Nuclear Control Rod Automation

Direct Instruction

Engage with Nuclear Power!

Start the Engage section by presenting the students with the lesson challenge. Tell students:

"For this challenge, you will assume the role of Robotic Nuclear Engineers at ORA Mechatronics. Fissile Power Generation, a regional nuclear power company, is looking at using robotic arms to automatically control the reaction rate in the new power plant they are commissioning in early 2027. They have hired your team to evaluate a program that will be used to automatically control the reaction rate within the nuclear reactor, as well as engineer a failsafe if the reaction rate is too high.

Have the students spend a few minutes thinking about nuclear power (and how the power they use is generated) and answering the questions in the Engage section of the Student Activity Sheet. Then tell the students:

"Before we can solve this challenge, we need to learn more about robotic arms in the nuclear power industry and the careers related to them!"

Next, show the Lesson 7 video.

Explore Nuclear Power Plant Operator Career Connections

Students will do a brief guided virtual scavenger hunt related to Nuclear Power Generation Jobs. Individually or in small groups, have them complete the Explore section on the Student Activity Sheet. If students are struggling with the job outlook section, have them go to the US Department of Labor and Statistics Occupational Outlook Handbook. In this tool, you can find information about thousands of jobs. On the Index page, search for your career (Use Ctrl+F on a Windows machine or Chromebook). When you click on the career of your choice, there is a short video about the career as well as several key pieces of information. On the website, there are a few relevant jobs: Nuclear Technician, Nuclear Engineer, and Power Plant Operator, Distributor, and Dispatcher.

Explain the uses of robotic arms in the Nuclear Power Industry.

Part 1:

Start the Explain section by asking the students, "How are robotic arms used in the nuclear power industry?" Students should be able to recall from the video

that robot arms are used in moving heavy materials and removing waste from a decommissioned or damaged reactor.

Ask the students, "In today's lesson, we will be evaluating a program using ORA to regulate a nuclear reaction. Does anyone know how a nuclear reactor functions?" Students may or may not have an idea of how they work. [This video gives a brief overview of the basics of how a nuclear reactor functions]. If you'd like to skip over how fission works, you can jump to 1:30 where the reactor itself is discussed. This video discusses how the control rods can be inserted into the reactor to absorb neutrons and decrease the reaction rate.

Have the students take a few minutes to look at the code for the Elaborate section and answer the questions at the top of the Elaborate Section. Tell them that the target reaction rate is 10. Ask them, "What happens when the reaction rate is less than or equal to 2? What happens when the reaction rate is less than or equal to 7? What happens when the reaction rate is greater than or equal to 13?"

After students have written their answers, let them know that when the reaction rate is less than or equal to 2, that is too low. To bring the reaction rate higher, ORA moves the control rod higher by 40 millimeters, allowing neutrons to react with the uranium. The reaction rate is then increased by the Z-height divided by 200.

When the reaction rate is less than or equal to 7, that is slightly too low. To bring the reaction rate higher, ORA moves the control rod higher by 10 millimeters, allowing neutrons to react with the uranium. The reaction rate is then increased by the Z-height divided by 200.

When the reaction rate is greater than or equal to 13, that is slightly too high. To bring the reaction rate lower, ORA moves the control rod lower by 10 millimeters, allowing more neutrons to be absorbed. The reaction rate is then decreased by the Z-height divided by negative 200. There is an if/do statement in this to keep the ORA from hitting the bottom of the reactor with the cylinder.

Part 2:

Ask the students, "In a nuclear power plant, what happens when the reaction rate is too low?" They likely will say that not enough energy is being released to

generate power. Then ask the students, "What happens when the reaction rate is too high in a nuclear power plant?" Students may know that it causes a meltdown.

Tell the students that nuclear power plants have to have a failsafe system to reduce the risk of a meltdown. The primary method to prevent a meltdown is to drop the control rods into the reactor to absorb as many free neutrons as possible to stop the reaction.

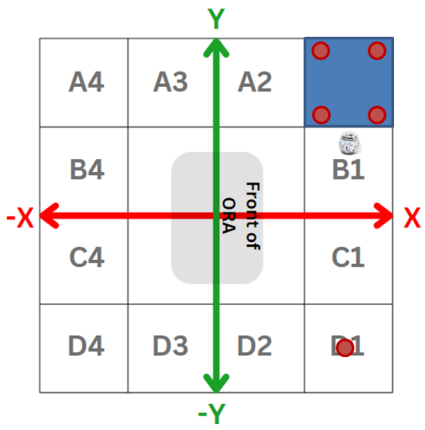
In our example nuclear reactor, a reaction rate of 20 is too high and is at a high risk of a meltdown. Students must then add a failsafe to the Elaborate Code to activate when the reaction rate is greater than or equal to 20!

Elaborate: Failsafes for increased safety!

In this challenge, students will be altering the Elaborate code to include a failsafe when the reaction rate is greater than or equal to 20.

Setup:

Place a red, wooden cylinder (control rod) in the center of D1. Place a 150x150x60mm cardboard box in A1. Place 4 red, wooden cylinder fuel rods in the corners of the box. Place Evo next to the cardboard box in B1.



Task Requirements:

1. Students must alter the Elaborate Starter Code to include:
    a. A failsafe to drop the fuel rod into the reactor when the reaction rate is greater than or equal to 20
    b. An alert/alarm system using Evo's lights and sounds
    c. In the event of a failsafe situation, ORA must return to the Initial Position.

Direct students to plan this code in the Elaborate section of their Student Activity Sheet. After writing the pseudocode, direct students to create the code on their devices in the Ozobot Editor. Ensure students are connected to your shared workspace.

As students complete their code, they will test their code. Click on a given student's or student group's tab on the Ozobt Editor. Click "Run" to execute their code. Reset the materials between each code run. Remember to follow the Safety Protocol established in ORA Essentials. Example solution code.

Note: The reaction rate and control rod system are pretty stable in the existing code. To test the failsafe, at the top of the program, locate the "Set

Reaction Rate to" block. Change the value from 10 to 20 and then run the code. This should set off the failsafe code right away.

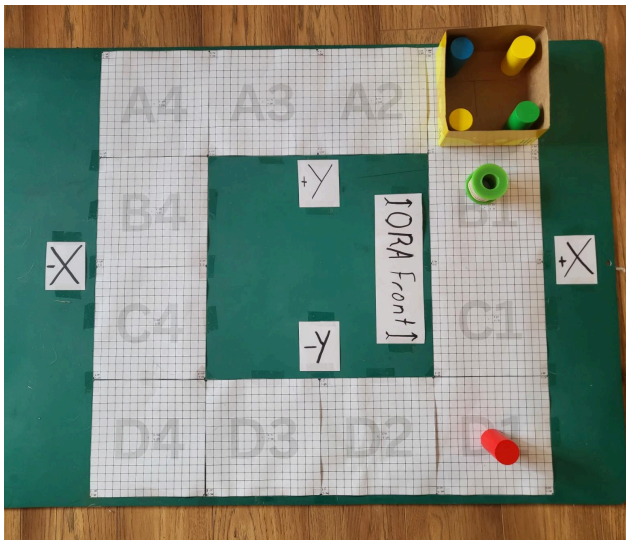
If students are waiting for the ORA, they could:

- Complete the Evaluate section of the Activity Sheets as an exit ticket.

Elaborate: Example solution

1. Setup

a. Right is an image of the setup for the lesson challenge. Note: Evo is represented by a green spool of similar size.

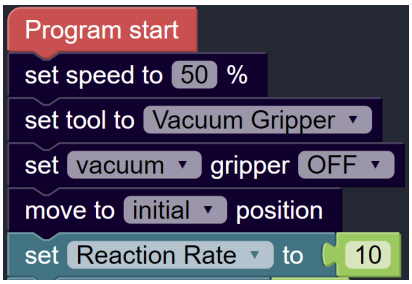


2. Designed Materials

a. For this challenge, the only extra material needed is a box approximately 150mm x 150mm x 60mm in size. As in the above picture, the box does not need to fit the dimensions exactly.

3. Sample Code

a. Example Solution Code



4. Code Description

a. The code begins when ORA moves to pick up the cylinder in D1. The cylinder is moved to A1 at an initial z-height of 90mm. As the variable "Reaction Rate" fluctuates, by a random integer between -2 and +2, the control rod (wooden cylinder in ORA's end tool) moves up and down accordingly to slow down or speed up the reaction (see Explain Part 1). The code is not very visually exciting as the variable values are not shown on screen. To test the Failsafe at the end of the code, set the reaction rate at the top of the program to a value greater than 20. The program will instantly go into failsafe mode.

Evaluate: Exit Ticket

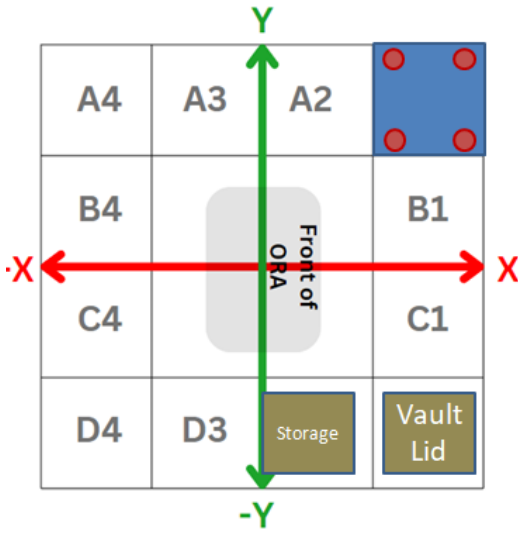
Students will fill out and submit the Evaluate section of the Activity Sheets as an exit ticket.

Optional Extension: Decommissioning the Reactor

Source: Canva

The reactor used in the Elaborate activity has reached the end of its operational lifespan and will need to be decommissioned. This involves the removal and containment of the fuel rods as well as putting a vault or lid over the reactor to contain any radioactive substances.

In this activity, students will use ORA to decommission a nuclear reactor!



Setup: Place a 150x150x60mm box in A1 with four red, wooden cylinder fuel rods. Place a student-created fuel rod containment device in D2 and a student-created containment device for the whole reactor in D1.

Task Requirements:

1. ORA must start in the initial position.
2. Students must program ORA to:
    a. Pick up and place the four fuel rods in a storage container.
        i. The storage container must have a lid of some type
    b. Pick up and place the vault lid over the empty reactor.
3. ORA must finish in the Initial Position.