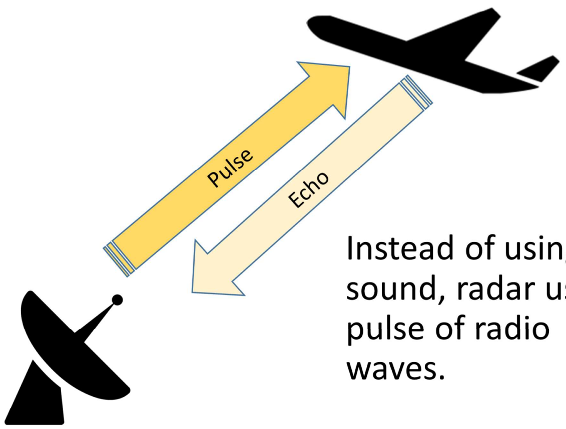
Overview of Radar Technology

Radar uses the principle of echoes to measure distance to an object.



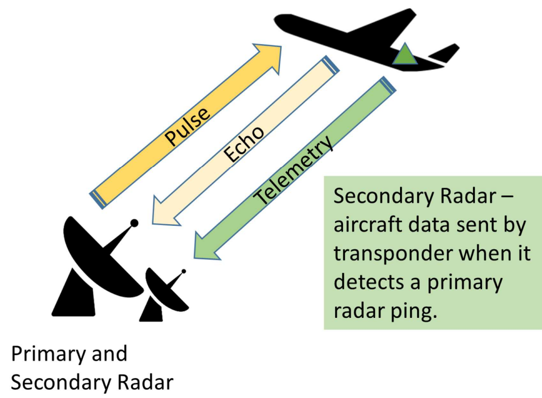
Instead of using sound, radar uses a pulse of radio waves.

Q: *if* c_0 *is the speed of light and* Δt *is the time between the pulse being transmitted and the echo received, write an equation to find the distance to the plane.*

Check student responses and ask how realistic this model is. Can we use this simple model to actually implement a radar system?

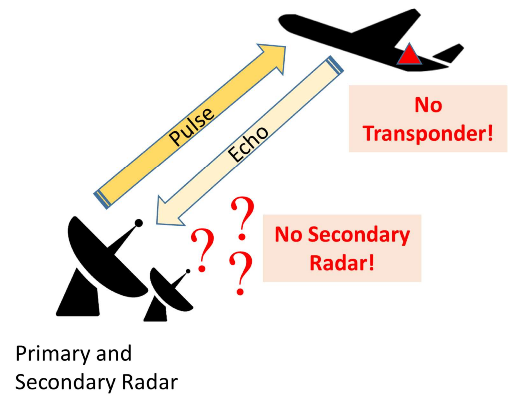
Ask them what real-world complexities are not represented in this explanation. See the project outline for a sample list. As the students to brainstorm, write their ideas on the board and have them write them also in their notes.
Alternatively have students brainstorm at their desks with their teammates.

Air traffic is managed by two radio technology systems – traditional radar and plane-based radio transponders, referred to as secondary radar.



Primary radar sends a ping and waits for the echo. Secondary radar refers to a device on the aircraft called a transponder. The transponder on the airplane listens for the primary radar ping. When it detects the ping it responds with a packet of data that includes the aircrafts identification, altitude, location, bearing, velocity, etc. What we call the radar system has a second receiver that is listening for the telemetry data from the aircraft's transponder.

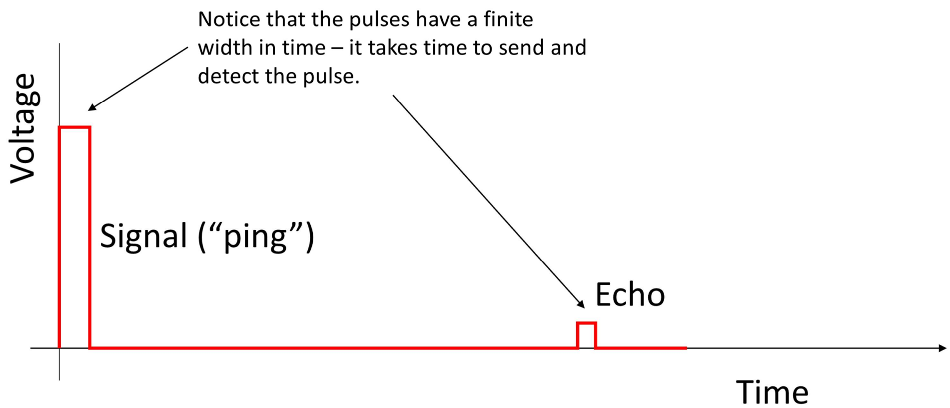
What if the transponder fails and secondary radar isn't available? In this project we will investigate how accurate primary radar is in the absence of secondary radar.



The global air traffic control system has one important limitation – it assumes that planes want to be found and tracked. The transponder and secondary radar system are used to track most of the critical and precise flight data.

In the MH370 incident both transponders were either turned off or failed. Military planes can turn their transponders off. The question is how good is the commercial radar system in the absence of secondary radar? That's what we will investigate in this project.

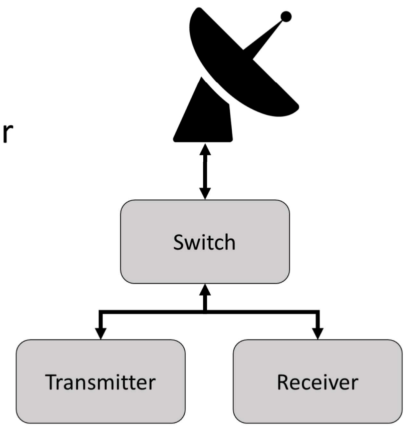
Fundamentally, the system is only using a clock and watching a voltage that is proportional to the strength of the transmitted and received pulses.



The voltage of the signals will be proportional to the radar energy being transmitted and received. Not that the echo energy is much lower than the ping energy. This means that you should probably consider transmitter power and receiver sensitivity – what’s the lowest echo energy the receiver can detect? What is the ratio of transmitter power to receiver sensitivity?

Radar uses mostly the same equipment to both transmit and receive a signal.

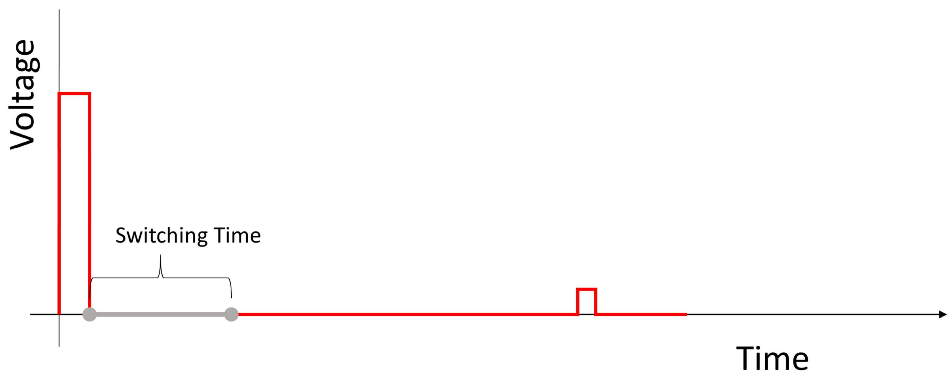
- The switch decides whether the transmitter or the receiver is using the radar dish.



- It takes time to switch between them.

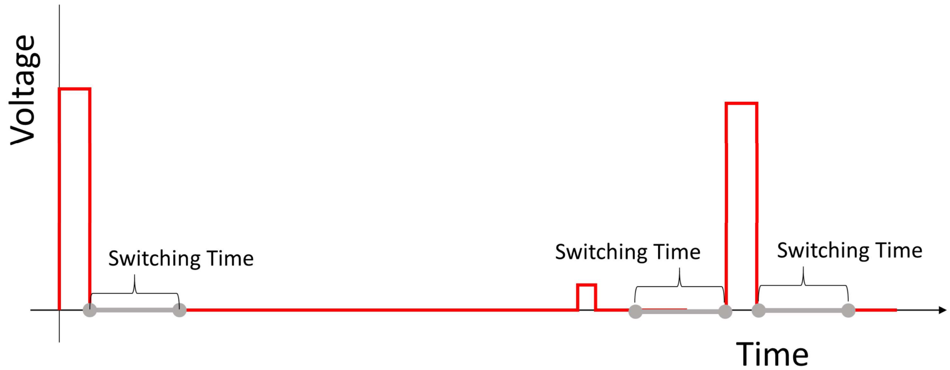
The main issue here is that the system can't "listen" for the echo when it is transmitting and also when the switch is switching between the devices.

Switching from transmitter to receiver takes time.



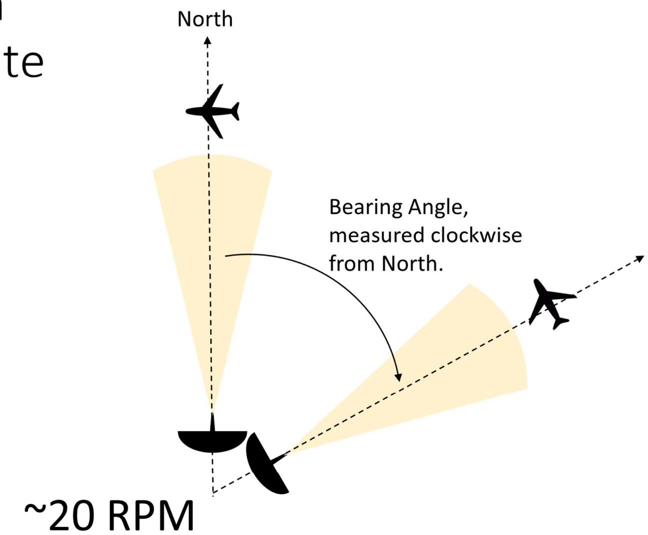
During the switching time the radar station is blind – it cannot detect anything that is within that switching time of the ping.

The radar will send a sequence of pulses, many times per second, each requiring a switch between transmitter and receiver.



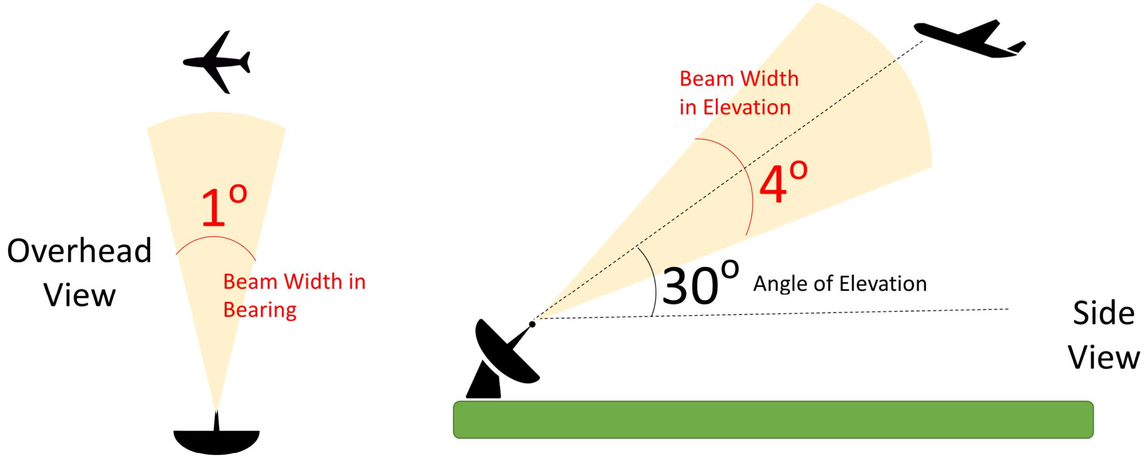
Not the switching time applies both before and after the ping.
What is the impact of the total time between pings becoming smaller or larger?
Note that the echo pulse may or may not be associated with the immediately preceding ping. What impact does that have on the computed range to the airplane?

The radar dish will spin several times per minute to detect planes in different directions.



The bearing is the direction to the airplane measured clockwise from polar north. (in reality a magnetic correction is applied to magnetic north, but we don't need to concern ourselves with that).

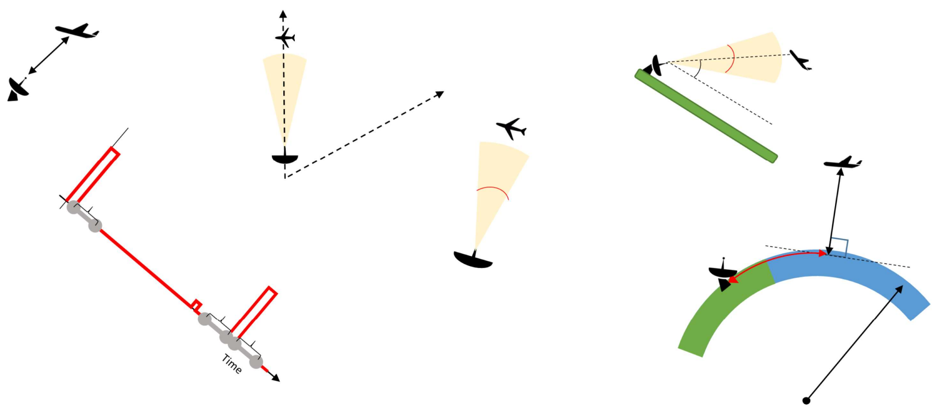
The radar beam is narrow and will spread out as it leaves the dish.



The amount of spread in the radar beam is called the beam width and is typically measured in degrees. The beam width measured from above is the width in bearing whereas the beam width measured from the side is the width in elevation. Note that the angle of elevation is measured from the horizontal to the center of the radar beam. If the airplane is anywhere within the radar beam an echo will be generated regardless of the plane being in the center of the beam or near the edge of the beam. Finally consider that over large distances (tens of kilometers or more) the curvature of the Earth becomes noticeable. This may impact your definitions of altitude or height.

Approaching the Project

There are many aspects and sub-problems related to how radar works – pick one - you don’t need to solve all of them.



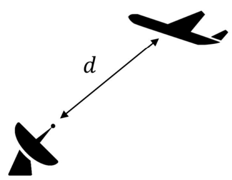
There are many different aspects to implementing radar. Your job will be to select one or two sub-problems and solve them. Taken together your team will solve several problems in total and describe them. For example, you may choose to determine the equations to determine uncertainty in altitude of the target whereas your teammate may choose to determine how far away from the airport the plane is. These are separate but related aspects of characterizing the radar system.

You may want to coordinate with your teammates so that together you solve several related problems and more fully characterize one major aspect of radar.

After selecting a sub-problem, you want to describe it like a word problem from a text book.

A plane is flying an unknown distance d kilometers from a radar tower. The radar station emits a radar pulse and detects a radar echo from the plane t seconds later. Find an equation for the distance to the airplane. Assume the speed of the radar pulse is c km/sec.

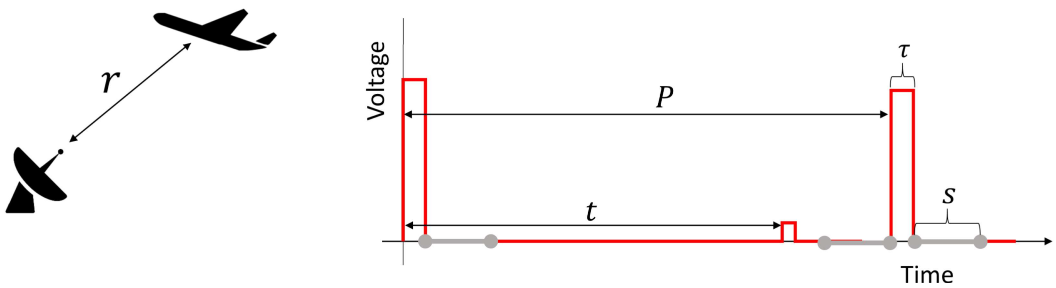
A brief paragraph that provides context, background, and definitions related to the problem.



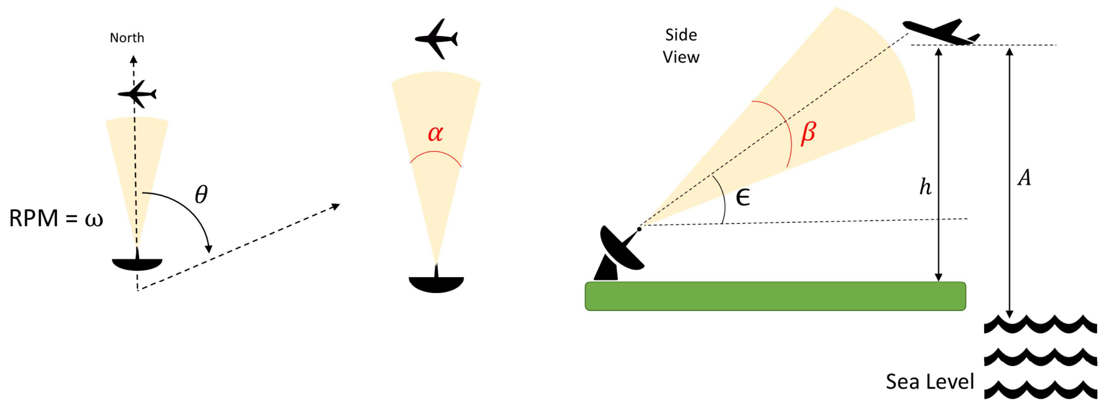
A diagram that illustrates the geometric relationships between objects in the word problem and appropriate notation.

You have to carefully define the problem you are trying to solve. A poorly defined problem may not have enough information to allow a solution, or may have unclear wording. The more complicated the problem the more important it is to provide a labeled diagram to help others understand the scenario.

Using variables allows you to substitute values later without worrying about arithmetic during your analysis.



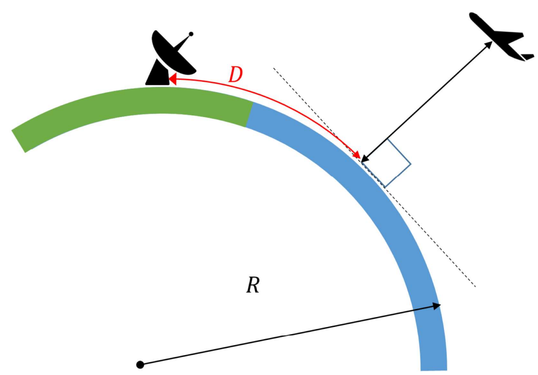
Greek letters are typically used for angle measures.



As you move forward in mathematics, you will encounter more complex notation and Greek letters/variables will become more common.

There are two different ways to measure the vertical position of an airplane, height above ground and alititude above sea-level.

Remember, the Earth is not flat!



Over small distances, assuming the earth is flat is acceptable. However, radar can operate over hundreds of kilometers, so the curvature of the Earth may be significant. You can determine the significance by solving the problem assuming both a flat Earth and a curved surface. Often times, solving the flat case is simpler and can help you figure out how to solve the curved scenario.

Questions?