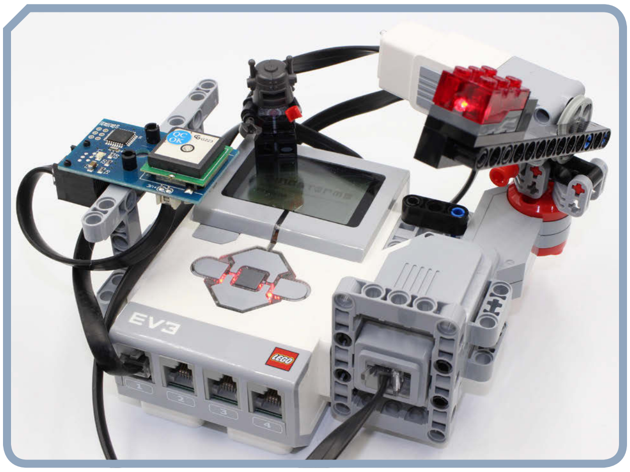


FIGURE 1: The LEGO Satellite Spotter uses a GPS sensor and two motors.

what you'll need

Figures 2 and 3 show the LEGO parts you'll need.

In addition to these parts, the LEGO Satellite Spotter uses the dGPS sensor from Dexter Industries, also used in the LEGO Car Tracker bonus project, to measure time.

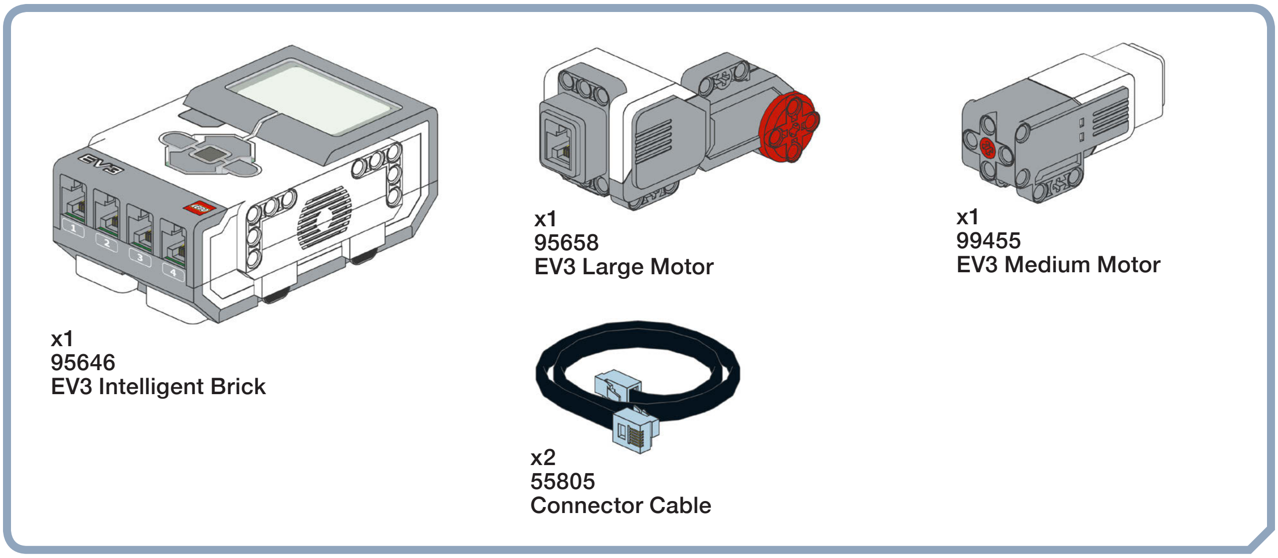


FIGURE 2: *EV3 parts used to build the LEGO Satellite Spotter*

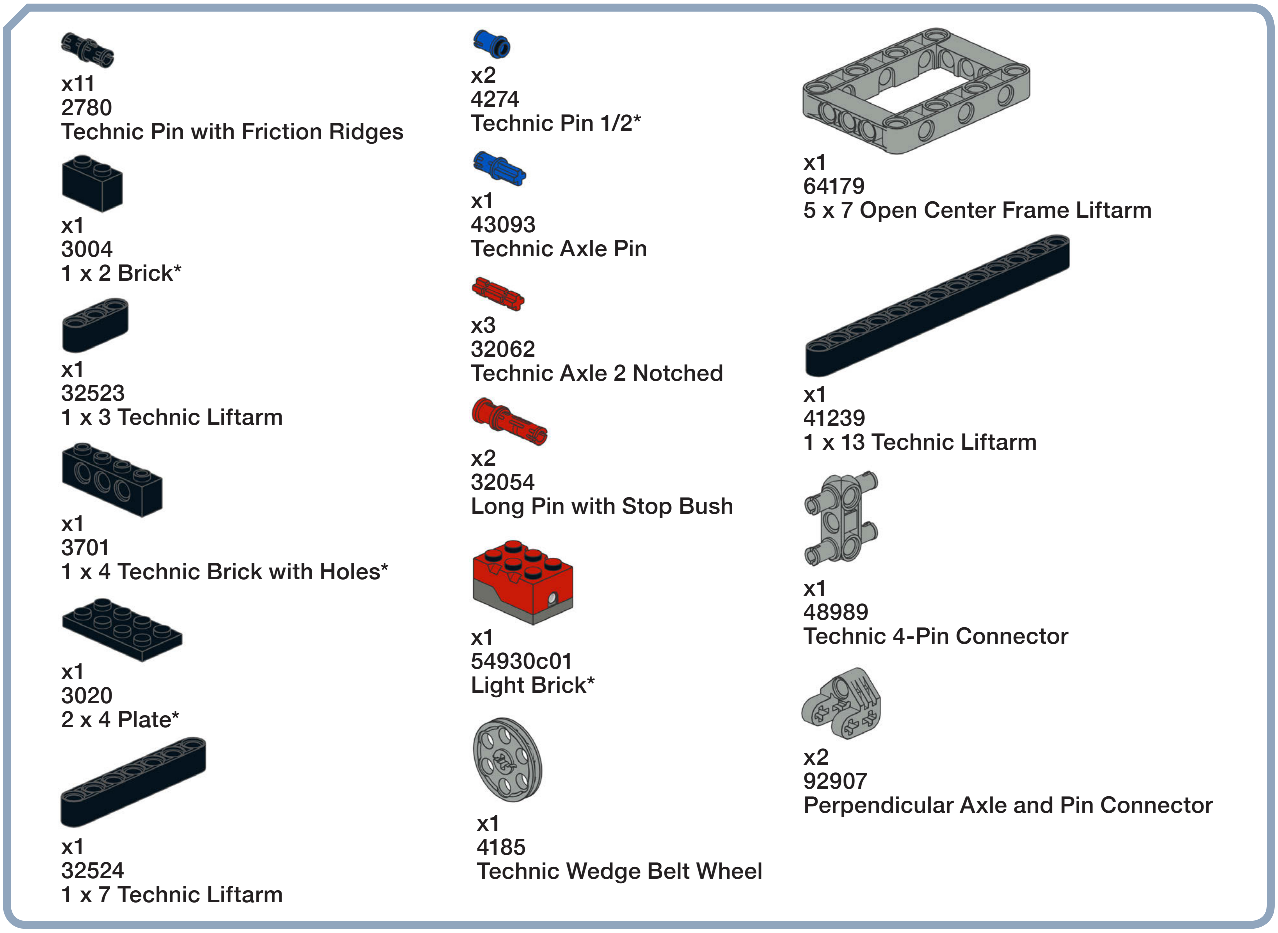


FIGURE 3: *Other LEGO parts used in the LEGO Satellite Spotter. Parts marked with an asterisk are not in the MINDSTORMS EV3 #31313 set.*

building the pointer

The LEGO Satellite Spotter uses two motors: an EV3 Large Motor to point toward the azimuth, which can be anywhere from 0 to 360 degrees, and an EV3 Medium Motor to point toward the elevation, which can be anywhere from 0 to 90 degrees. The EV3 Medium Motor rides on the EV3 Large Motor, as shown in Figure 4.

Use the following building instructions to build the motorized pointing arm. The mount for the dGPS is the same as the one used in the LEGO Car Tracker bonus project, moved to the other side of the EV3 Intelligent Brick.

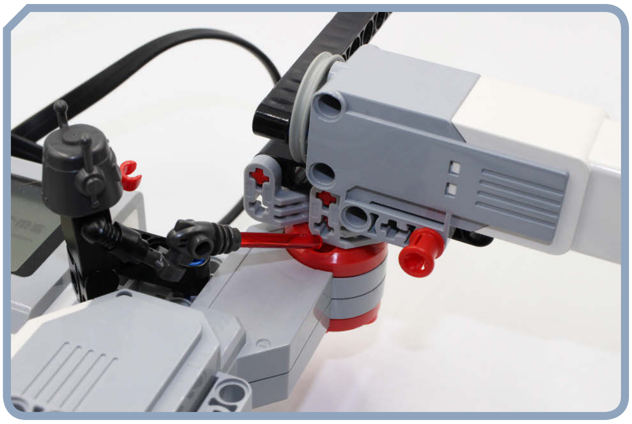
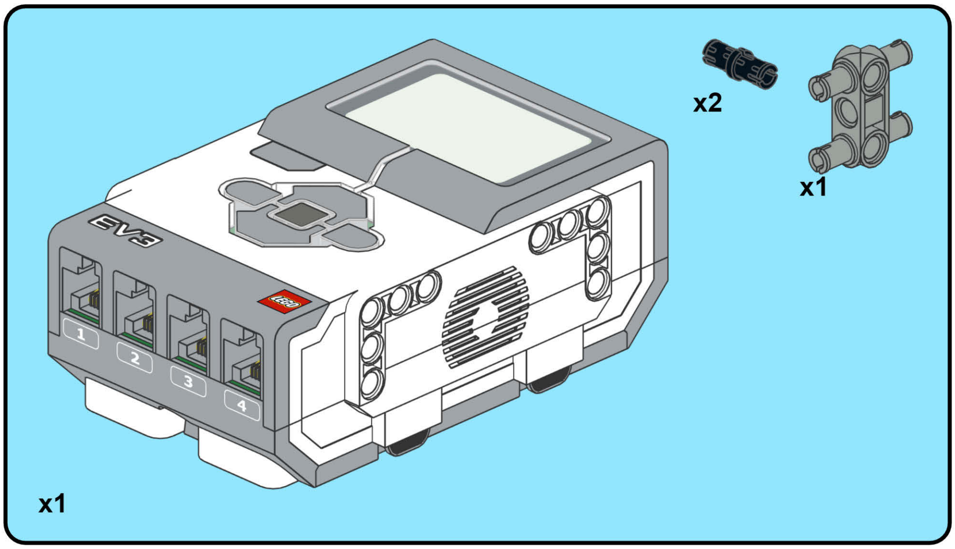


FIGURE 4: The EV3 Medium Motor rides on top of the EV3 Large Motor.



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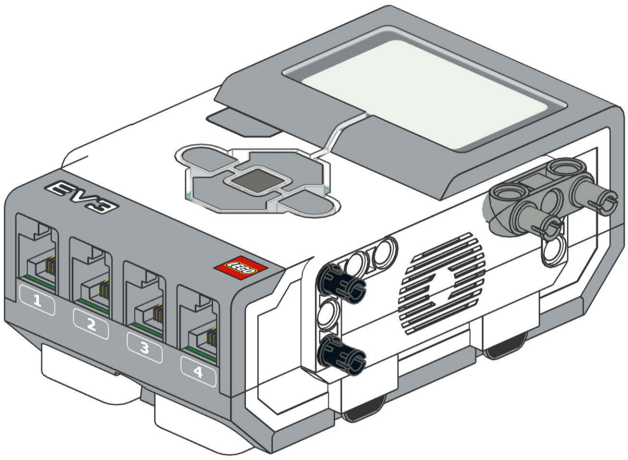

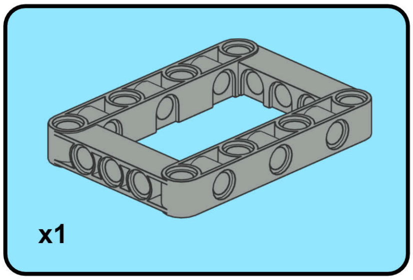

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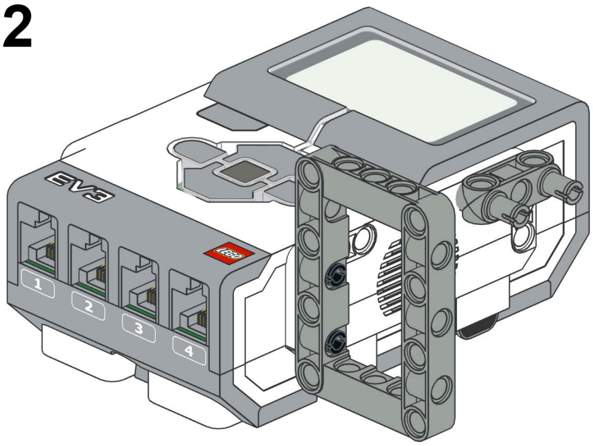

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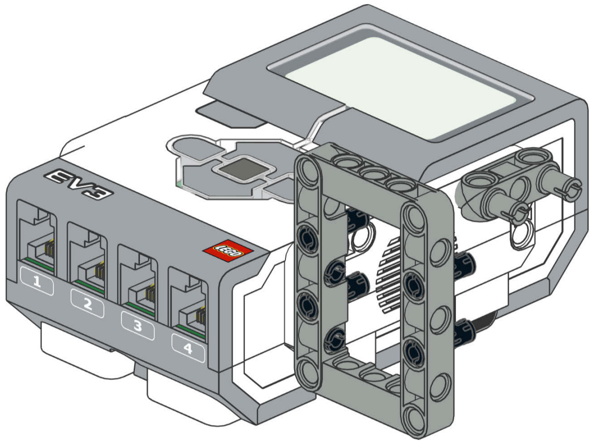

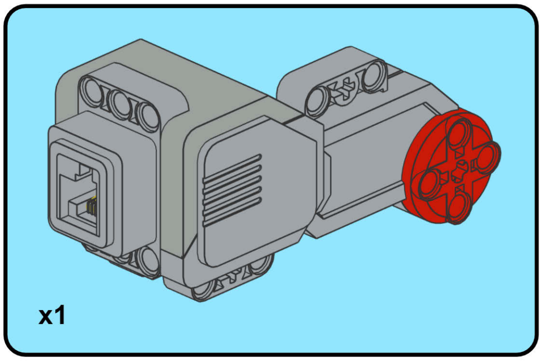

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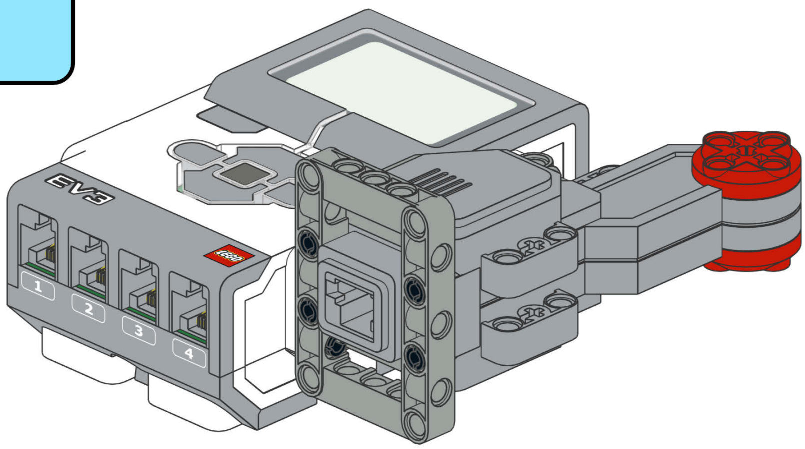

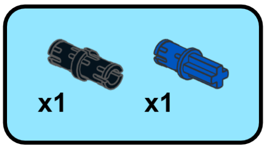

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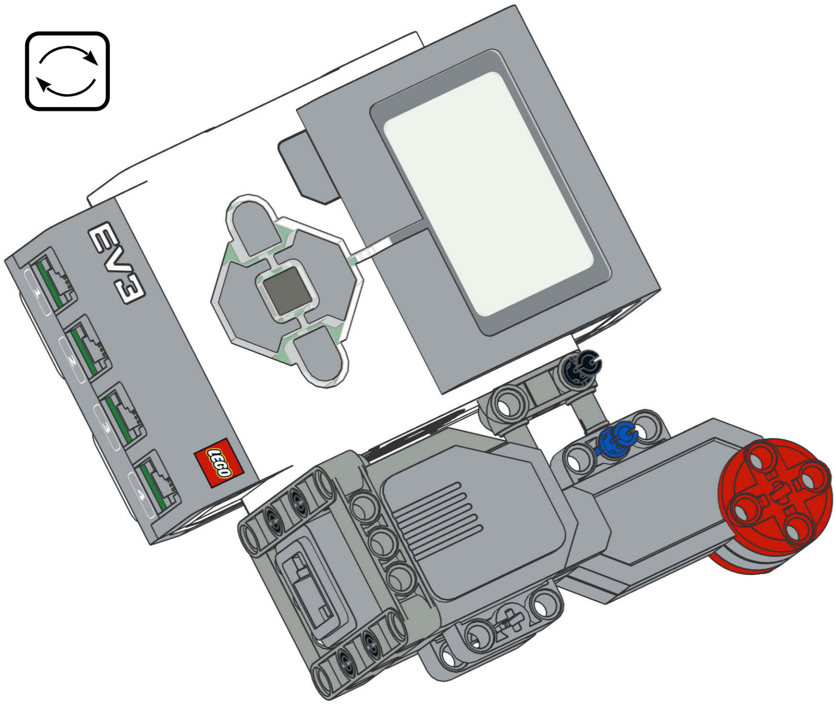

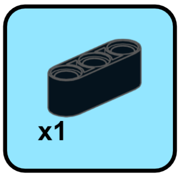

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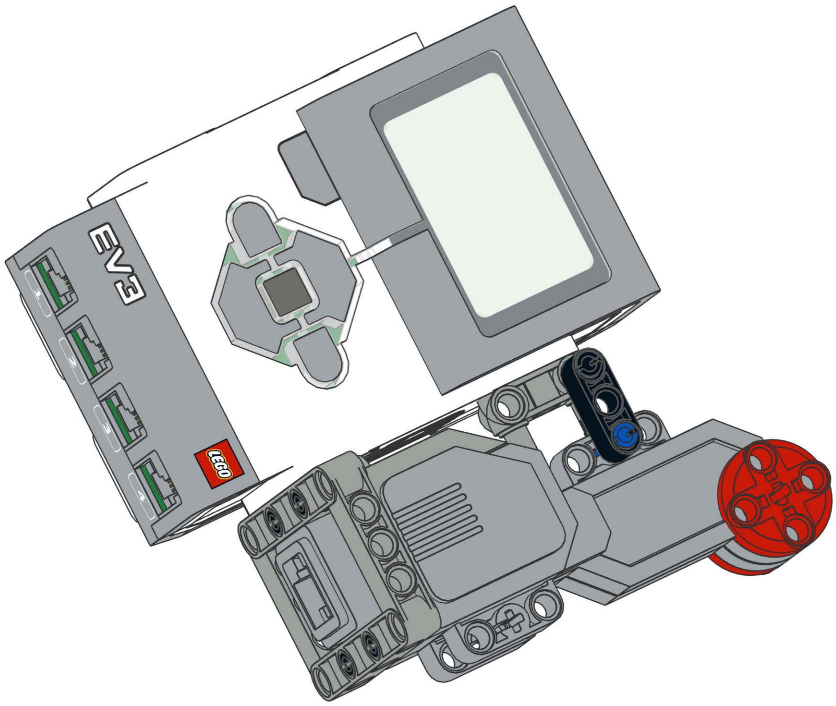

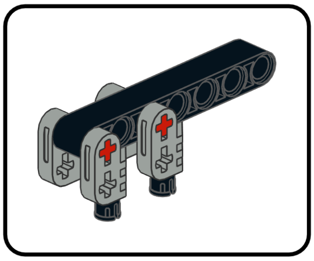

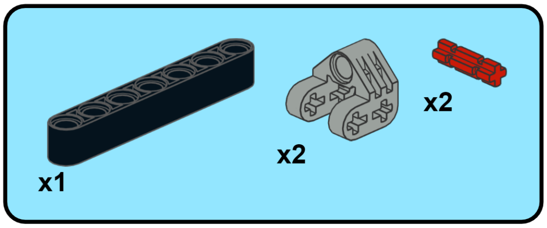

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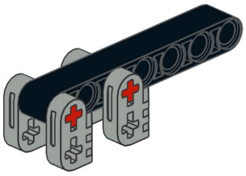

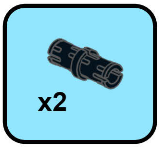

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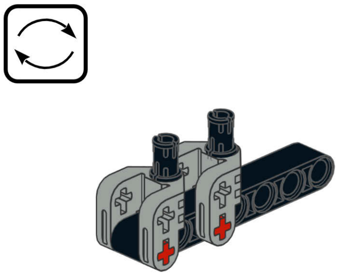

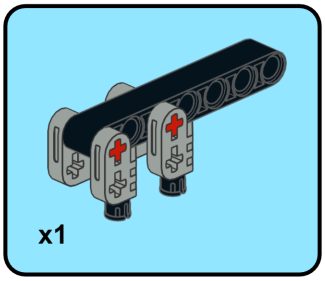

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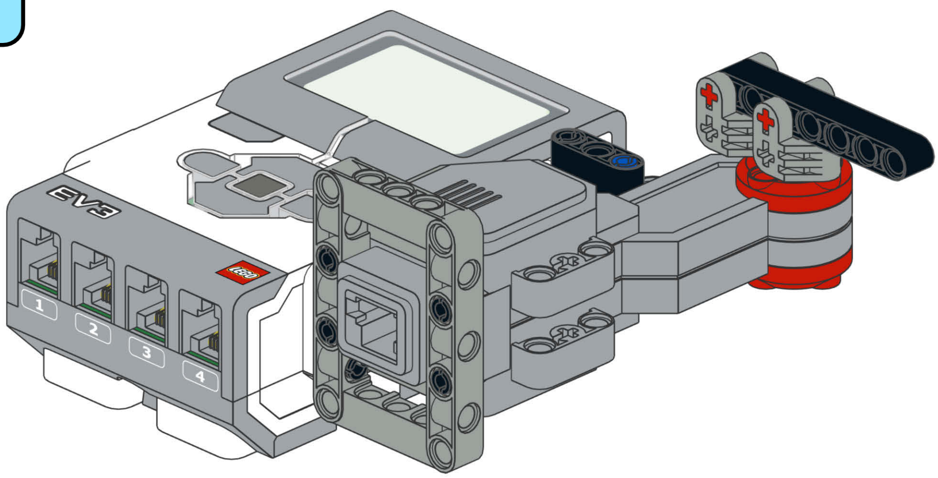

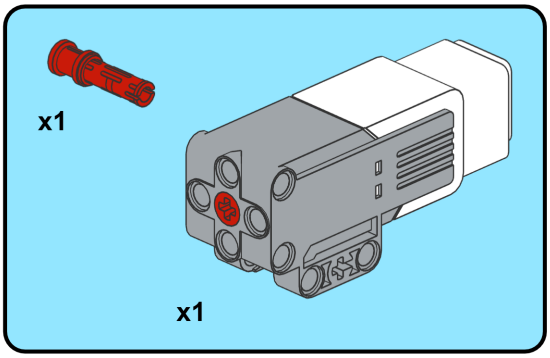

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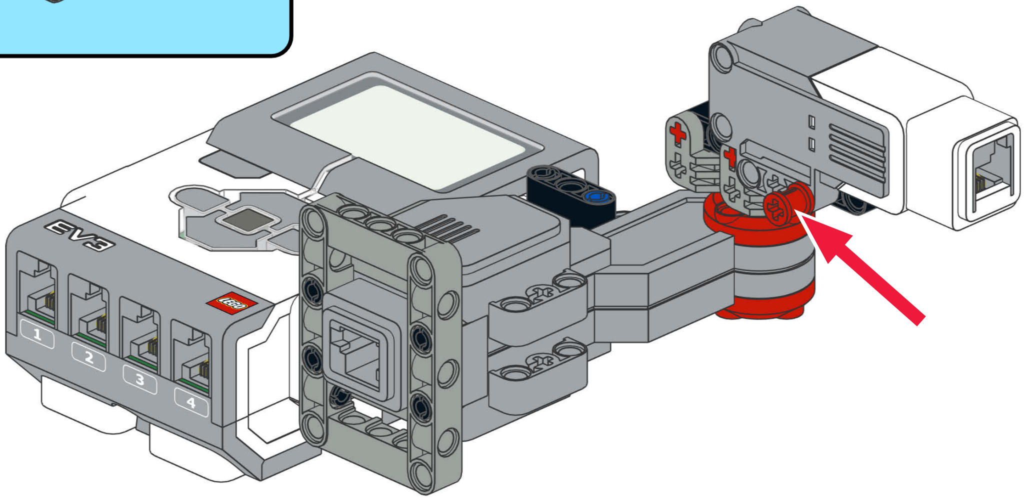

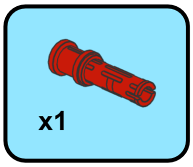

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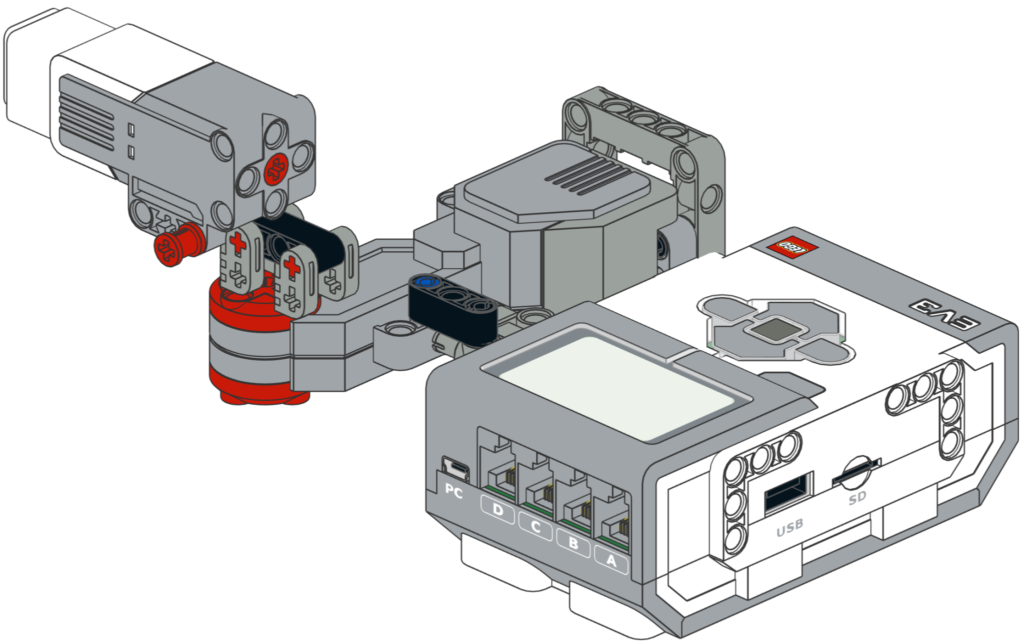

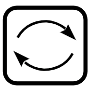

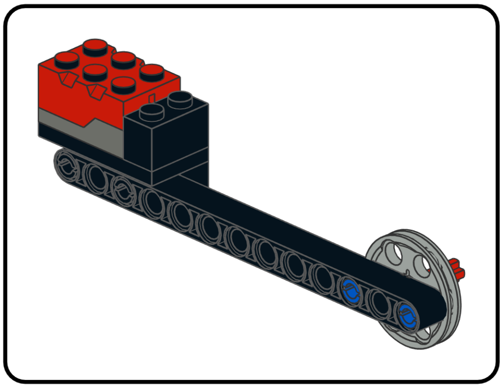

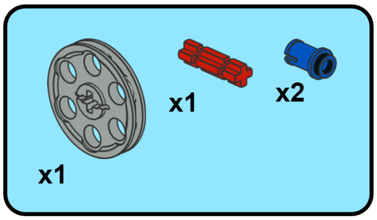

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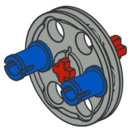

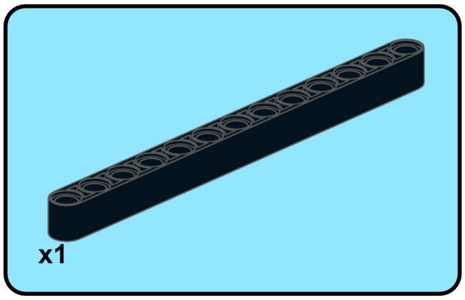

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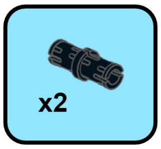

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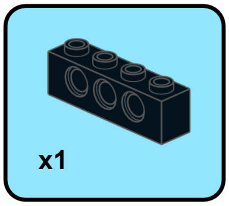

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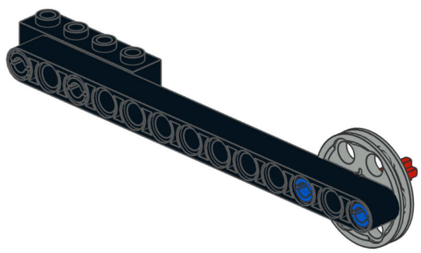

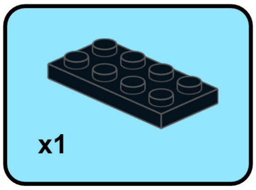

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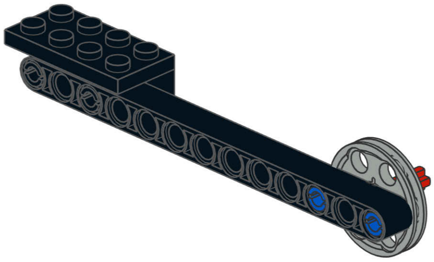

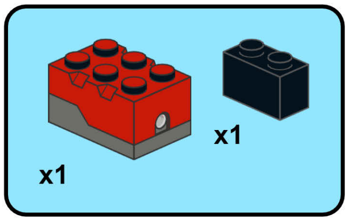

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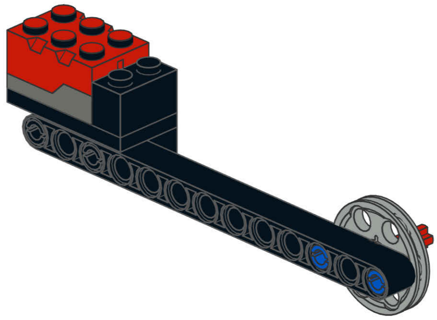

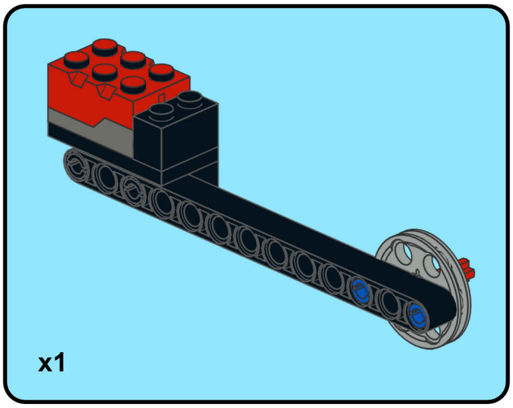

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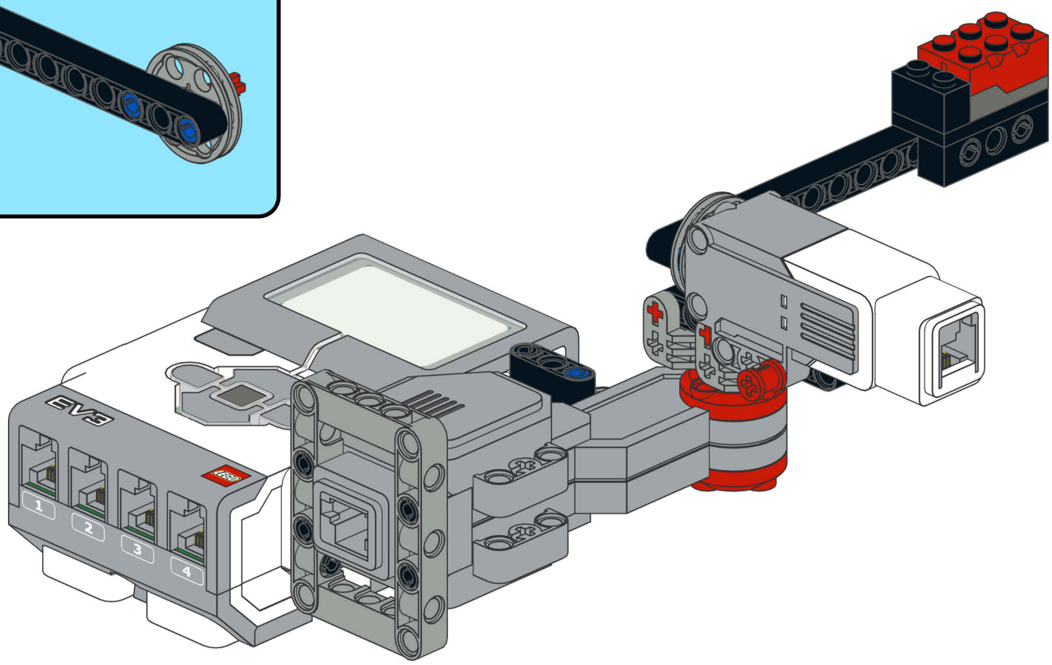

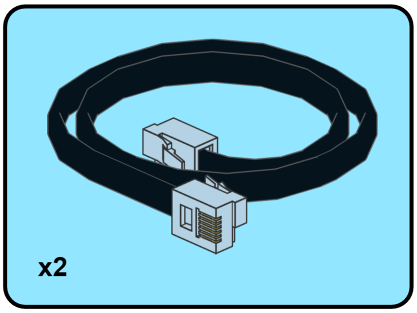

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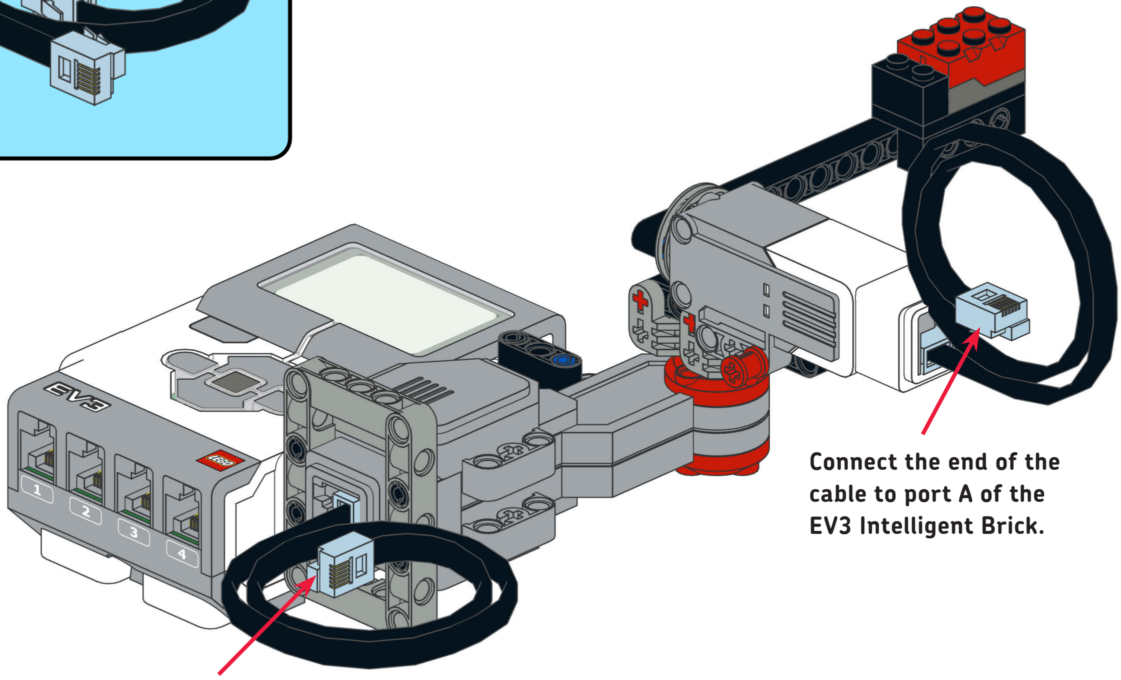


Connect the end of the cable to port A of the EV3 Intelligent Brick.

Connect the end of the cable to port D of the EV3 Intelligent Brick.

writing the software

The program for the LEGO Satellite Spotter, shown in Figure 5, uses an incoming satellite's start time and start angles, like the ones from Table 1, to rotate motors and point to the satellite's starting location. The program then waits for the time when the satellite is scheduled to come into view. When that time grows near, the EV3 Intelligent Brick will give you an audible signal so you know when to begin paying attention.

You'll need to download the dGPS block from Dexter Industries. The LEGO Car Tracker bonus project explains how to do this.

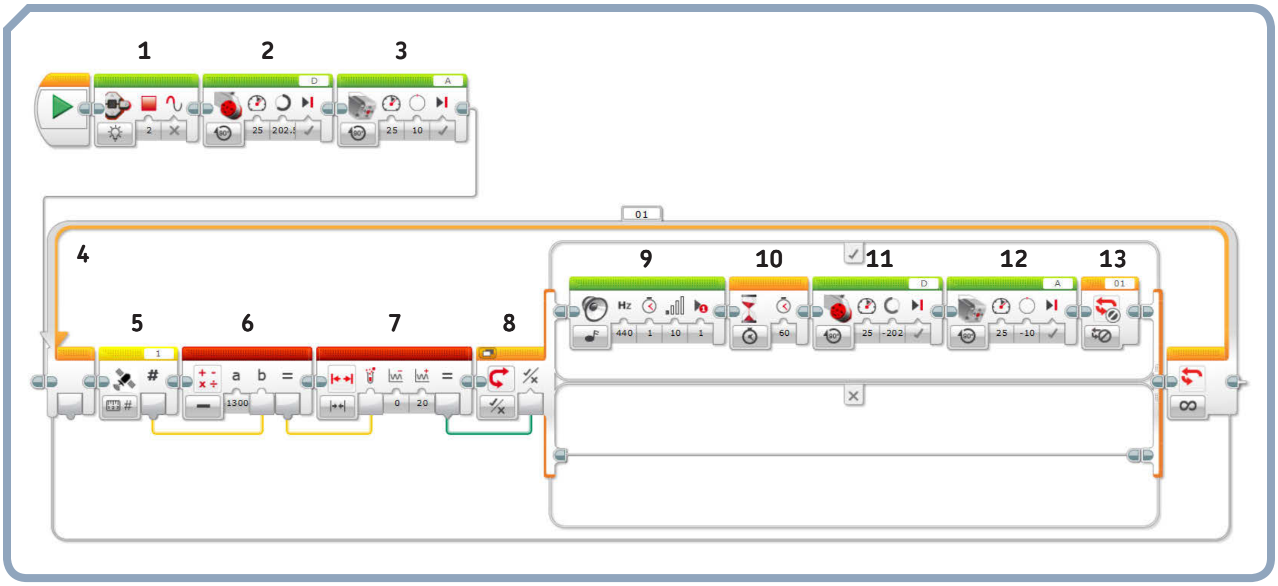
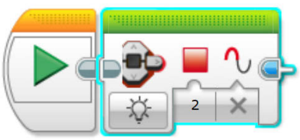


FIGURE 5: *The software controls the LEGO Satellite Spotter by setting the angle of the two motors.*

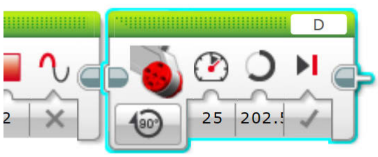
Use the following blocks to write the program:

1. **Brick Status Light block** This sets a red light on the front panel of the EV3 Intelligent Brick. Without this block, the status light would use its default mode, a green blinking light, which might distract you during your night viewing.



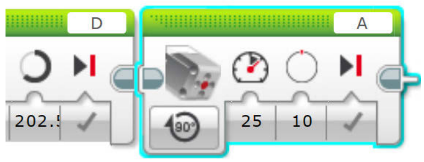
Place the Brick Status Light block after the program Start. Set **Brick Status Light** to **On**, **Color** to **2**, and **Pulse** to **False**.

2. **Large Motor block** This block spins the EV3 Large Motor to the azimuth you predicted for the satellite's appearance. In this example, the azimuth is set to 202.5 degrees, taken from the first row of Table 1.



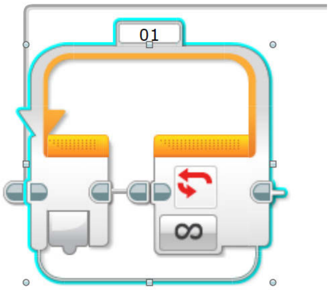
Place a Large Motor block after the Brick Status Light. Set **Large Motor** to **On for Degrees**, **Port** to **D**, **Power** to **25**, **Degrees** to **202.5**, and **Brake at End** to **True**.

3. **Medium Motor block** This block spins the EV3 Medium Motor to the elevation you predicted for the satellite's appearance. In this example, the elevation is set to 10 degrees, taken from the first row of Table 1.



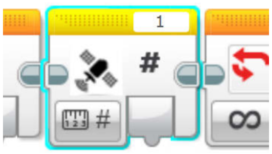
Join a Medium Motor block after the Large Motor block. Set **Medium Motor** to **On for Degrees**, **Port** to **A**, **Power** to **25**, **Degrees** to **10** (for the example in Table 1—place your elevation degree value here), and **Brake at End** to **True**.

4. **Loop block** This constantly compares the dGPS sensor time measurement to the time when the satellite overpass begins (which you'll input in step 6). Figure 5 and the following steps show the loop underneath the previous three blocks to allow the program to fit on the page. You can do this as well or continue the program in a straight line.



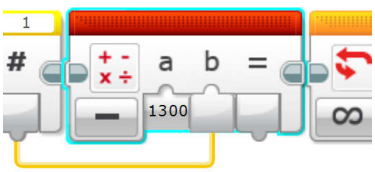
Insert a Loop block after the Medium Motor block.

5. **dGPS Block** This reports time from the dGPS receiver. This block is a download from Dexter Industries, as described in the LEGO Car Tracker bonus project. The time measured from the dGPS is in a decimal form of UTC.



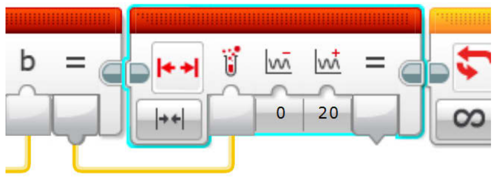
Place the dGPS block into the loop. Set **dGPS** to **Read UTC Time** and **Port** to **1**.

6. **Math block** This subtracts the satellite start time, such as the value entered from Table 1, from the time measured from the dGPS. This mathematical operation is crude, because the time from the dGPS is reported as a decimal number without the colons that usually separate hours, minutes, and seconds. While not perfectly accurate, subtracting times as decimal numbers should work well enough to trigger an indicator that the satellite is almost in sight.



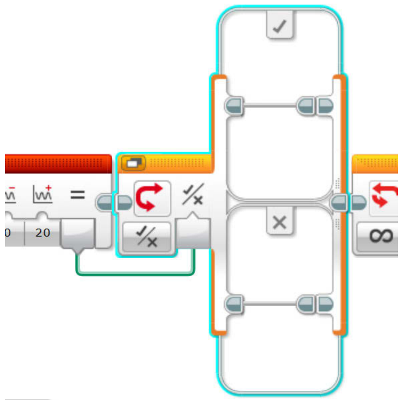
Place the Math block after the dGPS block. Set **Math** to **Subtract**, and **a** to the UTC start time for your particular satellite. Connect a wire from the output of the dGPS to the **b** input of the Math block.

7. **Range block** This tests whether the time from the dGPS clock is within 20 seconds of the satellite approach time. If the result of the calculation in step 6 is less than 20 seconds, this block raises a flag of true. Otherwise, the flag remains false.



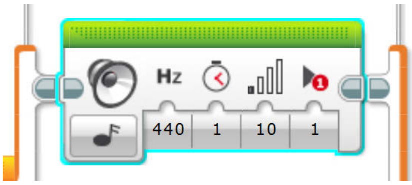
Insert the Compare block after the Math block. Set **Range** to **Inside**, **Lower Bound** to **0**, and **Upper Bound** to **20**. Connect a wire from the output of the Math block to the **Test Value** input of the Compare block.

8. **Switch block** This monitors the flag generated by the Compare block. When the flag is false, this block takes no action and repeats blocks 5–8. When the flag is true, which occurs when the satellite start time is less than 20 seconds away, the Switch block executes blocks 9–13.



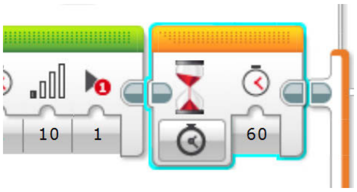
Place the Switch block after the Compare block and set **Switch** to **Logic**. Connect a wire from the **Result** output of the Compare block to the **Logic** input of the Switch block.

9. **Sound block** This emits a tone to warn you that the satellite is about to appear. This sound tells you to look in the direction indicated by the pointing arm.



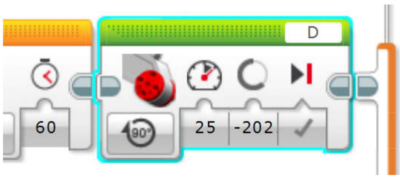
Insert the Sound block in the true path of the Switch block. Set **Sound** to **Play Tone**, **Frequency** to **440**, **Duration** to **1**, **Volume** to **10**, and **Play Type** to **1**.

10. **Wait block** This pauses the program for 1 minute.



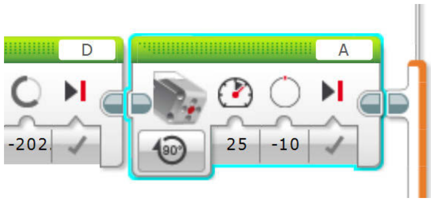
Insert the Wait block after the Sound block. Set **Wait** to **Time** and **Seconds** to **60**.

11. **Large Motor block** This resets the azimuth to the home position by reversing the angle of the Large Motor used in block 2.



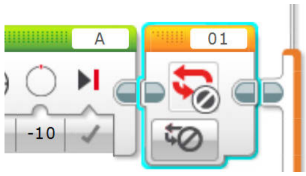
Place the Large Motor block after the Wait block. Set **Large Motor** to **On for Degrees**, **Port** to **D**, **Power** to **25**, **Degrees** to **-202.5** (or the negative of the value you input to block 2), and **Brake at End** to **True**.

12. **Medium Motor block** This resets the elevation to the home position by reversing the angle programmed in step 3.



Insert the Medium Motor block after the Large Motor block. Set **Medium Motor** to **On for Degrees**, **Port** to **A**, **Power** to **25**, **Degrees** to **-10** (or the negative value of the value set in step 3), and **Brake at End** to **True**.

13. **Loop Interrupt block** This exits the infinite loop.



Close the true path of the Switch block by placing the Loop Interrupt block after the Medium Motor block.

If you're expecting more than one satellite, copy the program and paste it onto the end of the program for the first satellite. Change the start time (block 6), azimuth (blocks 2 and 11), and elevation (blocks 3 and 12).

observing satellites with the LEGO satellite spotter

Spotting satellites requires a clear sky, so use your LEGO Satellite Spotter on a cloudless morning or evening. Check sky-watching websites for satellites passing overhead during those times and use the information from those sites to program the EV3 Intelligent Brick.

Before the first satellite start time, and before turning on the EV3 Intelligent Brick, use a compass to orient the Satellite Spotter so it's pointing north, as shown in Figure 6.

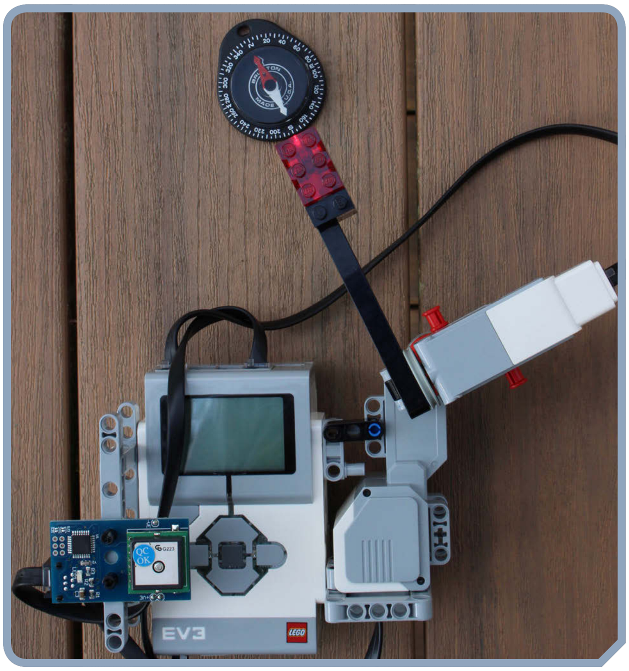


FIGURE 6: *Before beginning an observing session, align the LEGO Satellite Spotter's pointing arm to the north.*

Also make sure that the LEGO Satellite Spotter is leveled horizontally, without any tilt. Once you activate it, you can let your mind wander, since the LEGO Satellite Spotter will give you an alert when it's time to look for the satellite.

what you learned

In this chapter, you built a MINDSTORMS EV3 device to help you watch the sky for satellites passing overhead. The LEGO Satellite Spotter points to the section of the sky where the satellite will come into view and sounds an alarm as it approaches. You used two LEGO motors to build a device that points to a specific set of coordinates and learned how to incorporate time into LEGO inventions.