**How Can You Improve and Validate a Surveillance System to Track Airplanes?**

grade level(s): 9-10

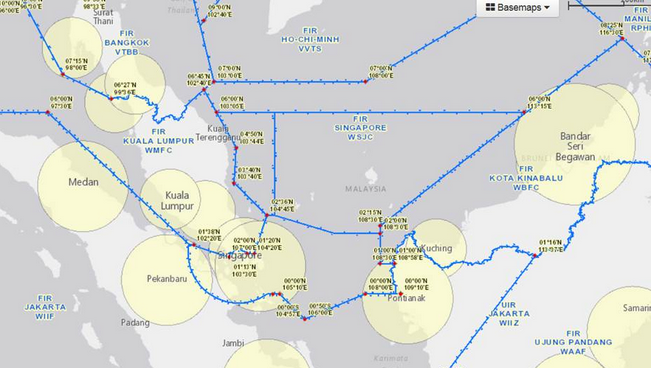
subject(s): Geometry, Engineering

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**Problem Statement:**

How can you improve and validate a surveillance system to track airplanes?

On March 8, 2014, the Malaysia Airlines flight 370 went missing over the South China Sea. Could an improved surveillance system have prevented this issue? Your team are radar engineers who will propose an updated surveillance system in order to mitigate issues like the lost MH 370 flight and present your solution to a country in the region. Given a limited budget and information about your country, you will determine how many new towers to place as well as which sites to improve. You will also need to create a method to validate the success of your solution or model your solution using technology.



**Conceptual Storyline:**

This lesson plan was designed for two types of classes, one with access to various aspects of wi-fi technology and another class limited access to technology. In these lesson plans we will designate (high-tech)HT and (low-tech) LT.

In Engineering (high-tech [HT]), students will explore the connections between existing data available on the internet and how to use that data to determine best practices. Students will use ultrasonic sensors to simulate existing and proposed radar systems. Small groups will take information provided on pre-selected countries to find a solution for providing the most thorough improved radar system given existing conditions and cost.

In Geometry (low-tech [LT]), students will explore applications of circles in mapping. Regions of coverage by surveillance systems can be modeled using equations of circles, while the path of a plane can be modeled as either a chord (from above) or an arc (from the side).

In both Engineering and Geometry, students will go through the Engineering Design Process displayed below.

|  |  |
| --- | --- |
| **Lesson 1: Identify** | Students will identify the problem by watching a video on the missing Malaysia Airlines flight and create a list of their knows/need-to-knows. |
| **Lesson 2: Describe** | Students will describe the need for an improved radar system in neighboring countries to avoid large areas of limited coverage. They will choose a specific country to focus on and then characterize the system by researching and mapping the existing surveillance system. They will also determine the best method to measure the effectiveness of their system. |
| **Lesson 3: Generate** | Students will generate concepts for an improved system individually, compare solutions within their group, and then select the best solution using a structured selection process. |
| **Lesson 4: Embody** | Students will embody their solution through an interactive map and Arduino networking system [HT] or through accurate maps drawn to scale [LT]. Students will test/validate their design using the method that they created earlier. |
| **Lesson 5: Finalize** | Students will present their solution by creating a video explaining their solution to their country. |

**Project Overview:**

|  |  |
| --- | --- |
| **Criterion** | **Description** |
| **Timescale** | 3 weeks of in-class team work |
| **Student Deliverables** | * Video explaining improved system * Map of improved system * [HT] Suggested model of network using electronic sensors * [LT] List of improved sites with locations and equations |
| **Teaming** | Teams of three |
| **Differentiation** | Strong teams/individual students can go deeper in the validation portion, developing quantitative methods to compare solutions. Weaker students can compare solutions more qualitatively. |
| **Teacher Role** | Teachers will scaffold students with relevant content background. Teacher will circulate during project work time to monitor progress and assist. |
| **Grading** | The video and maps/list of solutions will be graded separately using rubrics. Students should also be assessed individually using traditional assessments. |

**Unit Standards (NGSS, CCSS, CTE):**

|  |  |
| --- | --- |
| **NGSS Science and Engineering Practices**  <http://www.nap.edu/read/13165/chapter/7#42> | 1. Asking questions (for science) and defining problems (for engineering)  2. Developing and using models  5. Using mathematics and computational thinking  6. Constructing explanations (for science) and designing solutions (for engineering)  8. Obtaining, evaluating, and communicating information |
| **NGSS Content Standards** | HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.  HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.  Using Technology to Model and Determine Accuracy of Information from data  **ETS2: Links Among Engineering, Technology, Science, and Society**  A: Interdependence of Science, Engineering, and Technology  B: Influence of Engineering, Technology, and Science on Society and the Natural World |
| **CCSS Math Practices**  <http://www.corestandards.org/> | [CCSS.Math.Practice.MP1](http://www.corestandards.org/Math/Practice/MP1/) Make sense of problems and persevere in solving them.  [CCSS.Math.Practice.MP3](http://www.corestandards.org/Math/Practice/MP3/) Construct viable arguments and critique the reasoning of others.  [CCSS.Math.Practice.MP4](http://www.corestandards.org/Math/Practice/MP4/) Model with mathematics.  [CCSS.Math.Practice.MP5](http://www.corestandards.org/Math/Practice/MP5/) Use appropriate tools strategically. |
| **CCSS Geometry Standards [LT]**  <http://www.corestandards.org/> | **Understand and apply theorems about circles**  [CCSS.Math.Content.HSG.C.A.2](http://www.corestandards.org/Math/Content/HSG/C/A/2/)  Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.  **Translate between the geometric description and the equation for a conic section**  [CCSS.Math.Content.HSG.GPE.A.1](http://www.corestandards.org/Math/Content/HSG/GPE/A/1/)  Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.  **Apply geometric concepts in modeling situations**  [CCSS.Math.Content.HSG.MG.A.3](http://www.corestandards.org/Math/Content/HSG/MG/A/3/)  Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).\* |
| **ISTE Standards [HT]** | Standard 4. Critical thinking, problem solving, and decision making  Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. a. Identify and define authentic problems and significant questions for investigation  Standard 6. Technology operations and concepts Students demonstrate a sound understanding of technology concepts, systems, and operations.  d. Transfer current knowledge to learning of new technologies |
| **21st Century Skills** | Students will build and apply their critical thinking and collaboration when creating a solution for the problem. They will then work on their communication skills when presenting their solution. |

**Locally and/or Personally Relevant for Students:**

In our community, there is a strong presence of aerospace engineering and aviation because of Boeing. Many students have been in airplanes before and knew about the missing Malaysia Airlines flight. Airplane security and incidents are high-profile news stories (for example, EgyptAir Flight 804 was downed while we were teaching the unit).

**Connections to career and educational pathways:**

Students will experience what radar engineers would do as well as gain exposure to the different communication technologies involved in surveillance systems. They also gain insight into the transportation and defense industries.

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# Lesson 1. Identify

**Problem Statement:**

How can you improve and validate a surveillance system to track airplanes?

In this lesson, students are presented the problem statement and identify what they know/need to know to solve the problem.

**Learning Objectives:**

Students will be able to define the problem and identify knows/need-to-knows.

**Lesson Standards (NGSS, CCSS, CTE):**

**NGSS Science and Engineering Practices:**

1. Asking questions (for science) and defining problems (for engineering)

#### [CCSS.Math.Practice.MP1](http://www.corestandards.org/Math/Practice/MP1/) Make sense of problems and persevere in solving them.

**Materials:**

|  |  |
| --- | --- |
| *Why Planes Vanish* questions | See “Why Planes Vanish Question” in Student Sheet, Geometry (LT), or link here: <https://drive.google.com/open?id=1oGj0k27yLftbBZ9ScNSCQpBoArCYRbuJ7neymdkRDgw> |
| *Why Planes Vanish* video | Search for *NOVA: Why Planes Vanish* (available on Netflix) |

**Lesson Preparation:**

Teacher should be familiar with the disappearance of Malaysia Airlines flight 370 in 2014. Ideally, the teacher should watch the documentary in advance to understand where relevant information is shared.

Teacher should decide expectations for students during the movie (notes, interesting facts, graphic organizer, etc.) and form of exit ticket.

**Time Required: 90 minutes**

**Grouping of students for instruction:**

Teams are grouped in three based on teacher assignment. Ideas for how to group include heterogeneous grouping based on personality inventories (such as True Colors, Six Hats, or Myers-Briggs), heterogeneous grouping based on student performance, or random grouping.

**Lesson 1. Procedure:**

***Understand The Problem:***

Introduction/Problem Launch

* (55 minutes) Set up context (MH370 video)
  + Students watch the Nova video “Why Planes Vanish” (available through Netflix or similar streaming services) and write down interesting facts and questions. It is possible to show just the first 25-30 minutes since the important context is how radar works and that the transponder that communicates with secondary radar (with a much larger range) was deliberately turned off.
  + Students complete an exit ticket
    - What are 3 theories for how the plane vanished?
    - How can we ensure this situation doesn’t happen again?
    - What questions (at least one) do you have about this situation?
* (5 minutes) Review the video
  + Ask for students to summarize the video
  + Ask questions to help set-up the problem statement
    - How did the plane “vanish”?
    - What were some of the technology involved in tracking the airplane?
* (5 minutes) Receive the problem
  + Students receive problem statement: How can you improve and test a surveillance system to track airplanes?
    - Students need to create a model for their improved surveillance system for their chosen region, including all existing and new primary surveillance radar (PSR).
      * For Engineering [HT], the model should be an interactive map of a chosen region made using technology as well as a sample Arduino network.
      * For Geometry [LT], the model should be an accurate scale drawing of the region with equations of all circles, as well as an mathematical explanation of how to validate the solution.
    - Students need to explain their solution through a video.

Brainstorm What Students Know/Need to Know

* (15 minutes) Generate a class list of knows/need-to-knows with students. Students should refer to their exit tickets or video notes as a starting point.
  + Example knows
    - Region in the world
    - Where the airplane was located
    - Airplane was deliberately manipulated
    - Transponders were turned off
    - etc.
  + Example need-to-knows
    - Where existing radar sites are located
    - How curvature of the earth affects radar
    - Etc.

Define/Redefine the Problem

* (10 minutes) Discuss knows/need-to-knows with students to fully define the problem. Students should mark the knows/need-to-knows that are especially relevant to the problem. Important points to clarify:
  + We know that the transponders were deliberately turned off, so secondary surveillance radar could not track the plane. We are going to focus on primary surveillance radar.
  + Out of scope of the problem are satellites (Inmarsat) and military radar.
  + Teams will focus on specific countries to improve.
* Student teams should choose specific countries or regions in Southeast Asia

**Assessment:**

|  |  |  |
| --- | --- | --- |
|  | **Individual** | **Group** |
| **Informal** | Exit Ticket | Knows/Need-to-Knows |
| **Formal** |  |  |

**Accommodations:**

* Play movie with captions on
* Provide written summary of movie or Malaysia Airlines incident
* Allow another student to share video notes

**Extensions:**

Students can research need-to-knows from the list and then revisit their list of knows/need-to-knows based on new knowledge.

**References/Resources:**

PBS Nova video *Why Planes Vanish*: <http://www.dailymotion.com/video/x27pvf0_pbs-nova-2014-why-planes-vanish-720p-hdtv-x264-aac-mvgroup-org_shortfilms>

# Lesson 2. Describe

**Problem Statement:**

How can you improve and validate a surveillance system to track airplanes?

In this lesson, students are now describing and defining the problem for themselves. By the end of the lesson, students will mapped the existing radar stations. They will also have a better understanding of the quantitative success metrics of their solution.

**Learning Objectives:**

Students will be able to apply relevant Geometry and Engineering content in order to characterize and analyze the existing radar system.

**Lesson Standards (NGSS, CCSS, CTE):**

**NGSS Science and Engineering Practices:**

5. Using mathematics and computational thinking

**CCSS Standards:**

**Math Practices:**

#### [CCSS.Math.Practice.MP1](http://www.corestandards.org/Math/Practice/MP1/) Make sense of problems and persevere in solving them.

#### [CCSS.Math.Practice.MP3](http://www.corestandards.org/Math/Practice/MP3/) Construct viable arguments and critique the reasoning of others.

#### [CCSS.Math.Practice.MP4](http://www.corestandards.org/Math/Practice/MP4/) Model with mathematics.

#### [CCSS.Math.Practice.MP5](http://www.corestandards.org/Math/Practice/MP5/) Use appropriate tools strategically.

**Geometry Standards:**

**Understand and apply theorems about circles**

[CCSS.Math.Content.HSG.C.A.2](http://www.corestandards.org/Math/Content/HSG/C/A/2/)

Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.

**Translate between the geometric description and the equation for a conic section**

[CCSS.Math.Content.HSG.GPE.A.1](http://www.corestandards.org/Math/Content/HSG/GPE/A/1/)

Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

**Apply geometric concepts in modeling situations**

[CCSS.Math.Content.HSG.MG.A.3](http://www.corestandards.org/Math/Content/HSG/MG/A/3/)

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).\*

Using Technology to Model and Determine Accuracy of Information from data

**ETS2: Links Among Engineering, Technology, Science, and Society**

A: Interdependence of Science, Engineering, and Technology

B: Influence of Engineering, Technology, and Science on Society and the Natural World

**Materials:**

**Ht:**

|  |  |
| --- | --- |
| Database of International Surveillance Radar | <http://gis.icao.int/icaoviewernew/#>  Check the box: ICAO RADAR SSR PSR VHF  Check the box underneath: Primary PSR radar coverage (Secondary was the response back from a plane’s transponder) |
| Spreadsheet of MH 370 airports | See SE Asia PSR Location spreadsheet (in student sheets) |
| Flight data from MH370 | See MH370 Flight Path data (in student sheets) |
| Triangulation Exercise | See Lesson Plans: GPS and Navigation  <http://www.navystemfortheclassroom.com/lesson-plans> |

**LT:**

|  |  |
| --- | --- |
| Database of International Surveillance Radar | <http://gis.icao.int/icaoviewernew/#>  Check the box: ICAO RADAR SSR PSR VHF  Check the box underneath: Primary PSR radar coverage (Secondary was the response back from a plane’s transponder) |
| Maps of existing radar sites  *Teams each choose a different region.*  *Each student should receive his/her own map, as well as each team receiving a team map.* | See “SE Asia Country Maps” in Student Sheets, or link here: <https://drive.google.com/open?id=1d6vhuv_55p3_FVOWfALZT46ObMY9khK8l0i-UtWxnWE> |
| Student packet  *Each student group receives one.* | See “Airplane Surveillance System Project Packet” in Student Sheets, or link here: <https://drive.google.com/open?id=1Bv1Z14owFOPOVw5k31xEN8FCYBoULEWnPg-6m7H3L3Q> |
| Arc Lengths Lesson | See “Arc Length Exploration: How long is a nautical mile?” in Student Sheets, or link here: <https://drive.google.com/open?id=1LonCbdtsSExCC4jE4O-_sWTcknFB7ufz59wF2yk91oM>  See “Geometry - How Long is a Nautical Mile?” in PowerPoints, or link here: <https://docs.google.com/presentation/d/1gSHLlSp3Fg7LEygyJeRGALRzwvqiwy0ufbfhBJvbMc8/edit?usp=sharing> |
| Unit Circle Lesson | See “Unit Circle Instructions” in Student Sheets, or link here: <https://drive.google.com/open?id=17_sxOTm7BOvpq7Eqomq7xGAzaXMeRaTtOYkLQYEqw2Q> |

**Lesson Preparation:**

Before teaching this lesson, the teacher should decide what content scaffolding is necessary for the project and for course learning standards, and choose appropriate lessons for those standards (for example, equation of a circle). The teacher should be familiar with the GIS ICAO database for airplane radar and should know how to view and toggle relevant radar layers on the map.

**Time Required:**

100 min - 240 min, depending on content scaffolding

**Grouping of students for instruction:**

Students will be in groups of 3.

**Procedure:**

***Describe (2 Days):***

Describe the Need (Day 1):

* (5 min) Requirements and Constraints
  + Provide budget ($50M suggested, though this differs depending on the size of the region-see individual maps) and costs of different towers.

|  |  |  |  |
| --- | --- | --- | --- |
|  | S-band  60 NM | L-band  160 NM | L-band  220 NM |
| Airport (TCA) | $6M | $7.5M  ($3M cost to upgrade) | -- |
| Land (not a major airport) | $8.5M | $10.5M  ($4M cost to upgrade) | -- |
| Sea (buoy-based) | -- | $18M | -- |
| Air (blimp/balloon) | -- | -- | $25.5M |

* (100-180 min) Content Scaffolding
  + *Geometry [LT]:* Teacher should go through lessons to introduce relevant math concepts.
    - Areas of circles refresher
    - (90 min) Exploration lesson to derive the equation of a circle and create the Unit Circle: <https://docs.google.com/document/d/1C_qsPd2wIZfvh2jr8xDHDI6uGksxkC19SIEVTyroiz4/edit?usp=sharing>
    - (50 min) Arcs and sectors - How long is a nautical mile? <https://docs.google.com/document/d/1M1swKZN55TDkdhtlo29vEoid9CCdfqghay1fKwt9RmE/edit?usp=sharing>
    - Unit conversions explanation (statute miles, kilometers, and nautical miles)
  + Engineering [HT]: Teacher should refer to the available resources:
    - Geolocating Airports: (50 min).
      * Open Excel spreadsheet of time stamp and geo location of MH370 and demonstrate placing ping points on an Excel map (in Office 2013 and above) or import sheet into Google Fusion Tables and geocode the data.
      * Flight path of MH370:  
        <https://drive.google.com/open?id=0By3J7DN0mMCNQXlKbFhUMnhqV28>
      * Verify with students that the content has a geographical component. Demonstrate how to add this content to Google Fusion tables or Excel Maps.
    - How radar works demonstration (40 min):
      * Students will determine how triangulation will provide an approximal distance between existing systems or improving existing systems to minimize gaps
      * We completed an activity in having a student be the constant while other students were at staggered distances. You could determine how far away they were based on the constant rate that the one student would walk towards them.
      * Resource: How does radar work (triangulation exercise)

Characterize and Analyze the System:

* [LT] (55 min) Students analyze the existing radar system on a paper map.  
  [HT] (55 min) Students get specific details from International Civil Aviation GIS site: <http://gis.icao.int/icaoviewernew/#> (see student instruction sheet)
  + Student teams are provided with maps of their region. Each person should get a map for their individual work, as well as an extra map for the team solution.
  + Each student adds a grid on their map using the units of choice (decided on by the team).
  + Student teams figure out the locations and ranges of existing radar systems.
  + Student teams write equations of circles for these radar stations using their grid.
* (20 min) Performance Metrics
  + Ask: How do we measure good coverage?
  + Students think and write individually, share with their teams, and then share out to the class.
    - Students might come up with maximizing the area covered, minimizing the cost, reducing the number of changes to the existing system, reducing overlap between existing and new systems, construction efficiency, etc.
    - Depending on the class topic (Engineering versus Geometry), teacher should maintain a class list and draw diagrams of the mathematical situations to explore later.
* If time: research
  + Who’s already giving information?
  + What technology has already gone into those?
  + Flight paths?

**Assessment:**

|  |  |  |
| --- | --- | --- |
|  | **Individual** | **Group** |
| **Informal** | Gridded map of country |  |
| **Formal** | Suggested: Quizzes over relevant content | List of existing radar systems and their equations |

**Accommodations:**

* Provide student with printed class notes of problem statement and materials list
* Allow another student to share class notes of problem statement and materials list
* Provide student with pre-written criteria
* Provide student paper map with grid pre-drawn
* Provide list of locations and ranges, so students only need to write equations

**Extensions:**

If time allows, students can initially develop their own customer needs statement following this procedure:

* (25 min) Developing a Customer Needs Statement
  + Students will identify the customer who they think is most important, and explain why.
  + Students will read through their Knows/Need-to-Knows list and choose the top 4-5 items they think are the most important to the customer.
  + *Me:* Each student writes a customer needs statement in one sentence encompassing the main ideas of the challenge.
  + *We:* Each team member shares their customer needs statement, and the team combines the statements into one.
  + *Us:* The teacher facilitates the creation of a class customer needs statement by asking teams to share their statements and capturing key ideas.

Students can also research existing metrics for measuring good coverage as well as research existing technology for improving coverage.

**References/Resources:**

Triangulation lesson from Navy STEM in the Classroom ([www.navystemfortheclassroom.com/](http://www.navystemfortheclassroom.com/))

Database for radar from GIS (<http://gis.icao.int/icaoviewernew/#/>)

Geometry content lesson plans developed by Melanie Kong

# Lesson 3. Generate

**Problem Statement:**

How can you improve and validate a surveillance system to track airplanes?

In this lesson, students individually generate at least one viable solution for improving surveillance coverage in Southeast Asia, and then compare and select the best solution using a structured selection process.

**Learning Objectives:**

Students will be able to consider cost and coverage trade-offs as they individually generate a solution for a new radar system. Students will be able to validate solutions mathematically and select a solution as a team.

**Lesson Standards (NGSS, CCSS, CTE):**

**NGSS Science and Engineering Practices:**

2. Developing and using models

6. Constructing explanations (for science) and designing solutions (for engineering)

**CCSS Standards:**

**Math Practices:**

#### [CCSS.Math.Practice.MP3](http://www.corestandards.org/Math/Practice/MP3/) Construct viable arguments and critique the reasoning of others.

#### [CCSS.Math.Practice.MP4](http://www.corestandards.org/Math/Practice/MP4/) Model with mathematics.

#### [CCSS.Math.Practice.MP5](http://www.corestandards.org/Math/Practice/MP5/) Use appropriate tools strategically.

**Geometry Standards:**

**Understand and apply theorems about circles**

[CCSS.Math.Content.HSG.C.A.2](http://www.corestandards.org/Math/Content/HSG/C/A/2/)

Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.

**Apply geometric concepts in modeling situations**

[CCSS.Math.Content.HSG.MG.A.3](http://www.corestandards.org/Math/Content/HSG/MG/A/3/)

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).\*

**Materials:**

LT - Student groups should continue following the student packet from Lesson 2. Each student needs a copy of their country map. Other materials that may be helpful are rulers and compasses.

**Lesson Preparation:**

The teacher should prepare answers to potential student questions during concept generation, such as whether teams are allowed to increase their budget for special requests, if students are allowed to place just one site instead of multiple, etc.

**Time Required: 55 minutes**

**Grouping of students for instruction:**

Students will be in heterogeneous groups of three.

**Procedure:**

***GENERATE:***

* (20 min) Generate Concepts
  + Each student comes up with a layout for the improved surveillance system given budget and materials list. Students do this by hand using compass [LT] OR using technology [HT].
  + Scaffolding for students:
    - Give map of flight routes
    - Provide a starting station
* (30 min) Select a Concept
  + Students share solutions within their groups.
  + Teams take notes in their student packets.
  + Students follow a structured method (provided in student packet) for comparing the different solutions and to select their top solution.
    - Balance pros/cons of each solution
    - Select best solution out of 3 using structured method

[HT]: (55 min) Student investigate research available for countries starting with existing radar systems already provided. After coming up with their own solutions, use the paper provided to lay out solutions. Students solutions could overlap but after discussion, there needs to be a consensus.

* There are Requests for Proposals and bids on airports for students to see how pricing works for new airports versus upgrading.

**Assessment:**

|  |  |  |
| --- | --- | --- |
|  | **Individual** | **Group** |
| **Informal** | [HT] Find a local airport and determine range of airport radar and location. |  |
| **Formal** | Individual solutions on map | Selection process documentation |

**Accommodations:**

* Reduce the individual “Generate” assignment so student chooses to place 1-2 stations instead of coming up with an entire solution
* Provide student groups with radar range distances in different units

**Extensions:**

Students can come up with multiple solutions, with each solution focusing on a different criteria (maximizing land coverage, maximizing ocean coverage, minimizing cost, minimizing new construction, etc.) so teams have more solutions to compare.

# Lesson 4. Embody

**Problem Statement:**

How can you improve and validate a surveillance system to track airplanes?

In this lesson, student teams will draw their final solution on a map based on the team’s concept generation and selection processes.

**Learning Objectives:**

Students will be able to embody their solution either by hand or digitally and identify locations, ranges, and equations of new radar sites. [HT] Students will be able to model their solutions using Arduino hardware and software.

**Lesson Standards (NGSS, CCSS, CTE):**

**NGSS Science and Engineering Practices:**

2. Developing and using models

5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)

**CCSS Standards:**

<http://www.corestandards.org/>

**Math Practices:**

#### [CCSS.Math.Practice.MP1](http://www.corestandards.org/Math/Practice/MP1/) Make sense of problems and persevere in solving them.

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#### [CCSS.Math.Practice.MP4](http://www.corestandards.org/Math/Practice/MP4/) Model with mathematics.

#### [CCSS.Math.Practice.MP5](http://www.corestandards.org/Math/Practice/MP5/) Use appropriate tools strategically.

**Geometry Standards:**

**Understand and apply theorems about circles**

[CCSS.Math.Content.HSG.C.A.2](http://www.corestandards.org/Math/Content/HSG/C/A/2/)

Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.

**Translate between the geometric description and the equation for a conic section**

[CCSS.Math.Content.HSG.GPE.A.1](http://www.corestandards.org/Math/Content/HSG/GPE/A/1/)

Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

**Apply geometric concepts in modeling situations**

[CCSS.Math.Content.HSG.MG.A.3](http://www.corestandards.org/Math/Content/HSG/MG/A/3/)

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).\*

**Materials:**

LT - Student teams should continue using their student packets and maps to embody their solutions. Other materials that may be helpful are rulers and compasses.

**Lesson Preparation:**

The teacher should decide whether or not to require students to embody their solution through an Arduino network in addition to a hand-drawn map.

**Time Required: 55 - 110 min, depending on technology integration**

**Grouping of students for instruction:**

Students will be in heterogeneous groups of three.

**Procedure:**

* [LT] (55 min) Student teams embody their team solution on a paper map.
  + Teams draw a grid on their maps.
  + They precisely graph circles of correct ranges on their map using a compass.
  + They record the equations of each circle.
* [HT] Student teams embody their team solution using an interactive map as well as modeling the solution using Arduinos. (work can be distributed among team members).
  + (55 min) Student teams embody their team solution using Excel maps or Google Fusion Tables.
    - Students will use a mapping coordinate system to place their proposed radar systems in their determined locations.
    - Teams will also need to determine range of their systems as cost parameters will influence placement and depth of range.
  + (55 min) Student teams create an electronic model of their solution.
    - In order to prove the system, students use a scaled down electronic sonar system to show how successful the system layout is in sensing objects.
    - Students simulate these systems with Arduinos and ultrasonic sensors. These sensors are placed in locations on the scaled model to demonstrate how the new system could work as LED lights or Piezo buzzers would sound when an object travels between the two systems.

**Assessment:**

|  |  |  |
| --- | --- | --- |
|  | **Individual** | **Group** |
| **Informal** | [HT] export geographical components from an excel spreadsheet to a map. |  |
| **Formal** |  | Final Solution on Map  [LT] List of Equations for New Sites |

**Accommodations:**

* Allow students more time to complete project

**Extensions:**

Students can come up with additional recommended solutions depending on client needs.

# Lesson 5. Finalize

**Problem Statement:**

How can you improve and validate a surveillance system to track airplanes?

In this lesson, students create a presentation to share their solution for an improved surveillance system.

**Learning Objectives:**

Students will be able to present and explain their solution, including their placement of radar towers, cost analysis, and system validation.

**Lesson Standards (NGSS, CCSS, CTE):**

**NGSS Science and Engineering Practices:**

8. Obtaining, evaluating, and communicating information

**CCSS Math Practices:**

[CCSS.Math.Practice.MP3](http://www.corestandards.org/Math/Practice/MP3/) Construct viable arguments and critique the reasoning of others.

**Materials:**

Students will need access to technology to create their presentations, whether it be phones or computers.

**Lesson Preparation:**

The teacher should decide if s/he wants to change the requirements for the presentation and if students will present in front of each other.

**Time Required: 55 - 180 min, depending on student presentations**

**Grouping of students for instruction:**

Students will be in heterogeneous groups of three.

**Procedure:**

Present the Solution:

* (45-150 min) Students create video presentations for their solution. This will take anywhere from 45-150 minutes, depending on available resources and expectations for the presentations.
  + [HT] (150 min) Students create a multimedia presentation.
    - Using embodied examples of Arduino sensors, lights and sound, students should include a film of how the system works with a light or sound sensor turning on as something approaches within range of the scaled system.
    - Additionally, they will provide their findings and placing of radar as it corresponds to a multimedia map in Google Earth or Excel Maps. With a tool like Google Earth or Excel Maps, students will show the path of MH370. There will be two additional layers, one layer for the existing system and the second layer for the new, embodied system.
    - Students should include their cost analysis for their final solution
    - The report itself should resemble a pitch to a decision making body. Use the media and data to explain why placement has been optimized. The final product is a presentation with videos embedded.
  + [LT] (45 min)Students create a video presentation using their phone cameras answering the following questions:
    - What is the challenge?
    - What did the existing system look like?
    - What is your solution? Show the map and cost.
    - Explain your solution. Why did you choose to improve or add sites? What was your reasoning?
    - Explain why your solution is better than the original using the criteria your team selected.

Debrief the problem:

* (30 min - optional) Students present their videos in front of the class.
* (10 min) Students complete provided reflection sheet.

**Assessment:**

|  |  |  |
| --- | --- | --- |
|  | **Individual** | **Group** |
| **Informal** | Reflection Sheet |  |
| **Formal** |  | Final Presentation |

**Accommodations:**

* Allow students more time to complete project
* Eliminate presentation requirement

**Extensions:**

Students can present their videos in front of the class.

Students can put together a greater map of the entire region with improved surveillance systems.

Students can compare solutions for different regions.