National Aeronautics and Space Administration

Robotic Search and Rescue Challenge

Educator Guide

COMPUTER SCIENCE AND ENGINEERING

Next Gen STEM – Aeronaut-X

For more about Next Gen STEM visit https://www.nasa.gov/stem/nextgenstem/aeronaut-x

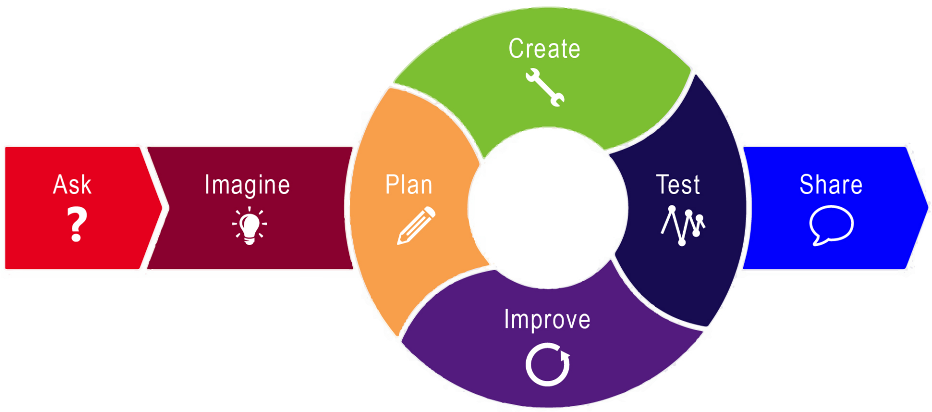
Education Product	
Educators and Students	Grades 6-8

Contents

Engineering Design Process

The engineering design process (EDP) is crucial to mission success at NASA. The EDP is an iterative process involving a series of steps that engineers use to guide them as they solve problems. The steps outlined below can be used by student teams to solve the challenges in this activity guide. Learn more about the EDP with NASA's Educator Professional Development Collaborative at https://www.txstate-epdc.net/models-of-the-engineering-design-process/.

1. **Ask**: Identify the problem, requirements that must be met, and the constraints that must be considered.
2. **Imagine**: Brainstorm solutions and research what others have done in the past.
3. **Plan**: Select and sketch a design.
4. **Create**: Build a model or a prototype.
5. **Test**: Evaluate solutions by testing and collecting data.
6. **Improve**: Refine the design.
7. **Share**: Communicate and discuss the process and solutions as a group.



Teamwork

Student activities can be completed either as a team or individually, depending on time and preference. Grouping strategies during the design challenges can be used to efficiently break up student tasks, help promote student engagement, and appeal to a variety of learning styles and student strengths.

It is important that everyone on the team be able to participate and contribute throughout these activities. Everyone is a scientist and an engineer! If one student does all the building, other students may be very bored during the building process. If one student is the leader, other students may not have a chance to share their ideas. Students can be rotated through team roles to give them an opportunity to experience new roles, build upon their strengths, or improve upon their weaknesses in team dynamics.

Tip: Create team role name tags for each member of the team. This strategy not only helps students visually identify peer roles but also helps students feel individually accountable for team success.

Here are some possible roles that students can take:

Student Role	Description
Communications and Outreach	Takes notes of all team decisions and actions for use in a final presentation. If a camera is available, takes video and/or photos throughout the investigation or challenge for use in a final presentation.
Logistics	Makes sure that the team has all the resources they need, that resources are distributed fairly, and that the team knows when resources are running low.
Mission Assurance	Makes sure the team is following the plan. Keeps track of time and makes sure that everyone has a chance to have their voice heard.
Safety	Ensures all team members are wearing their safety goggles and following safety protocols.

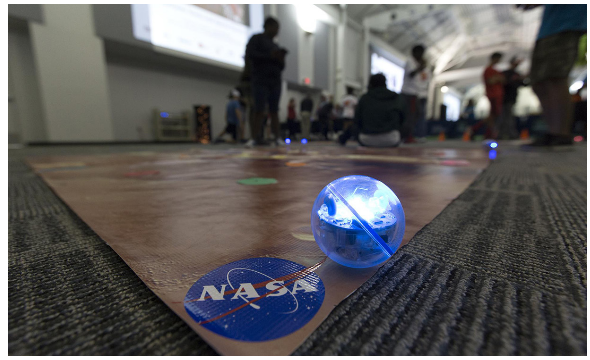
Curriculum Standards Alignment

Science and Engineering (Next Generation Science Standards)	
Disciplinary Core Ideas • MS.ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technology to mitigate their effects. *Crosscutting Concepts* • Cause and Effect: Cause-and-effect relationships may be used to predict phenomena in natural or designed systems. *Science and Engineering Practices* • MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	*Science and Engineering Practices (continued)* • MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. • MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. • MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved
Computer Science (CS) (Computer Science Teacher Association K 12 CS Standards)	
Standards for Students • 2-CS-02: Design projects that combine hardware and software components to collect and exchange data. • 2-CS-03: Systematically identify and fix problems with computing devices and their components. • 2-DA-08: Collect data using computational tools and transform the data to make it more reliable. • 2-DA-09: Refine computational models based on data they have generated.	*Standards for Students (continued)* • 2-AP-15: Seek and incorporate feedback from team members and users to refine a solution that meets user needs. • 2-AP-17: Systematically test and refine programs using a range of test cases. • 2-AP-18: Distribute tasks and maintain a project timeline when collaboratively developing computational artifacts. • 2-AP-19: Document programs in order to make them easier to follow, test, and debug.
English Language Arts (ELA) (Common Core State Standards)	
Writing Standards • CCSS.ELA-LITERACY.W.7.2 and 8.2: Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.	*Writing Standards (continued)* • CCSS.ELA-LITERACY.W.7.10 and 8.10: Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.
Mathematics (Common Core State Standards)	
Math Content Standards • CCSS.MATH.CONTENT.6.NS.C.8: Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.	

Introduction and Background

NASA Technologies

The New Future


A programmable robot at a student event at NASA's Kennedy Space Center. (NASA)

A new future for air transportation is in the works at NASA—a future where both people and packages will take to the air. Researchers have already studied, designed, and tested tools and technologies that could be used in the near future to manage the airspace for drones, small aircraft that can fly remotely or autonomously. A drone is a type of unmanned aerial vehicle (UAV).

Believe it or not, the UAV, or the drone itself, is only one component of an entire system of hardware, software, and human input that makes up an unmanned aircraft system (UAS). The UAS comprises everything that makes a UAV work, including its global positioning system (GPS, or navigation system), ground control station, transmission systems, camera, all the software, and the person on the ground controlling the UAV. This guide uses the acronym UAV when referring to the drone and the acronym UAS when referring to the entire system.

In the future, these vehicles will fly at low altitudes, even in complex urban landscapes. This will allow for advances into the emerging world of passengers and goods traveling smoothly above our city streets.

Advanced Air Mobility

NASA conducts research based on a strategic plan that includes expanded research into advanced air mobility (AAM). NASA's vision for AAM is to help emerging aviation markets safely develop an air transportation system that moves people and cargo between places previously not served, or underserved, by aviation. The new transportation system will serve local, regional, intraregional, and urban areas using revolutionary new aircraft that are only just now becoming possible.

NASA's UAS research efforts are part of AAM. One example of NASA's innovations in this field is the UAS Integration in the National Airspace System (UAS–NAS) project. Until UAS–NAS, little research had been done to find ways to reduce technical barriers that prevented UAVs from safely flying through the same airspace as more traditional commercial aircraft. The UAS–NAS project, which concluded in 2020, worked to make sure the UAV delivering a package to a house would not interfere with the helicopter delivering patients to the local hospital. The technology and procedures developed during this nearly decade-long program are now assisting the Federal Aviation Administration (FAA) in developing the rules for certification of unmanned aircraft to help ensure they can safely coexist with other air traffic.

NASA currently has effective partnerships with industry, academia, and the FAA to identify and seek solutions to the challenges unique to enabling AAM operations in the NAS. NASA is uniquely positioned to work collaboratively with industry and academia on the technical challenges of AAM, building upon of decades of successful research to improve air traffic management.

Safeguard Technology

Researchers at NASA's Langley Research Center have developed an assured safety net technology for UAS. They are calling their breakthrough technology Safeguard. Safeguard can alleviate the dangers of unmanned aircraft flying beyond their authorized perimeters and into no-fly zones, taking action to guarantee the perimeters are not breached. The system does this with the use of geofences. "Think of it like an invisible dog fence, except for drones. Safeguard makes sure that you don't fly into a region, or even a building, that you're not supposed to," says Kelly Hayhurst, lead inventor of the technology.

Safeguard's intelligence is derived from formally verified algorithms and mathematical models that monitor and predict impending boundary violations through flight termination trajectory estimation, and a system architecture that facilitates performance certification. The technology is suitable for a variety of applications, such as cargo delivery; surveillance and monitoring; agriculture; or any private, commercial, and public sector operations in which range containment or prevention of entering no-fly zones is desirable.

Help With Natural Disasters

Although UAS may be programmed in a variety of ways to benefit society, this student challenge will highlight their use during natural disasters.

Natural disasters like wildfires and hurricanes can lead to many lives lost and billions of dollars in costs across the United States each year. To help reduce that impact, drones have great potential to assist emergency responders by making their interventions even faster, more targeted, and better able to adapt to changing circumstances. These vehicles, and the systems that support them, can multitask in unique ways; for instance, a drone may utilize software to track firefighters on the ground before dropping forest fire retardant a safe distance away.

Set in a post-natural-disaster scenario, this challenge will task teams with potential problems facing first responders. At each level, teams will be tasked with designing a solution using a programmable robot, such as a Sphero® (Sphero, Inc.) robotic ball, to complete a new challenge facing first responders in their quest to help survivors in the disaster zone.

Robotic Search and Rescue Challenge

Educator Notes

Learning Objectives

Students will

- Apply the steps of the engineering design process to successfully complete a team challenge.
- Conduct research, write a proposal, and create a basic budget.
- Program a spherical robot, such as a Sphero® robotic ball, using JavaScript (Oracle America, Inc.) or block programming to complete various leveled challenges.
- Design, build, and test solutions to each problem.
- Create a presentation and share results.

Challenge Overview

Students will explore challenges engineers face throughout different phases of NASA missions as they conduct research, propose a solution, create a design, build their designs, and test their solutions to a set of given problems. Students will investigate how their designs in each stage of the challenge lead to their final design solution. This guide contains educator background information, support materials, and student worksheets.

Suggested Pacing

2 to 3 hours per phase, or 15 to 20 hours if students engage in all activity phases

Challenge Context

Set in a post-natural-disaster scenario, this challenge will task teams with up to five potential problems (each more complex than the last) facing first responders. Teams will be tasked with designing solutions to each of the assigned problems using a programmable robotic ball to simulate an unmanned aerial vehicle (UAV) entering a disaster zone.

Challenge Preparation

30 to 45 minutes

Note: Make sure to plan time to find tutorials and learn more about block programming. Prior to this lesson, students should have knowledge of basic block programming. Example links: https://edu.Sphero.com/cwists/preview/21499x and https://code.org/

- Read the introduction and background information, Educator Notes, and Student Handout to become familiar with the activity.
- Determine the supplies that will be available for students throughout the challenge.
- Group students into teams of four or less for the duration of the challenge. (Placing students in pairs is ideal to broaden participation in the challenge.)
- Make copies of all student worksheets for each team:
  - Challenge Proposal (Appendix A)
  - Suggested Items and Prices (Appendix B)
  - Scoring Sheets (Appendix C)
  - Assessment Sheets (Appendix D)

    Note: Depending on students' level of ability, the advanced or beginner rubric may be used.
- Prepare the challenge space (maze, obstacles, etc.).
  - This student challenge is intended to be adaptable to best meet the needs of each group of students. The number of levels can be changed to suit students' skill level and/or the time available.
  - Design and lay out the maze for each level as needed, based on your chosen natural disaster, the level criteria and constraints, students' skill level, and challenge space.

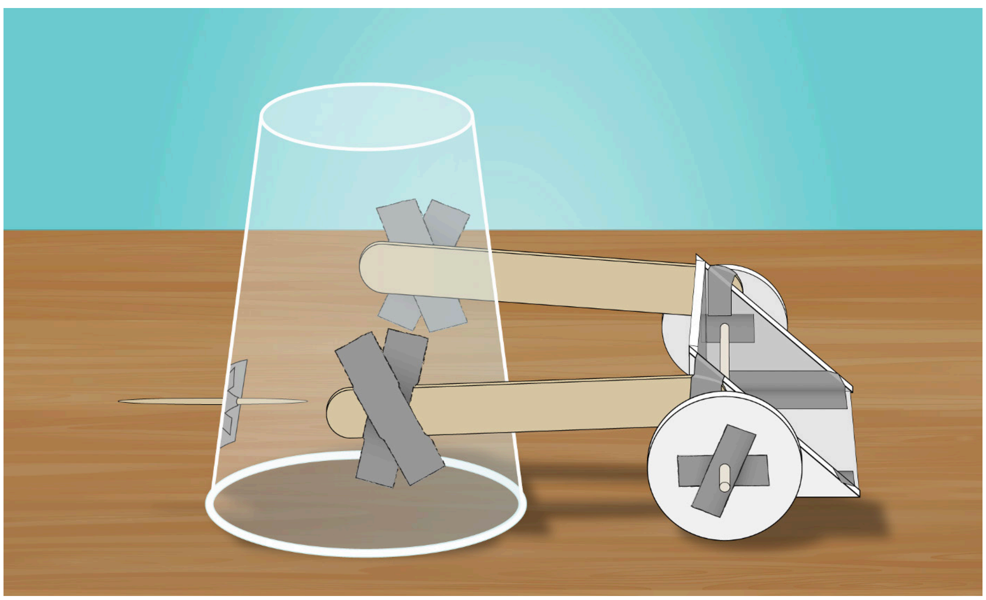
- A different maze will be used for each level.
- Ensure all teams compete on the same maze during each level.

Materials

- ☐ Sphero® robotic ball or any other spherical programmable robot (any size)
- ☐ Computer
- ☐ Tape or adhesive
- ☐ Scissors
- ☐ Empty plastic water bottles
- ☐ Assorted common craft supplies for maze (Suggested materials: polyvinyl chloride (PVC) pipe, paper towel rolls or craft rolls, painters tape, books)
- ☐ Assorted common craft supplies for teams to engineer tools or devices to complete the given task(s) in each scenario (popsicle sticks, paper clips, index cards, rover wheels, rubberbands, etc.) (See Appendix B for proposed budget and material costs.)
- ☐ Optional commercial/premade chariot

Safety

Students will likely be using scissors to cut irregularly shaped materials. Ensure that they use safe cutting practices.



The chariot pictured here can be shared to assist students in their initial designs; however, for best results, encourage students to be creative and engineer their own designs for each challenge.

Introduce the Challenge

- Provide context for the challenge using the introduction and background information provided in the guide. Facilitate a discussion on the different types of unmanned aircraft systems (UAS) and potential benefits they could bring during natural disasters.
- Inform students they will be working in the same teams throughout the challenge as they design a solution to the given problem.

Share With Students

Brain Booster

NASA's Scalable Traffic Management for Emergency Response Operations (STEReO) project envisions a new system for emergency response that has three broad goals: reduce response times, scale up the role of aircraft, and provide operations that can adapt to rapidly changing conditions during a disaster.

Illustration of an unmanned aircraft system, or drone, in front of a smoke-filled sky.

Learn more:
https://nasa.gov/ames/stereo

On Location

Researchers at NASA's Ames Research Center in Mountain View, California, conducted unmanned aircraft system (UAS) flight tests of drones at Moffitt Field.

UAS Traffic Management (UTM) project and Smart Mobility at Ames team getting ready for operation.

Learn more:
https://nasa.gov/feature/unmanned-aircraft-systems-uas-drone-flights-at-moffett-field/

Design Constraints

Each level of the challenge has its own specific criteria and constraints in addition to the general criteria and constraints listed in the table below.

Criteria	Constraints
Teams must submit a completed challenge proposal.	Teams must not exceed their budget when choosing supplies.
Teams must submit challenge reports after the completion of each challenge level.	Constraints will be level specific given each scenario.
Teams must program their robotic ball using JavaScript or block programming using their own code.	The robotic ball must not leave the maze boundaries during the challenge.
Teams must use materials provided by the educator to complete the given task(s) in the scenario.	

Facilitate the Challenge

Ask

- Introduce students to a level-based scenario decided upon by educator. Five scenarios are presented in these Educator Notes.
- Task students to conduct research on UAS designs that may potentially help them engineer a device to successfully complete the scenario.
- Ask students to describe the most surprising use of UAS during natural disasters that they found during their research.
- Reference the student scenario levels 1 to 5, described in the following pages. How would a UAS assist a first responder in solving the challenge? How might a first responder without a UAS solve the real-world challenge?

Imagine

- Provide teams with a budget as well as a list of available supplies and associated costs of items they can use to create devices that may help them complete the given scenario. Allow students time to view the available building supplies so they can create a design within budget.
- Have students propose a budget based on the educator's parameters.
- Have students discuss the strengths and weaknesses of the different materials.
- Have students best utilize their supplies to stay within budget while still accomplishing the challenge.

Plan

- Have students complete their challenge proposals, which should include their timeline, budget, and challenge design.
- After each level, students will provide any updates to their proposal for the next level of the challenge.
- Review the team proposals (Appendix A) at each level to ensure students can continue with the engineering design process.

Create

- Teams will create their design based upon their plan.
- Teams must program their robotic ball and navigate the selected level's maze to solve the challenge.

Test

- Teams may perform as many practice tests as time allows while designing and programing their robotic ball.
- Once final testing begins, teams will be given one test to evaluate their design using the score sheet.
- Each team will test their design and program by placing their robotic ball at the beginning of the course and running their program. Their design will be evaluated using the provided score sheet and each level's unique requirements.

Improve

- Teams should improve on their design and reprogram the robotic ball after each practice test as time allows.
- Remind students to record all significant improvements and modifications made to their design and/or coding and to include these revisions in their final presentations.
- Visual records (drawings, photos, screen shots, etc.) of any significant changes made may be included in their presentations.

Share

- At the end of each level, students will work as a team to record answers to the following discussion questions:
  - What was the greatest challenge for your team during this level? How did you address this challenge?
  - What parts of your design did you reuse from a previous level? What parts of this level could you use in future levels?
  - What was the purpose of this level's design constraints? How would this relate to problems facing NASA engineers or first responders in similar situations?
  - How did your research into real-world applications of UAS affect your solution to the challenges?
- At the highest level the team completes, students will present their findings.
- The presentation must include the following:
  - Research: Provide a brief summary of the research the team has completed on the real-world applications of UAS during the provided natural disaster scenario.
  - Programming: Explain how teams used JavaScript or block programming to program their robotic ball to navigate through the maze autonomously from start to finish. Be sure the teams document any significant modifications made to the JavaScript or block programming.
  - Budget: Describe how teams looked over each challenge task, designed a device for their robotic ball using materials provided, and stayed within the given budget.
  - Design Solution: Once the team has decided on materials, the team will sketch their engineering design on the worksheet provided.
  - Final Results: Students will discuss their responses to the following questions:
    - How did your research into real-world applications of UAS affect your solution to the challenges?
    - Did your design work as planned? Were you able to successfully complete this final level of the challenge?
    - What was the greatest challenge for your team during this final level? How did you address this challenge?
    - What parts of your design did you reuse from a previous level?
    - What is the purpose of this level's design constraints? How would this relate to problems facing NASA engineers or first responders?

Levels

Using available materials, educators will create a different maze for each level. When designing a maze, consider student skill levels, available space, the context of each level, and the challenge level. Remember, if implementing all levels, ensure the mazes have a progressing difficulty at each stage. An example context for each level has been provided, but this can be adapted if needed to better fit the challenge. Depending on the number of students, the educator may need to create several mazes so students have ample space to work.

Level 1

Scenario: First responders are not able to locate the survivors in a northern California forest fire, and the disaster area is unstable. Using your robotic ball, navigate the disaster area and go through all open doors to look for survivors, but do not hit any walls or cause them to fall. Use extra care when exiting an already-entered door to avoid any unstable walls.

Challenge: The educator will design a maze with open paths for the programmed robotic ball to enter, turn around, and leave the path through the initial entry point.

Level Points

- Robotic ball enters opening in maze (door), +1
- Robotic ball exits an already-entered opening in maze (exits door), +1
- Robotic ball hits an obstacle or wall within the maze, –1
- Student picks up or touches robotic ball after starting main program, –1

Level 1 Criteria	Level 1 Constraints
Teams must navigate their UAS (robotic ball) through the entire maze autonomously. Balls must be programmed, not remotely controlled from start to finish.	Teams must not hit any maze walls or obstacles within the maze. *Each obstacle or wall hit deducts 1 point (–1).*
Teams must navigate their robotic balls through all open doors. *Each door entered will earn teams 1 point (+1).* *Each door exited will earn teams 1 point (+1)*	Teams must not touch or interact with their UAS after starting their program. *Each touch deducts 1 point (–1).*

Scoring: Use the Scoring Sheets in Appendix C to score each team's final test.

Level 2

Scenario: First responders have identified a gas leak in a city hospital, but the shutoff valve is inaccessible. Use your robotic ball to navigate to the valve and design a device to fit through the area and shut off the valve.

Challenge: The educator will design a maze with a button or balloon at the end of the maze for the programmed robotic ball to press or pop to simulate shutting off a valve. Students will design a device given their budgeted materials to complete the scenario.

Level Points

- Robotic ball shuts off the valve (presses the button or pops the balloon), +10
- Robotic ball hits an obstacle or wall within the maze, –1
- Picking up or touching robotic ball after starting main program, –1

Level 2 Criteria	Level 2 Constraints
Teams must navigate their UAS (robotic ball) through the maze autonomously and complete the task using JavaScript or block programming.	Teams must not hit any maze walls or obstacles within the maze. *Each obstacle or wall hit deducts 1 point (–1).*
Teams must design a device for their robotic ball to use to pop the balloon or press the button. *Popping the balloon or pressing the button will earn teams 10 points (+10).*	Teams must not touch or interact with their UAS after starting their program. *Each touch deducts 1 point (–1).*

Scoring: Use the Scoring Sheets in Appendix C to score each team's final test.

Level 3

Scenario: A fallen tree has blocked the path for first responders to enter an area with survivors. Using your robotic ball, create a device for your robotic ball to push the tree out of the way and reach the survivors without moving any other objects that might be unstable.

Challenge: The educator will design a maze with an obstacle to be moved out of the path of the maze using the programmed robotic ball. When designing the maze, ensure there is a clearly marked spot for the object to be placed during each test to ensure consistency between each test and between all teams. Suggested objects for teams to move out of the path include a toy building brick such as a LEGO® (LEGO Group) piece, a small magnetic object (washer), or a small tree figurine.

Level Points

- Robotic ball moves the obstacle out of the path, +10
- Robotic ball moves the obstacle out of the path without hitting anything within the maze with the obstacle, +5
- Robotic ball hits an obstacle or wall within the maze, –1
- Picking up or touching robotic ball after starting main program, –1

Level 3 Criteria	Level 3 Constraints
Teams must navigate their UAS (robotic ball) through the maze autonomously and complete the task using JavaScript or block programming.	Teams must not hit any maze walls or obstacles within the maze. *Each obstacle or wall hit deducts 1 point (–1).*
Teams must design a device for their robotic ball to use to move the obstacle out of the path of their robotic ball. *Moving the obstacle or object will earn teams 10 points (+10).* *Bonus: Successfully not touching or moving any other objects will earn teams 5 points (+5).*	Teams must not touch or interact with their UAS after starting their program. *Each touch deducts 1 point (–1).*

Scoring: Use the Scoring Sheets in Appendix C to score each team's final test.

Level 4

Scenario: First responders are not able to reach the survivors and bring them necessary supplies. Using your robotic ball, navigate the disaster zone and create a device to move bottled water from the holding area to the survivors.

Challenge: The educator will design a maze with an object to be picked up and moved to another section of the maze using a programmed robotic ball. When designing the maze, ensure there is a clearly marked spot for the object to be picked up and then placed during each test to ensure consistency between each test and between all teams. Suggested objects include a toy building brick such as a LEGO® piece, a small magnetic object (washer), or an empty miniature plastic water bottle.

Level Points

- Robotic ball picks up object from the designated spot, +10
- Robotic ball places object at designated drop zone, +10
- Robotic ball hits an obstacle or wall within the maze, –1
- Retrieved supplies hit an obstacle or wall within the maze, –1
- Picking up or touching robotic ball after starting main program, –1

Level 4 Criteria	Level 4 Constraints
Teams must navigate their UAS (robotic ball) through the maze autonomously and complete the task using JavaScript or block programming.	Teams must not hit any maze walls or obstacles within the maze. *Each obstacle or wall hit deducts 1 point (–1).*
Teams must design a device for their robotic ball to use to retrieve the necessary supplies and deliver them to the survivors. *Picking up the supplies will earn teams 10 points (+10).* *Delivering the supplies will earn teams 10 points (+10).*	Retrieved supplies must not hit any maze walls or obstacles within the maze during retrieval and delivery. *Each obstacle or wall hit with the supplies deducts 1 point (–1).*
	Teams must not touch or interact with their UAS after starting their program. *Each touch deducts 1 point (–1).*

Scoring: Use the Scoring Sheets in Appendix C to score each team's final test.

Level 5

This scenario combines all of the challenges of the previous four levels.

Example Scenario: First responders are responding to a mine collapse. To reach the survivors, the robot must navigate the maze-like mine shafts. Along the way, the robot must shut off a valve that is leaking fuel to prevent further explosions. As it nears the survivors, the robot must clear some rubble out of the way. The survivors will have been without water for many hours by the time the robot is expected to reach them, so the robot must bring a bottle of water for them. (Note: Educators are encouraged to create a "local" natural disaster scenario to make this level more relevant for their students.)

Challenge: The educator will design the maze to require the programmed robotic ball to perform the following actions: push a button or pop the balloon, move an object from one side to the other side while entering rooms, and pick up another object to complete the challenge. The robotic ball must also stay within borders from start to finish.

Level Points

- Robotic ball enters opening in maze (door), +1
- Robotic ball exits an already-entered opening in maze (exits door), +1
- Robotic ball hits an obstacle or wall within the maze, –1
- Picking up or touching robotic ball after starting main program, –1
- Robotic ball shuts off the valve (presses the button or pops the balloon), +10
- Robotic ball moves the obstacle out of the path, +10
- Robotic ball moves the obstacle out of the path without hitting anything within the maze with the obstacle, +5
- Robotic ball picks up object from the designated spot, +10
- Robotic ball places object at designated drop zone, +10
- Retrieved supplies hit an obstacle or wall within the maze, –1

Level 5 Criteria	Level 5 Constraints
Teams must navigate their UAS (robotic ball) through the maze autonomously from start to finish using JavaScript or block programming.	Teams must not hit any maze walls or obstacles within the maze. *Each obstacle or wall hit deducts 1 point (–1).*
Teams must navigate their robotic ball through all open doors. *Each door entered will earn teams 1 point (+1).* *Each door exited will earn teams 1 point (+1).*	Retrieved supplies must not hit any maze walls or obstacles within the maze during retrieval and delivery. *Each obstacle or wall hit with the supplies deducts 1 point (–1).*
Teams must design a device for their robotic ball to use to pop the balloon or press the button to simulate shutting off the valve. *Popping the balloon or pressing the button will earn teams 10 points (+10).*	Teams must not touch or interact with their UAS after starting their program. *Each touch deducts 1 point (–1).*
Teams must move all objects out of the path of their robotic ball using their robotic ball. *Each moved object will earn teams 10 points (+10).*	
Move the object without touching or moving any other objects that might be unstable. *Successfully not touching or moving any other objects will earn teams 5 points (+5).*	
Teams must design a device for their robotic ball to use to retrieve the necessary supplies and deliver them to the survivors. *Picking up the supplies will earn teams 10 points (+10).* *Delivering the supplies will earn teams 10 points (+10).*	

Scoring: Use the Scoring Sheets in Appendix C to score each team's final test.

Assessment: Use the Assessment Sheets in Appendix D to evaluate each team's overall performance for their terminal level.

Extensions and Adaptations

- This student challenge is intended to be adaptable to best meet the needs of each group of students. Depending on students' skill levels or the amount of time available, more or fewer levels could be implemented.
- Provide students the opportunity to create and imagine their own mazes or scenarios to celebrate "student voice."

- Award groups extra money in their budget for accomplishing certain tasks within a challenge level.
- Add extra obstacles within the challenge-level maze for students to avoid.
- Have students complete the Navigate Your Zone activity (Activity Three in the Unmanned Aircraft Systems Educator Guide) as a beginning or lead-in activity. https://nasa.gov/stem/nextgenstem/aeronaut-x
- Have a final bonus round where teams can only see a picture of the disaster area maze. They must then work as a team to navigate the disaster area based on the overhead picture and prior practice.
- For a simpler version of the challenge, have students use the same challenge with joystick controls for the robotic ball.

Additional Resources

Use of Small Unmanned Aerial Systems for Emergency Management of Flooding
https://www.fhwa.dot.gov/uas/resources/hif19019.pdf

NASA Earth Science: Applied Sciences: Enabling Disaster Risk Reduction and Resilience
https://disasters.nasa.gov/

What Is Scalable Traffic Management for Emergency Response Operations? (STEReO)
https://nasa.gov/ames/stereo

Drones for Disaster Response: NASA STEReO Project Kicks Off
https://nasa.gov/feature/ames/drones-for-disaster-response-nasa-stereo-project-kicks-off

Robotic Search and Rescue Challenge

Student Handout

Your Challenge

As a NASA engineer, you will design, build, and test solutions to real-life problems facing first responders entering natural disaster zones. You will progress through up to five levels of challenges before doing a presentation on your experience.

Design Constraints

Criteria	Constraints
Teams must submit a completed challenge proposal.	Teams must not exceed the budget provided when choosing supplies.
Teams must submit challenge reports after the completion of each challenge phase.	Constraints will be level specific given each scenario.
Teams must program their robotic ball using JavaScript or block programming.	The robotic ball must not leave the maze boundaries during the challenge.
Teams must use materials provided to complete the given task(s) in the scenario.	

Ask

- Your team will conduct research on unmanned aircraft system (UAS) designs that may potentially help your team engineer a device to successfully complete the scenario.
- Be prepared to answer the following questions:
  - What is the most surprising use of UAS during natural disasters that you found during your research?
  - How might a first responder without a UAS or unmanned/remotely controlled aircraft solve the real-world challenge?
  - How could a UAS assist first responders in solving the challenge?

Imagine

- Investigate the different materials provided by your teacher. What are the strengths and weaknesses of each material?
- How can you use the materials provided to design a device(s) to complete the challenge?
- How can you best utilize your supplies to stay within budget while accomplishing the challenge?

Plan

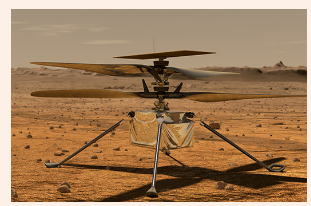
- Complete your challenge proposal, including a timeline, budget, and challenge design.
- After each level, you will submit a report detailing your solution and any updates to your proposal for the next level of the challenge.

Create

- Using your proposal, create your design to solve the challenge.
- You must also program your robotic ball to successfully navigate the course using your created design and stay within the criteria and constraints.

Fun Fact

Ingenuity, the first-ever Mars helicopter, launched on July 30, 2020, attached to the Mars rover Perseverance. Ingenuity was gently deployed from Perseverance after landing on the Red Planet. Ingenuity has made a number of short hops over the Martian surface, flying as high as about 4.572 meters (approximately 15 feet).



Learn more: https://mars.nasa.gov/technology/helicopter/

Career Corner

Michael Logan, head of NASA's Small Unmanned Aerial Vehicle Laboratory, designs, builds, and tests small unmanned aircraft systems at NASA's Langley Research Center in Hampton, Virginia.

Learn more: https://youtu.be/bIYAay3lwtI

Test

- You will be allowed as many practice tests as time permits while designing and programming your robotic ball based on your proposed timeline.
- Once final testing begins, you will be given one test to evaluate your final design.
- You will test your design and program by placing your robotic ball at the beginning of the course and running your program. Your design will be evaluated by the assessments provided in Appendix D, including the educator rubric and the level's unique requirement assessments.

Improve

- Use any extra time to improve your design and program after each practice test. Remember to record all improvements and modifications your team makes and include these in your final presentation.
- Be sure to include visual records (drawings, photos, screen shots, etc.) in your presentation of any significant changes in your design or your coding.

Share

- At the end of each level, your team will record answers to the following discussion questions:
  - What was the greatest challenge for your team during this level? How did you address this challenge?
  - What parts of your design did you reuse from a previous level? What parts of this level could you use in future levels?
  - What is the purpose of this level's design constraints? How would this relate to problems facing NASA engineers or first responders in similar situations?
  - How did your research into real-world applications of UAS affect your solution to the challenges?
- Worksheets will be provided by your teacher to help organize your final presentation after making it to your team's highest level.
- Your final presentation must include the following:
  - Research: Provide a brief summary of the research your team has completed on the real-world applications of UAS during the provided natural disaster scenario.
  - Programming: Explain how you used JavaScript or block programming to program your robotic ball to navigate through the maze autonomously from start to finish. Be sure to document any significant modifications your team made to the JavaScript or block programming.
  - Budget: Describe how you looked over each challenge task, designed a device for your robotic ball using materials provided, and stayed within the given budget.
  - Design Solution: Once your team has decided on materials, your team will sketch your engineering design to add to the robotic ball to help with the challenge on the worksheet provided.
  - Final Results: Discuss your responses to the questions listed below.
    - How did your research into real-world applications of UAS affect your solution to the challenges?
    - Did your design work as planned? Were you able to successfully complete this final level of the challenge?
    - What was the greatest challenge for your team during this final level? How did you address this challenge?
    - What parts of your design did you reuse from a previous levels?
    - What is the purpose of this level's design constraints? How would this relate to problems facing NASA engineers or first responders?

Appendix A.—Challenge Proposal

Team name: ______________________________________

Level number: __________

Name	Team duties	Description of duties

A.1 Research

Provide a brief summary of the research your team has completed on the real-world applications of unmanned aircraft systems (UAS) during the provided natural disaster scenario.

A.2 Challenge Timeline

Level number: __________

Proposed deadline	Task to complete
11.08.2021	*Finish proposal*
11.10.2021	*Begin initial design*

A.3 Budget

This is a projection that will change as you improvise and update your design during each level.

Suggested Budget: $100

Item	Cost per item	Quantity (how many?)	Total cost
			Total:

A.4 Design

Appendix B.—Suggested Items and Prices

Update the chart below using the items available for students to utilize during the challenge. Provide students with the individual prices set for each item, along with their grand total budget allowed. Their grand total budget will be dependent on the prices chosen for each item. (These are suggestions for items that might come in handy in the engineering design part of this challenge.)

Suggested budget: $100 per team

Item	Item description	Cost per item (or package)
Popsicle stick	A typical popsicle stick, roughly 112.7 mm long by 9.5 mm wide, representing a traditional 2- by 4-in. piece of lumber	$4.50
Straws	Bendy or non-bendy plastic drinking straws	$3.50
Cup	Plastic or paper cups (3 or 12 oz, depending on the size of the robotic ball)	$30.00
Adhesive	Choice of adhesive (tape, glue, etc.)	$10.00
Rubberbands	Various sizes for attaching items to robot	$2.00
Cardboard	Pieces cut to 10 by 10 in.	$6.00
Egg carton	12-count egg carton	$20.00
Wheels	Compact discs, premade wheels, cardboard wheels, etc.	$10.00
Paperclips	Various sizes (can be used to pop the balloon for Level 2)	$2.00
Index cards	Any size, lined or unlined	$2.00
Tacks	Items sharp enough to pop a balloon	$2.00

Appendix C.—Scoring Sheets

Teams will use the following scoring sheets to evaluate their team's performance during their final testing.

Level 1 Scorecard

	Points earned (+)	Points lost ( )
Robotic ball enters opening in maze (door) +1 point for each entry		
Robotic ball exits an already-entered opening in maze (exits door) +1 point for each exit		
Robotic ball hits an obstacle or wall within the maze –1 point for each hit		
Picking up or touching robotic ball after starting main program –1 point for each contact		
Total points earned and lost: Add up your points from each column		
Total score = (Points earned) – (Points lost)		

Level 2 Scorecard

	Points earned (+)	Points lost ( )
Robotic ball shuts off the valve (presses the button or pops the balloon) +10 points		
Robotic ball hits an obstacle or wall within the maze –1 point for each hit		
Picking up or touching robotic ball after starting main program –1 point for each contact		
Total points earned and lost: Add up your points from each column		
Total score = (Points earned) – (Points lost)		

Level 3 Scorecard

	Points earned (+)	Points lost ( )
Robotic ball moves the obstacle out of the path +10 points		
Robotic ball moves the obstacle out of the path without hitting anything within the maze with the obstacle +5 points		
Robotic ball hits an obstacle or wall within the maze –1 point for each hit		
Picking up or touching robotic ball after starting main program –1 point for each contact		
Total points earned and lost: Add up your points from each column		
Total score = (Points earned) – (Points lost)		

Level 4 Scorecard

	Points earned (+)	Points lost ( )
Robotic ball picks up object from the designated spot +10 points		
Robotic ball places object at designated drop zone +10 points		
Robotic ball hits an obstacle or wall within the maze –1 point for each hit		
Retrieved supplies hit an obstacle or wall within the maze –1 point for each hit		
Picking up or touching robotic ball after starting main program –1 point for each contact		
Total points earned and lost: Add up your points from each column		
Total score = (Points earned) – (Points lost)		

Level 5 Scorecard

	Points earned (+)	Points lost ( )
Robotic ball enters opening in maze (door) +1 point for each entry		
Robotic ball exits an already-entered opening in maze (exits door) +1 point for each exit		
Robotic ball hits an obstacle or wall within the maze –1 point for each hit		
Picking up or touching robotic ball after starting main program –1 point for each contact		
Robotic ball shuts off the valve (presses the button or pops the balloon) +10 points		
Robotic ball moves the obstacle out of the path +10 points		
Robotic ball moves the obstacle out of the path without hitting anything in the maze with the obstacle +5 points		
Robotic ball picks up object from the designated spot +10 points		
Robotic ball places object at designated drop zone +10 points		
Retrieved supplies hit an obstacle or wall within the maze –1 point for each hit		
Total points earned: Add up your points from each column		
Total score = (Points earned) – (Points lost)		

Appendix D.—Assessment Sheets

D.1 Advanced Rubric

	0	1	2	3
Team members	Missing all team members' full names, duties, and description of duties.	Missing some team members' full names, duties, or description of duties.	Includes all team members' full names and duties, but no description of duties.	Includes all team members' full names, duties, and description of duties.
Project timeline updates	The project timeline is not updated with any tasks or proposed completion dates.	Some phases in the challenge timeline are updated with a task or proposed completion date.	Some phases in the challenge timeline are updated with a task and proposed completion date.	Each phase in the challenge timeline is updated with a task and proposed completion date.
Challenge report	Does not include a written description of how the phase challenge was completed or any obstacles and how they were solved.	A written description of how the phase challenge was completed is included, but description does not include any obstacles or how they were solved.	A written description of how the phase challenge was completed is included; description includes obstacles but not how they were solved.	A written description of how the phase challenge was completed, including any obstacles and how they were solved, is included.
Codes	No codes used to solve the phase challenge are included.	Partial codes used to solve the phase challenge are included.	All codes used to solve the phase challenge are included, but not in their entirety.	All codes used to solve the phase challenge are included.
Budget	The team went over budget by more than $10 during the completion of their task.	The team went over budget by $10 or less during the competition of their task.	The team went over budget by $5 or less.	The team hit their budget on the mark or was under budget.
				Total score: _____/15

D.2 Beginner Rubric

	0	1
Programming	Robotic ball does not navigate through the maze autonomously from start to finish using JavaScript or block programming.	Robotic ball navigates through the maze autonomously from start to finish using JavaScript or block programming.
Design	Robotic ball does not contain a team-created design to the solution.	The team created an original design to solve the challenge.
Supplies	The challenge design contains extra supplies outside of the provided craft supplies.	The challenge design contains only provided craft supplies.
Challenge	The robotic ball did not complete the level challenge.	The robotic ball successfully completed the level challenge.
Maze	The robotic ball hit maze walls or maze obstacles.	The robotic ball did not hit any maze walls or maze obstacles.
		Total score: _____/5

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