Science, Technology, Engineering & Maths (STEM)

Mr Bateson

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Brief Introduction

- Electronic Engineering, University of York, 2001-05
- RAF Engineering Officer, 2006-11
- Cybersecurity Consultant, PwC and NCC Group, 2011-16
- Head of Cybersecurity, McLaren, 2016-20
- Information Security Manager, Slaughter and May, 2020-now









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Previous STEM Sessions

1. Bridge and crane building.
2. Emerging technologies.
   - Artificial Intelligence.
   - Self-driving cars.
   - Augmented Reality.
3. Introduction to programming.
4. Codes and codebreaking.
5. Space.



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This Session



Radar & Stealth

- What Radar is
- How Radar Works
- Civil Use of Radar
- Military Use of Radar
- Stealth (defeating radar)

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Before We Start

- These STEM sessions aren't on any exam.
- The slides can be downloaded from www.timbateson.co.uk/rafac/ at any time.
- No need to write everything down – please focus on taking part.

- If you have a question, then just ask as we're going along (or type it in the chat if you haven't got a mic).
- Staff – please shout if there are questions in the chat or anyone's hand is up (I can't see this while sharing my screen).

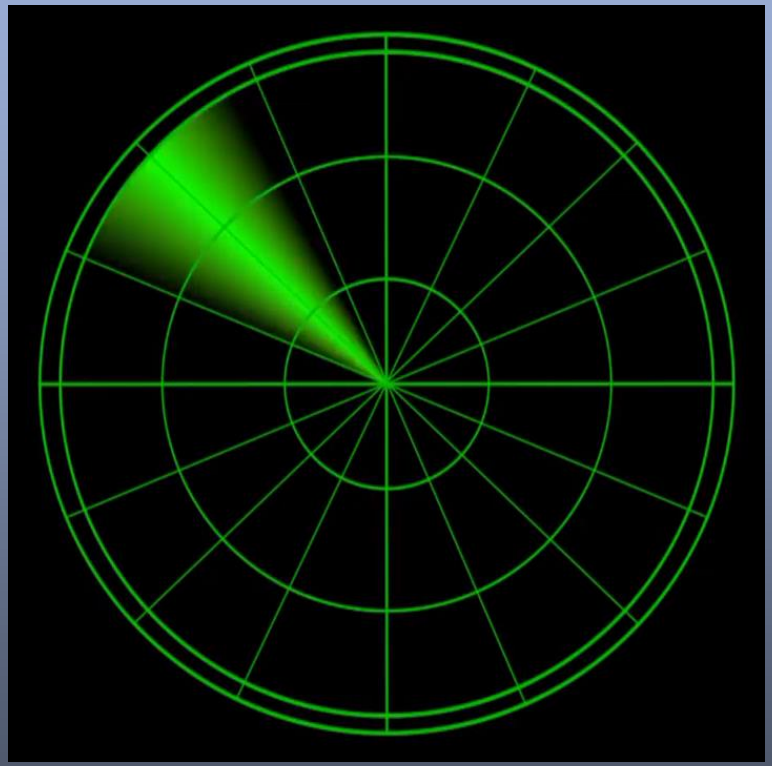
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What Radar is

- Radar is a way of detecting, locating and (sometimes) identifying things*.
  - The direction.
  - The distance.
  - The velocity (sometimes).
  - The height/depth (sometimes).
  - The size (sometimes).

*: we'll cover what types of things later on.



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What Radar is

- Original definition of RADAR: *RAdio Detection And Ranging*.
  - Using radio waves to detect things and tell how far away they are.
- Usually written *Radar* rather than *RADAR* these days.
  - Radar can often do more than just *detect* and *range*.
  - Related technologies: *Sonar* (using sound), *Lidar* (using light).
- Two main types of radar in the air domain:
  - Primary Surveillance Radar.
  - Secondary Surveillance Radar.
- Other, more specialised, types of radar do exist.

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How Radar Works: Primary Radar

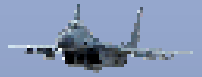
- **Primary** radar:
  1. Sends out pulses of radio energy (radio waves).
  2. Listens to see if an echo bounces back off anything.
  3. If it does receive an echo, it does some signal processing to determine the distance to and the direction of the relevant target.
  4. Presents that information on a screen for an operator to use.

- The target doesn't have to do anything.
  - So it doesn't matter whether the target cooperates or not.

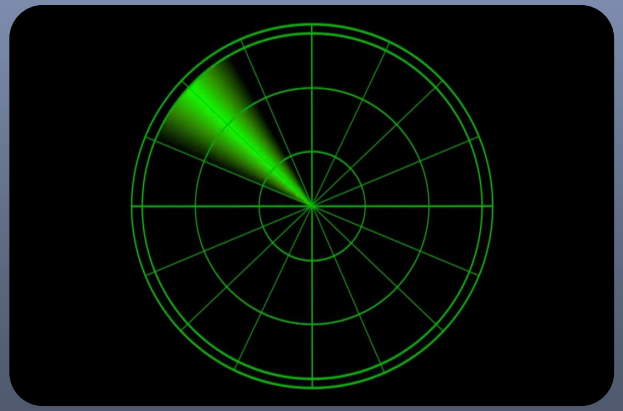
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How Radar Works: Primary Radar







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How Radar Works: Primary Radar



Direction

- The direction of the target is the direction that the radar is pointing when it receives the echo.
- A surveillance radar turns constantly, to scan the whole sky.
  - The speed it turns (perhaps 120˚ to 180˚/s) is very slow relative to the speed of radio waves and how often pulses are transmitted.

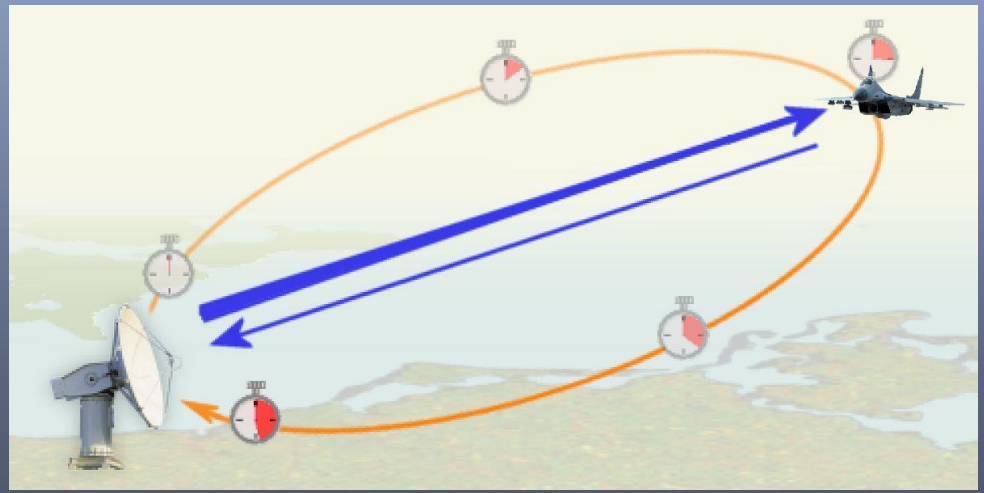
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How Radar Works: Primary Radar

Distance

- The time delay between transmitting a pulse and receiving an echo tells us how far away the target is.
  - Distance = speed x time.
  - Speed of radio waves = the speed of light (c) = 3×10^8m/s.
  - Distance = $c \times \frac{t_{roundtrip}}{2}$.
  - E.g. if t=1ms, d=93miles.



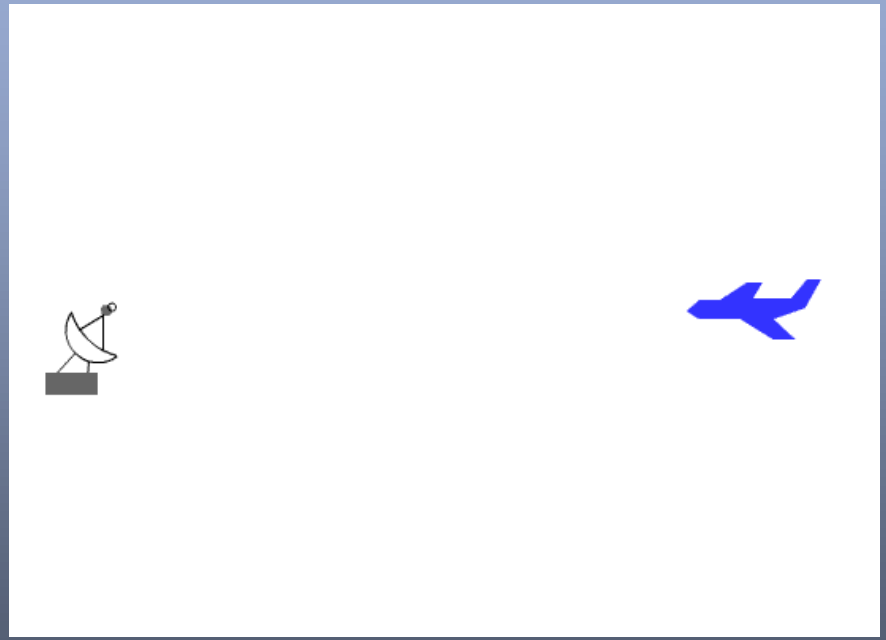
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How Radar Works: Primary Radar

Velocity (some radars only)

- Relies on the Doppler effect.
  - E.g. a police siren sounds different coming towards you to when it's moving away.
  - The frequency of the echo increases if the target is moving towards the radar.
  - The bigger the shift, the faster the target is moving.



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How Radar Works: Primary Radar

Design Parameter	Higher	Lower
Carrier frequency	• Higher resolution (better able to count the aircraft in a formation). • Higher discrimination (better at distinguishing targets from clutter).	• Better penetration of clouds/weather. • Can potentially see over the horizon.
Peak power output	• Longer maximum range. • Can detect smaller targets.	• Cheaper to produce and to operate. • Smaller, lighter, more portable. • Lower risk of interference.
Pulse width	• Can detect smaller targets. • Longer maximum range.	• Higher resolution (better able to count the aircraft in a formation). • Shorter minimum range.
Pulse Repetition Frequency (PRF)	• Better accuracy (can place a target in a smaller piece of sky).	• Less range ambiguity. • Potentially longer maximum range.

- Not all radars are the same – need to be matched to their role!

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How Radar Works: Secondary Radar

- Most aircraft are fitted with a *transponder* that, if asked by **secondary** radar, transmits information like the aircraft's:
  - Callsign.
  - Altitude.
  - Status code (its "squark").
  - GPS coordinates.
  - Speed.
- This can be overlaid on the radar picture.
- Relies on the aircraft cooperating.



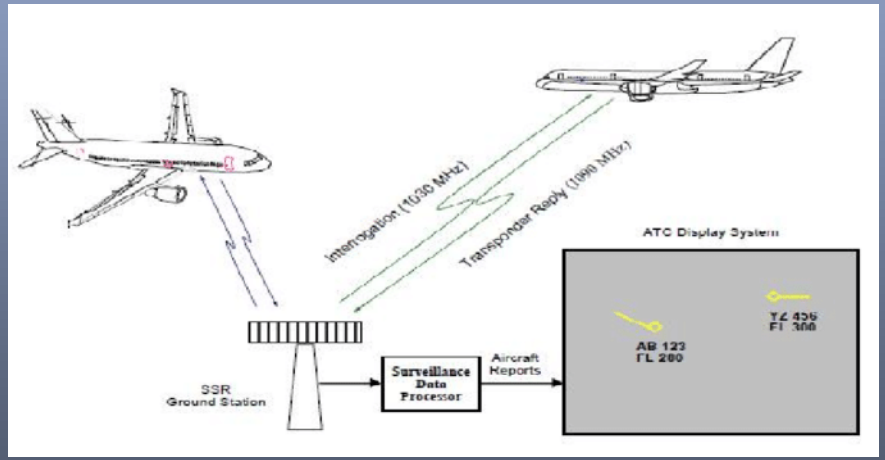
A typical light aircraft transponder

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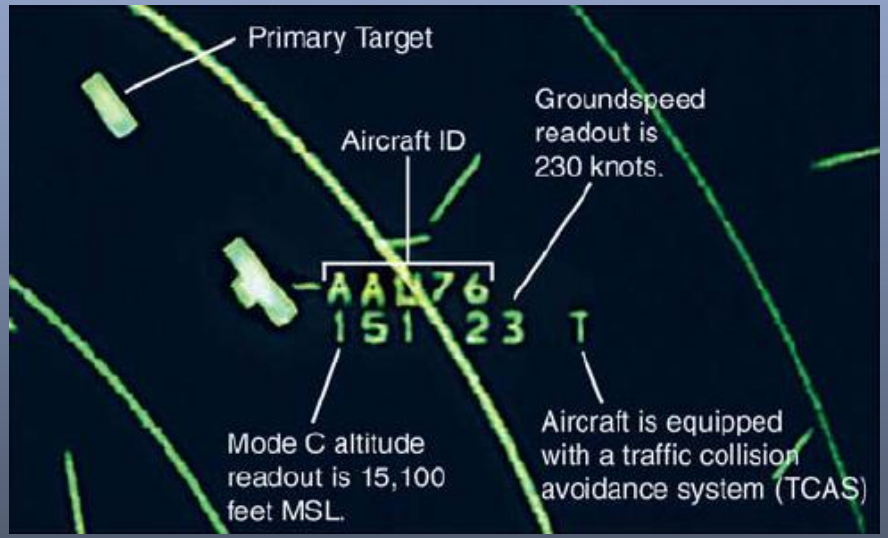
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How Radar Works: Secondary Radar

- Secondary Surveillance Radar (SSR) interrogating two aircraft:



- How this is presented to the radar operator:



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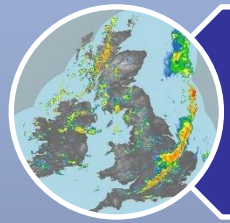
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Civil Use of Radar



Air Navigation

- Airspace Management
- Air Traffic Control
- Radar altimeters in aircraft



Weather Forecasting

- Storm tracking
- Rainfall maps



Marine Navigation

- Coastal radar
- Ship-borne radar



Ground Surveying

- Civil engineering
- Archaeology



Safety & Security

- Speed cameras
- Body scanners (e.g. at airports)



Space Surveillance

- Radio astronomy
- Satellite tracking

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Video 1

UK Airspace Management

Break

- End of Part 1
  - What radar is.
  - How radar works.
  - Civil uses of radar.
- Part 2 will cover:
  - Military uses of radar.
  - Stealth (defeating radar).
- Quick 5 minute leg-stretch.

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Military Use of Radar



Air Defence



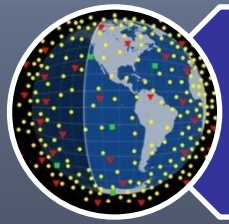
Ballistic Missile Defence



Ground/Sea Surveillance
(Moving Target Indication)



Point Defence
(Close-In Weapon System)



Space Surveillance & Tracking



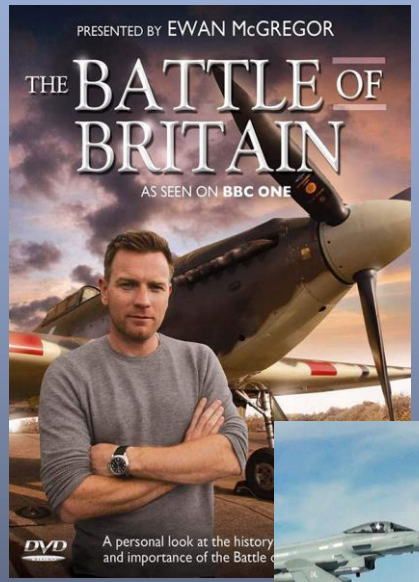
Weapon Guidance / Fire Control

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Air Defence

- Let's take a brief look at:
  - The origins of radar and integrated air defence: the Battle of Britain (1940).
  - Modern air defence of the UK: Quick Reaction Alert.





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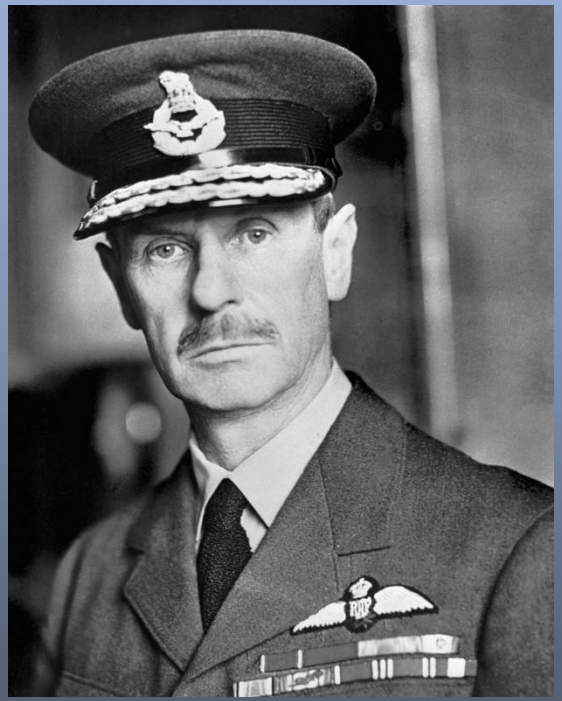
Video 2

Battle of Britain, Part 1

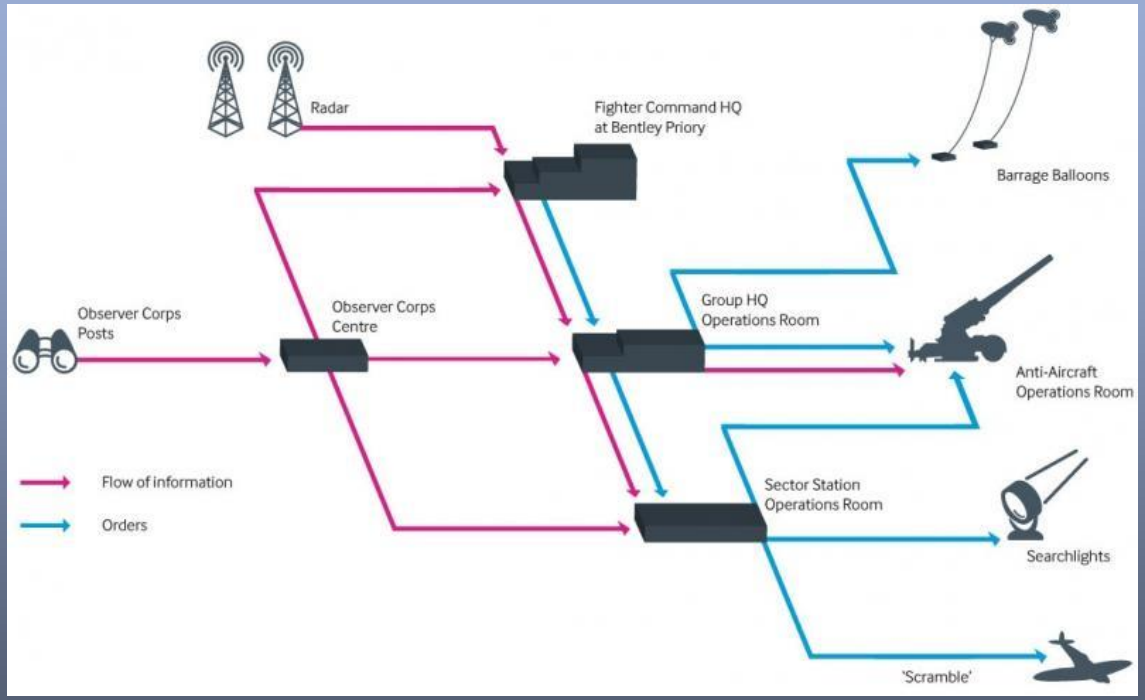
Video 3

Battle of Britain, Part 2

Air Defence: Battle of Britain



Air Chief Marshall Sir Hugh Dowding



The "Dowding System" – the world's 1st Integrated Air Defence System

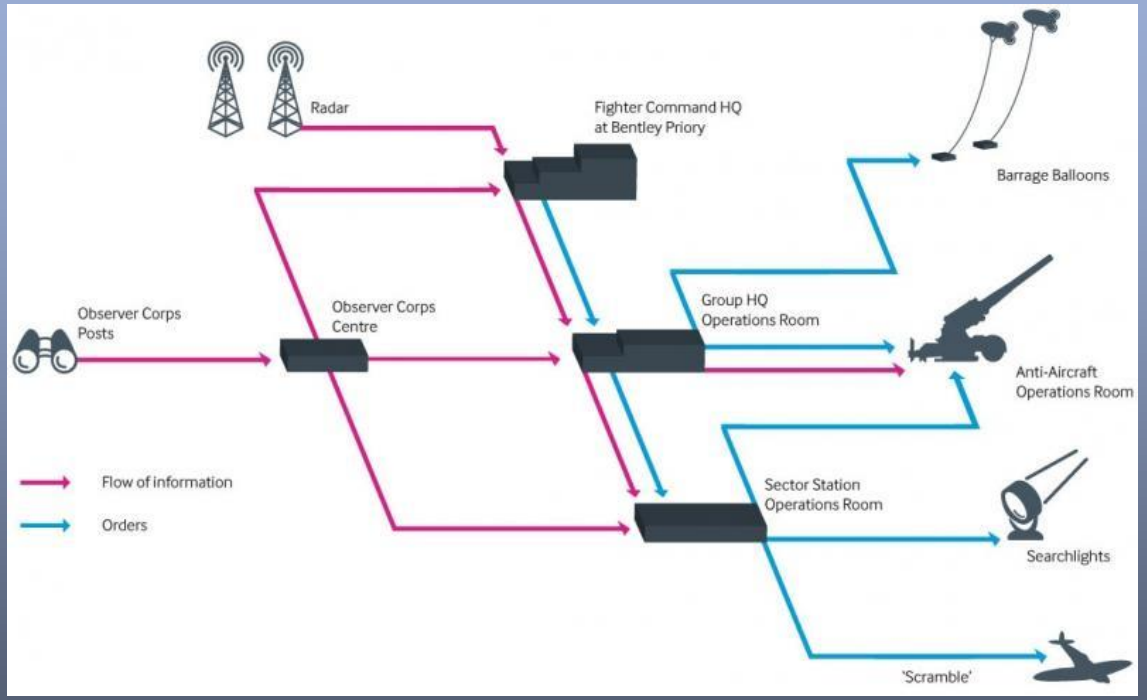
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Air Defence: Battle of Britain



A “Chain Home” Radar Station



The “Dowding System” – the world’s 1st Integrated Air Defence System

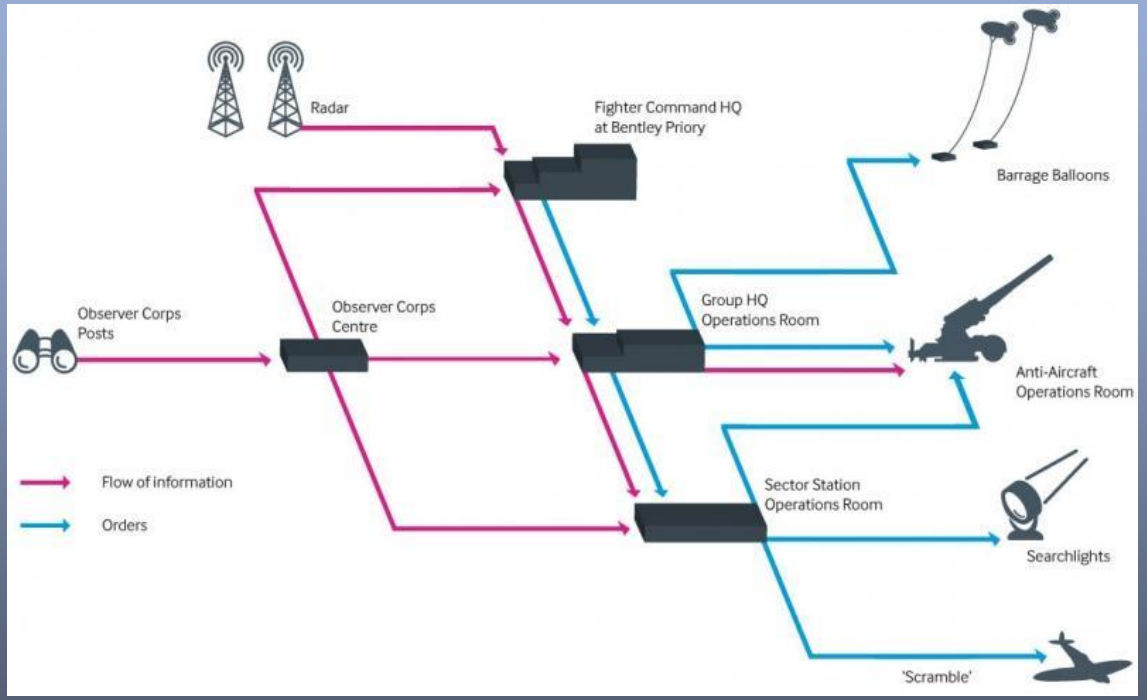
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Air Defence: Battle of Britain



Royal Observer Corps Post



The "Dowding System" – the world's 1st Integrated Air Defence System

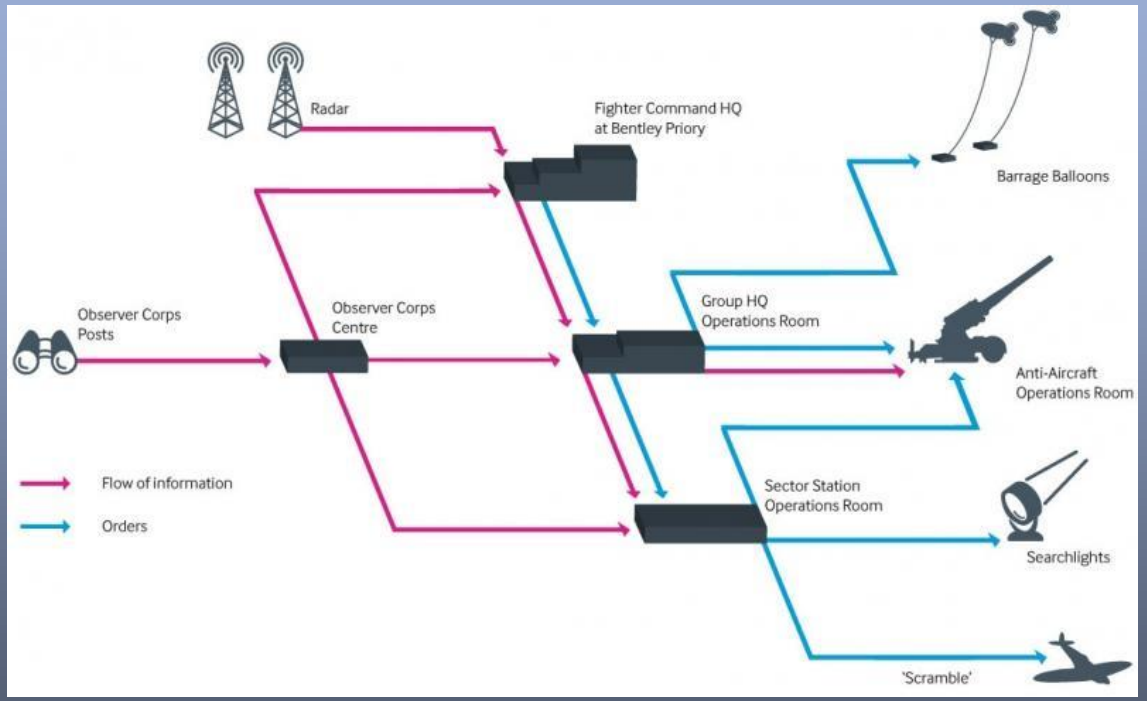
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Air Defence: Battle of Britain



Operations Room



The "Dowding System" – the world's 1st Integrated Air Defence System

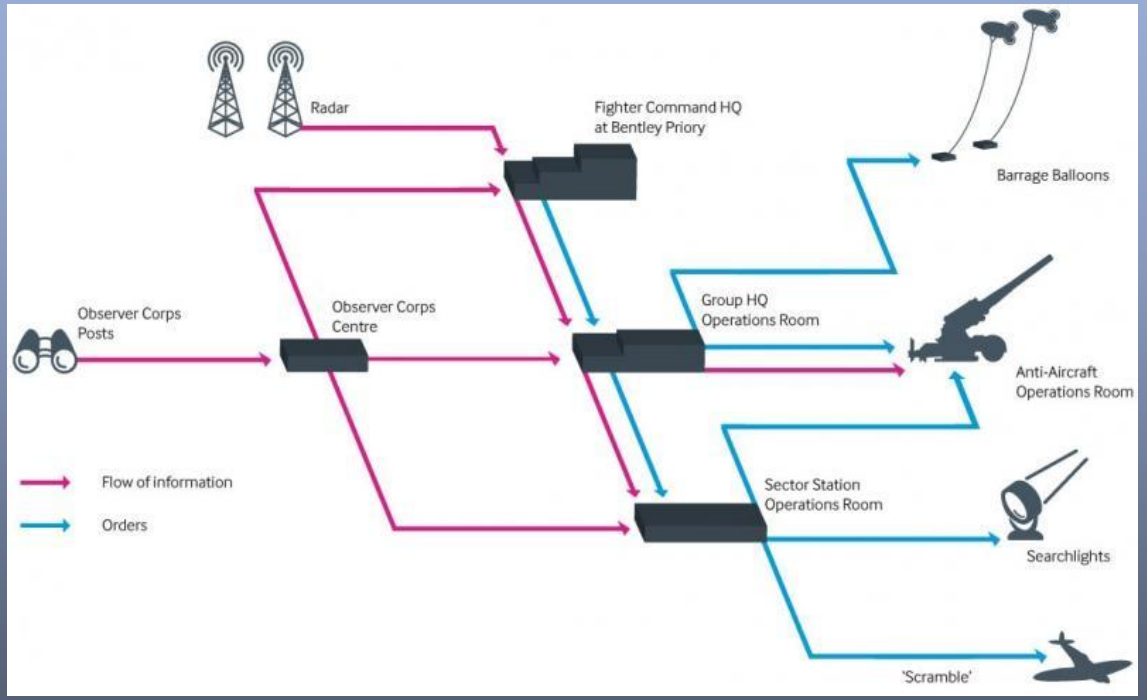
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Air Defence: Battle of Britain



Fighter Squadrons - “Scramble!”



The “Dowding System” – the world’s 1st Integrated Air Defence System

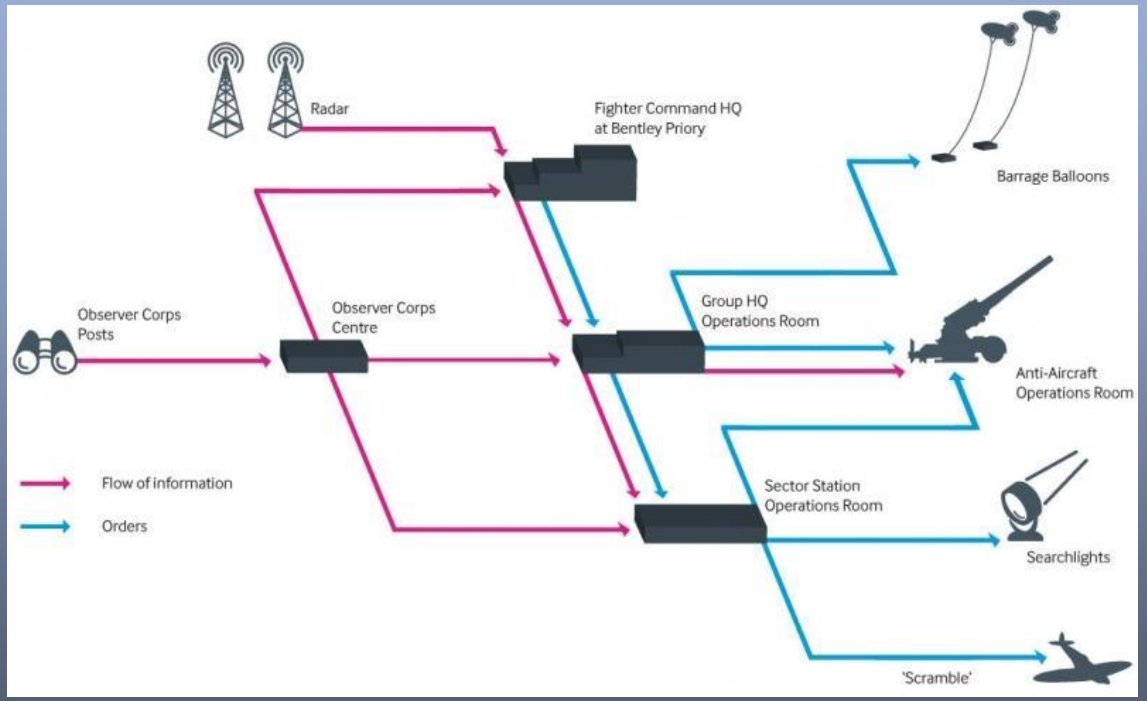
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Air Defence: Battle of Britain



Battle of Britain Groups



The "Dowding System" – the world's 1st Integrated Air Defence System

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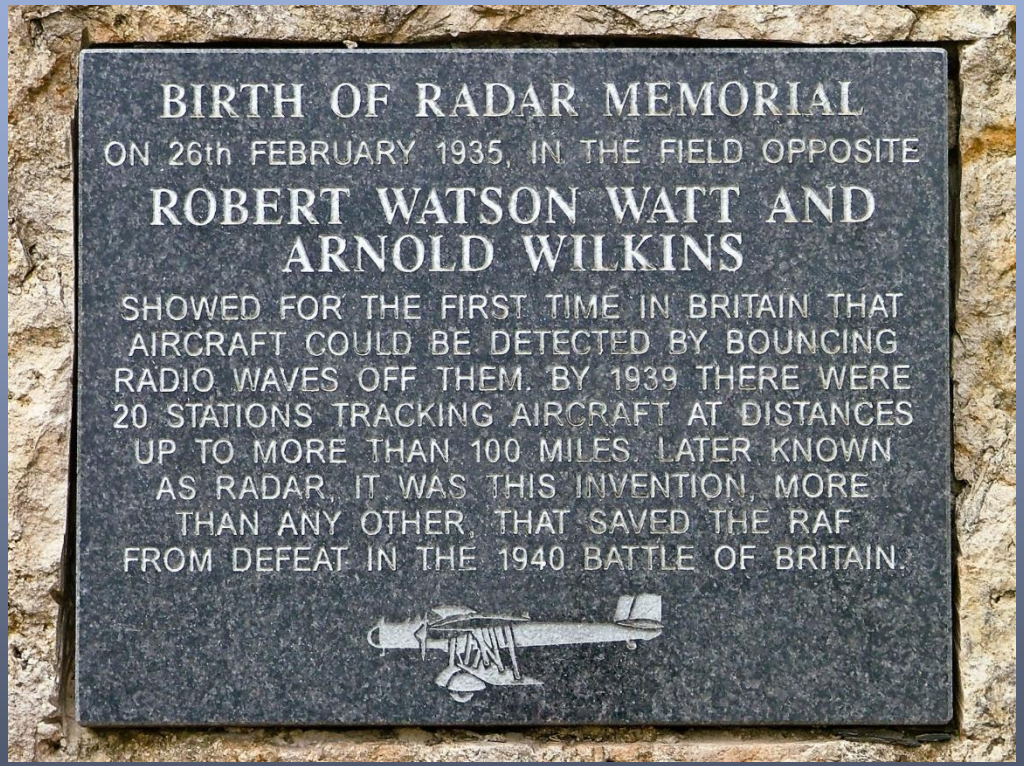
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Video 4

Battle of Britain, Part 3

Air Defence: Battle of Britain



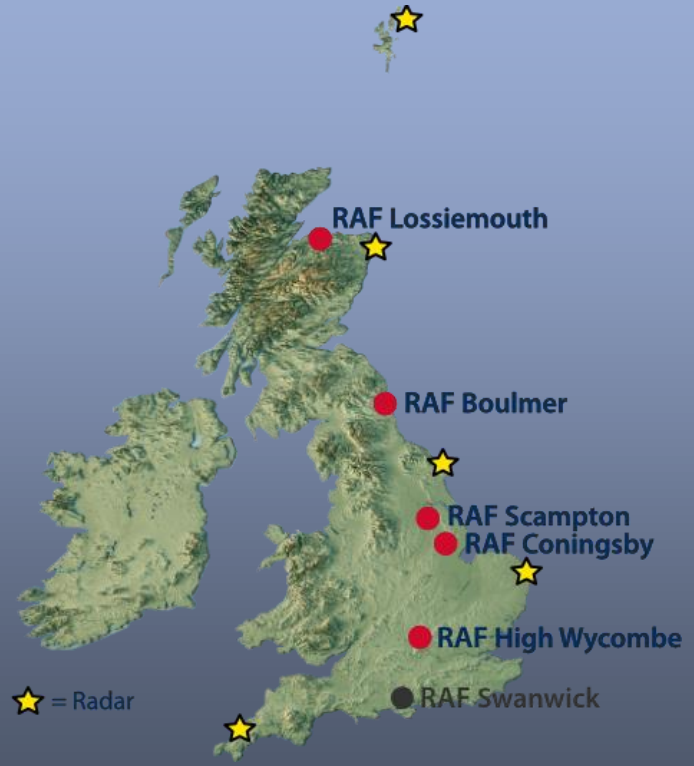
- Would Britain have won the Battle of Britain without:
  - The Dowding system?
  - Radar?
- Would Britain and its allies have won WW2 if we had lost the Battle of Britain?

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Air Defence: Modern Quick Reaction Alert

- How different are things today than during the Battle of Britain?
- Two brief videos on modern Quick Reaction Alert.



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Video 5

Modern Quick Reaction Alert, Part 1

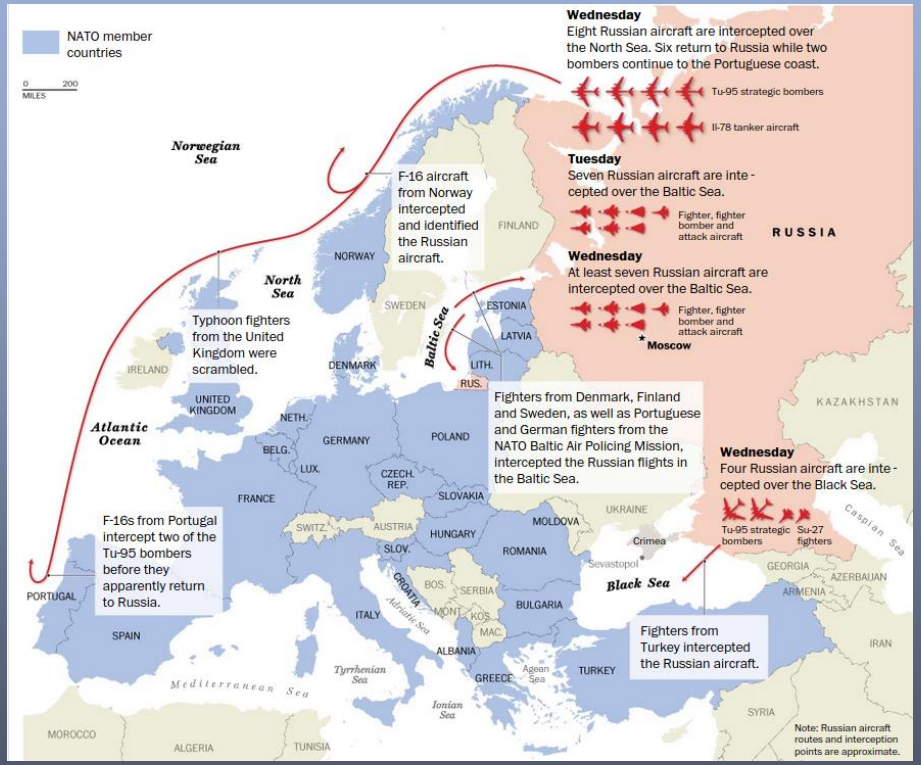
Video 6

Modern Quick Reaction Alert, Part 2

Air Defence: Modern Quick Reaction Alert

- What is QRA intercepting?
  - Civilian aircraft that are off flight plan or are not responding to radio calls.
  - Foreign military aircraft.





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Stealth

What is stealth?

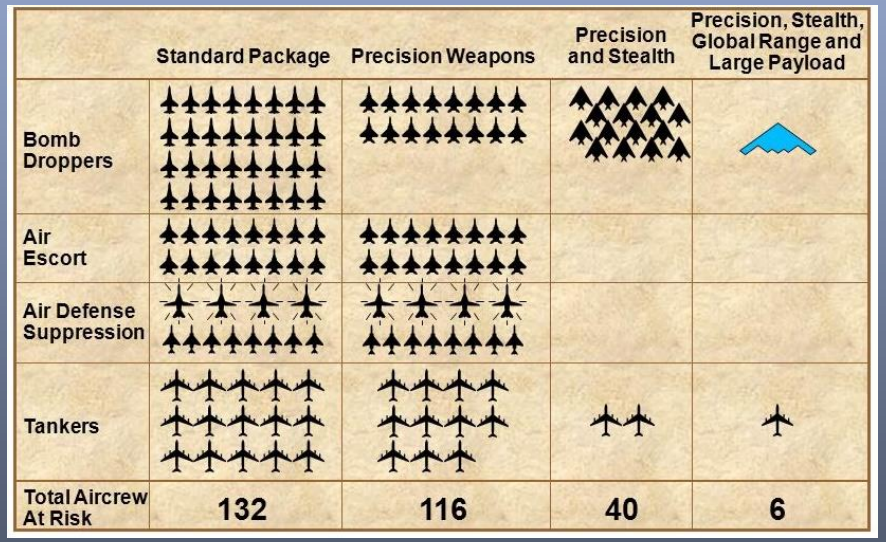
- ***"stealth** n.*

  1. The act of moving, proceeding, or acting in a covert way.

  2. The quality or characteristic of being furtive or covert."
- Basically: being hard to spot.
- Not necessarily just hard to spot on radar!

Why build stealthy aircraft?

- Hard to spot = hard to shoot!



	Standard Package	Precision Weapons	Precision and Stealth	Precision, Stealth, Global Range and Large Payload
Bomb Droppers				
Air Escort				
Air Defense Suppression				
Tankers				
Total Aircrew At Risk	132	116	40	6

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Stealth

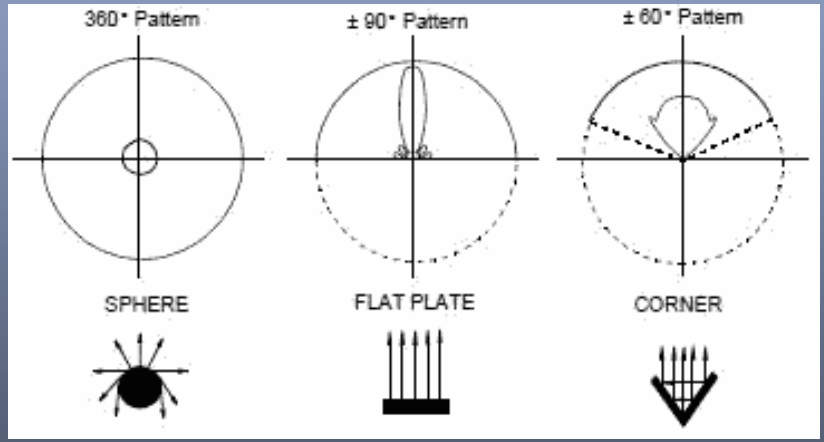
Making an aircraft stealthy

- Deflect radar energy away from the transmitter.



An American F117/A Nighthawk “Stealth Fighter”

- Objects of different shapes reflect different amounts of energy in different directions.



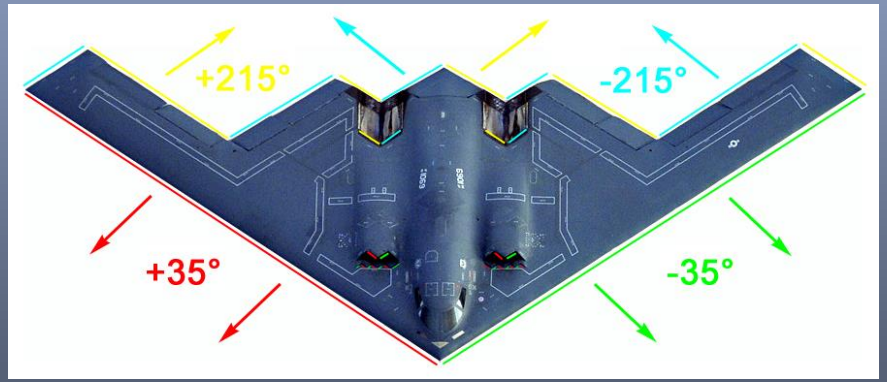
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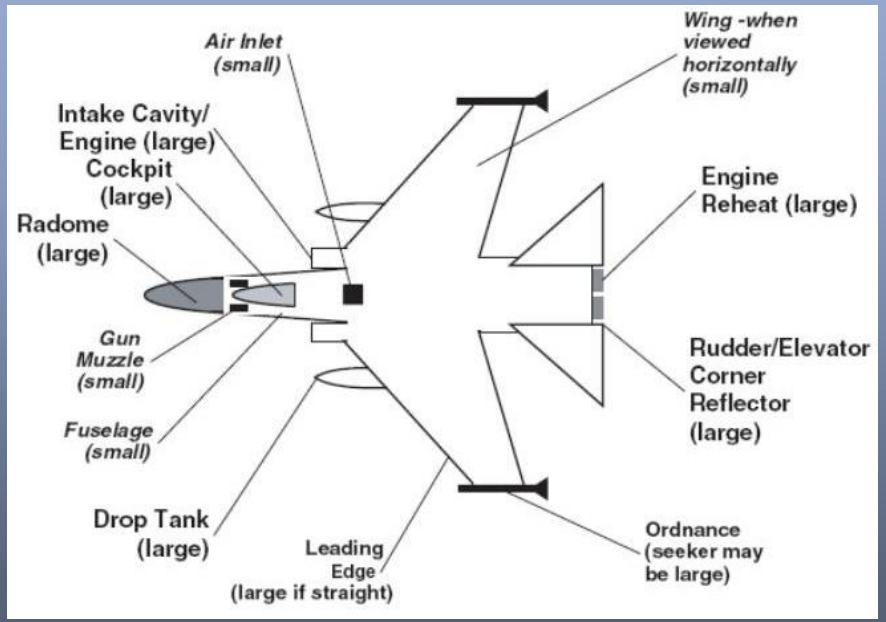
Stealth

Making an aircraft stealthy

- Deflect radar energy away from the transmitter.



An American B-2 Spirit “Stealth Bomber”



Dominant radar reflectors on a traditional aircraft

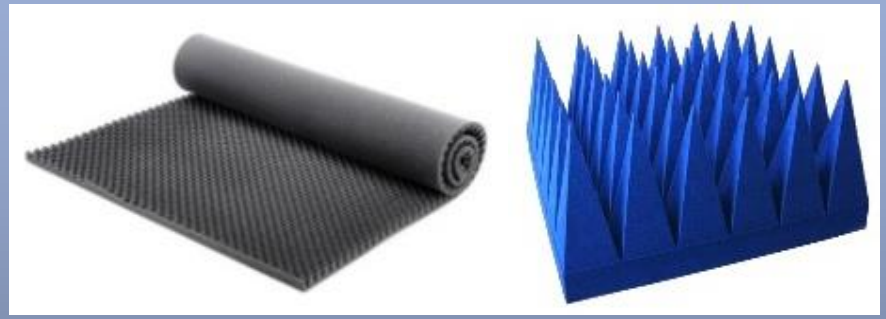
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Stealth

Making an aircraft stealthy

- Deflect radar energy away from the transmitter.
- Absorb radar energy using Radar-Absorbent Material.



- The surface is covered in little pyramids.
- The metal content increases gradually towards the base of the pyramid – this gradual change reduces reflections.

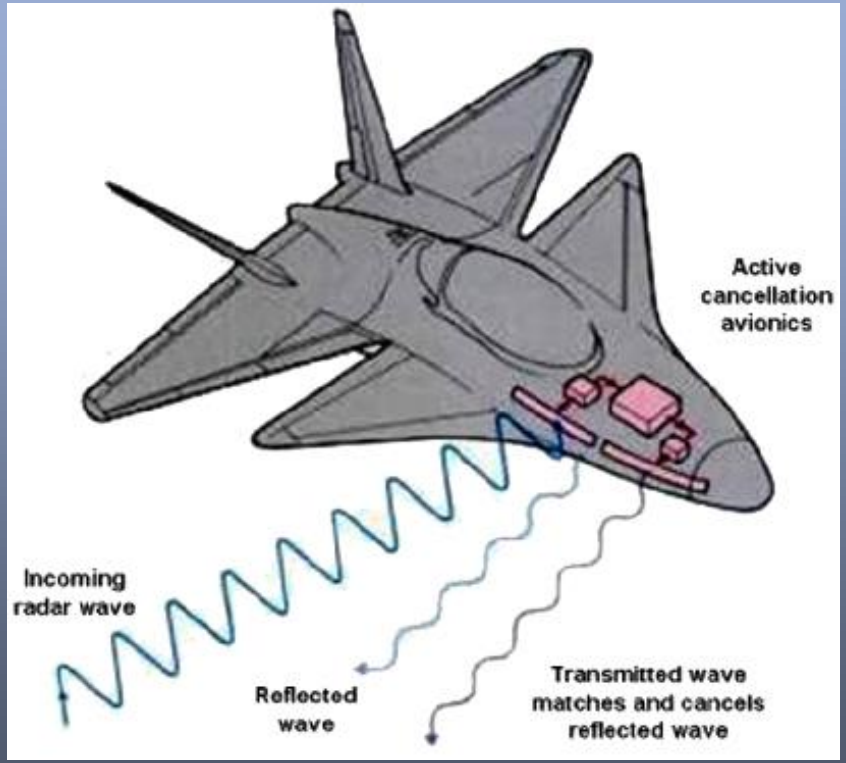
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Stealth

Making an aircraft stealthy

- Deflect radar energy away from the transmitter.
- Absorb radar energy using Radar-Absorbent Material.
- ‘Active Cancellation’.



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Stealth

Making an aircraft stealthy

- Deflect radar energy away from the transmitter.
- Absorb radar energy using Radar-Absorbent Material.
- ‘Active Cancellation’.
- Fly above radar cover.



An American U-2 “Spy Plane”, which can take detailed photos from an altitude of 70,000 feet

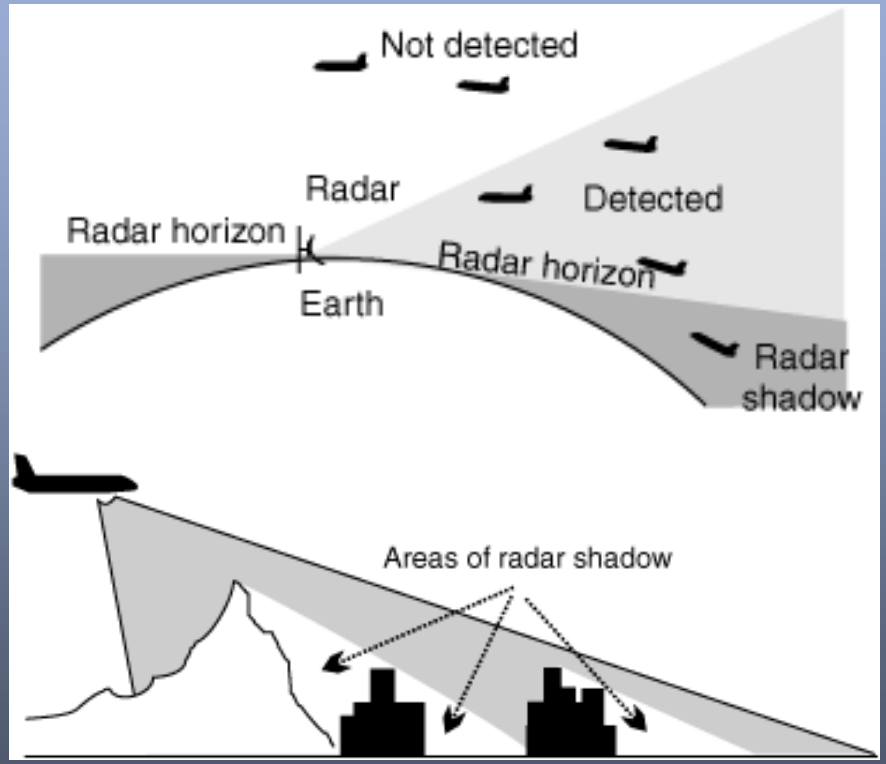
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Stealth

Making an aircraft stealthy

- Deflect radar energy away from the transmitter.
- Absorb radar energy using Radar-Absorbent Material.
- ‘Active Cancellation’.
- Fly above radar cover.
- Fly below effective radar cover.



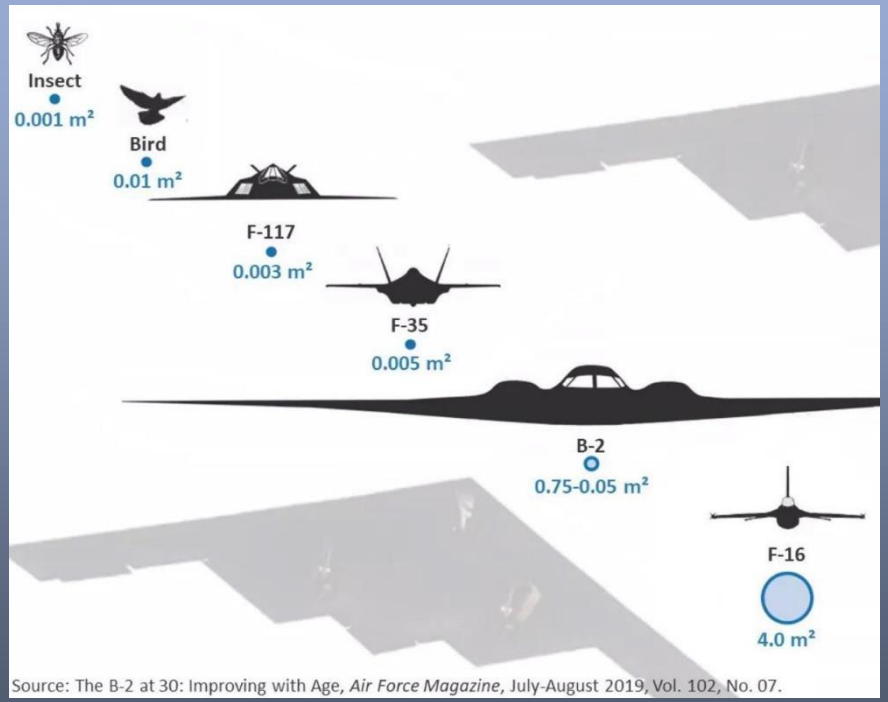
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Stealth

How stealthy is ‘stealthy’?

- The measure of how observable an object is on radar is called its **radar cross-section**.
- It equates the object’s radar signature to a perfect sphere of that cross-sectional area.
- Modern fighter aircraft are no more detectable than a bird.



Source: The B-2 at 30: Improving with Age, *Air Force Magazine*, July-August 2019, Vol. 102, No. 07.

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Stealth

Defeating stealth

- Don’t just listen for echoes at the radar that sent the pulse.
  - Many stealth aircraft rely on deflecting radio waves away from their source; but that isn’t as effective if it isn’t just the source that is listening for echoes…
- Use very sensitive directional infrared sensors, to look for flying heat sources (like an aircraft’s exhaust).
- Use very sensitive directional microphones to listen for aircraft.
- Use satellites to spot aircraft against clouds or the ground.

Summary

- What radar is and how it works. E.g. primary radar:
  - Sends out pulses of radio energy and see if they bounce back.
  - Uses the echoes to work out distance and bearing of the target.
- Civil uses of radar, e.g. air traffic management.
- Military uses of radar, including:
  - The Dowding integrated air defence system in the Battle of Britain.
  - The modern equivalent, Quick Reaction Alert.
- Stealth (avoiding detection).
  - Deflect/absorb/cancel radio waves or fly above/below radar cover.

Any Questions?

(Feel free to ask in private if you prefer)

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