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Leonardo Electronics

Multi-Sensor Tracking and Data Fusion

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UDRC Summer School – Sensing and Tracking

28th June 2022

Electronics

Helicopters

Aircraft

Cyber & Security

Space

Unmanned Systems

Aerostructures

SUMMARY

- Introductions
- Background
- Fusion architectures
- Real-world challenges
- Conclusions

Introductions

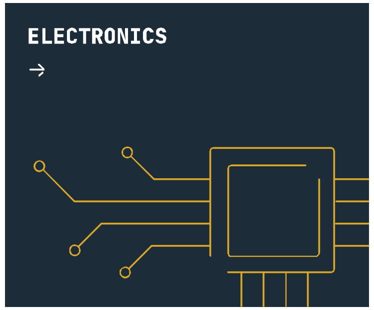
Introductions

- 2011 – 2016: MEng Electrical and Electronic Engineering from Heriot-Watt University
- 2016 – 2020: PhD in Signal Processing from Edinburgh/Heriot-Watt through the UDRC
- 2019 – Present: Principal Systems Engineer in Tracking/Data Fusion at Leonardo
- Currently seconded into Capability Management for Major Air Programmes

- My PhD was in multi-target tracking with sensor fusion/registration which we'll cycle back to later
- The following slides are a high-level summary of the fusion area, I've tried to avoid the maths as much as possible!
- Please feel free to jump in and ask questions as we go!

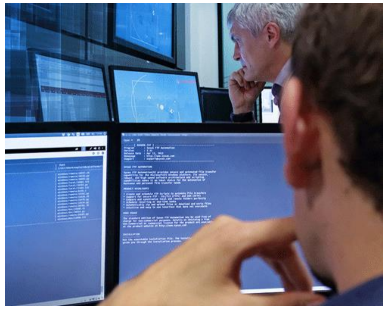
Introductions

Leonardo UK



Electronics

- Radars
- Infrared Counter Measures and Lasers
- Defensive Aid Suites
- Electronic Support/Counter Measures and Electronic Warfare Operational Support
- Naval Systems
- Force Protection and Soldier Radios
- Land Systems
- Infrared Detectors
- Cameras
- Precision Guidance
- Vehicle Mission Systems



Cyber & Security Solutions

- Police Forces
- Homeland Security

- Critical National Infrastructure (CNI)
- Large Enterprises
- Engineering
- Procurement
- Construction

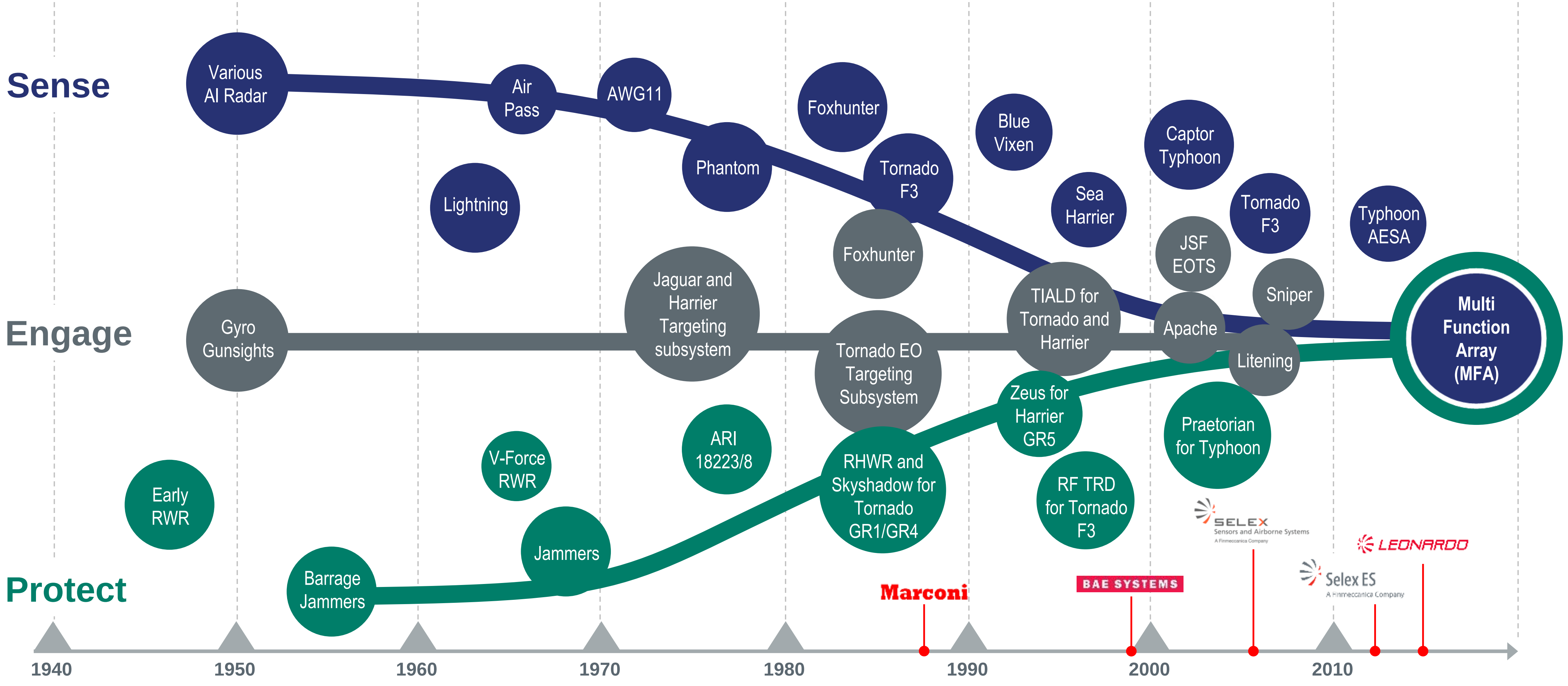
- Government
- Defence and International Agencies

Expertise across the full spectrum

- Components
- Sub-systems
- Systems
- Communications
- Training & Simulation
- Products
- Avionics Electronics
- Support and Service
- Cyber and Security
- Space

Introductions

RECOGNISING THE PAST. PROTECTING THE FUTURE.



Introductions

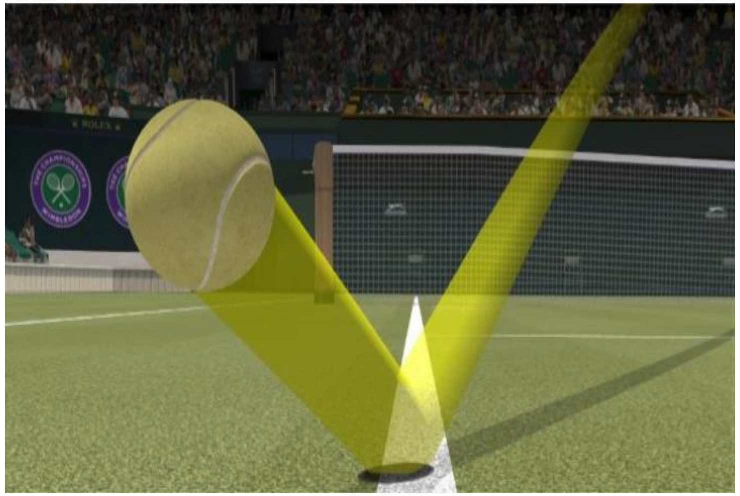
TEMPEST. Defining the future of Combat Air.

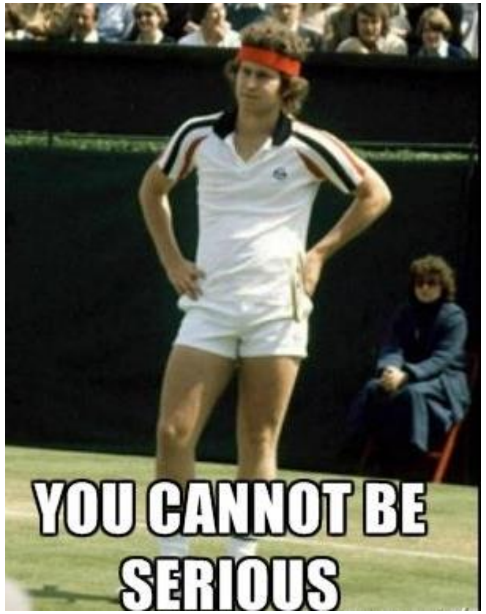
- Leonardo UK is leading the development of Tempest’s complex electronics, delivering sense to effect and communication capabilities
- These systems will allow Tempest to Sense, Engage and Protect
- Sense its environment, including threats and targets to deliver information advantage
- Engage threats across the battlespace
- Protect the pilot, platform and wider network from threats

Background

Background

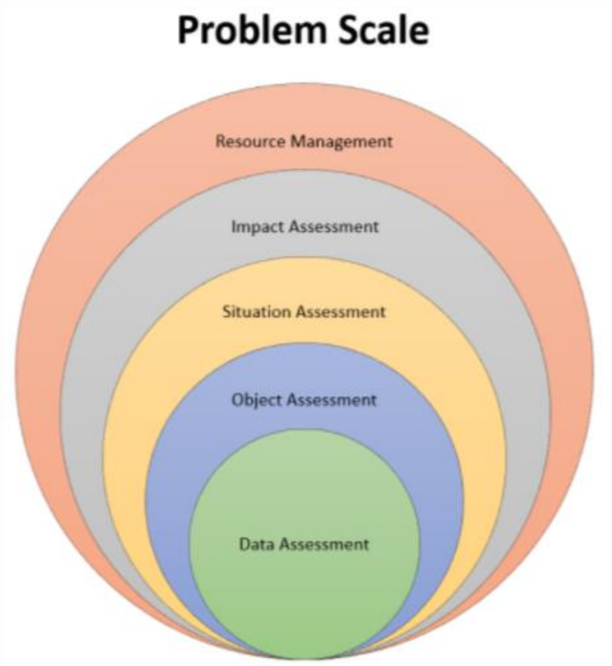
- Modern systems often exploit a range of different sensors, each of which may carry out a range of different tasks
- These could range from avoiding obstacles in your new self-driving car, or making sure poor John doesn't have another line-calling strop
- Sensor fusion is effectively the process of taking data from multiple sources, and combining it in a logical way to improve your awareness picture
- By "improve", this could mean
  - Tracking targets at a faster rate;
  - Detecting targets further away;
  - Improved confidence in the stuff I observe.

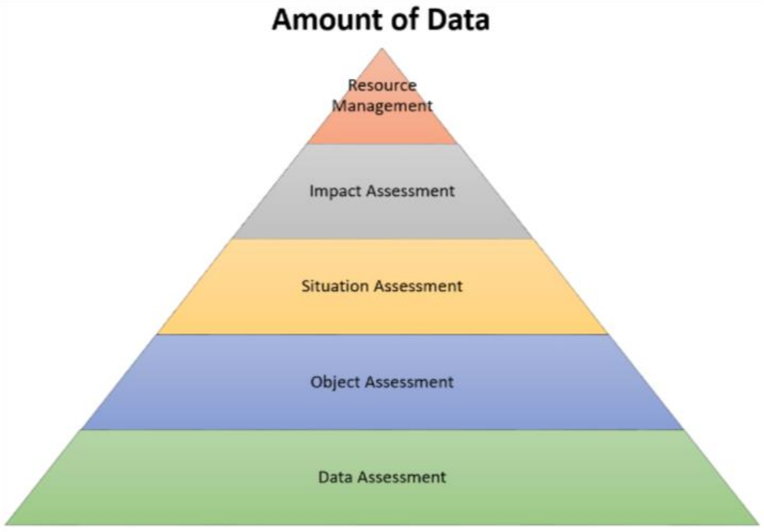




Background

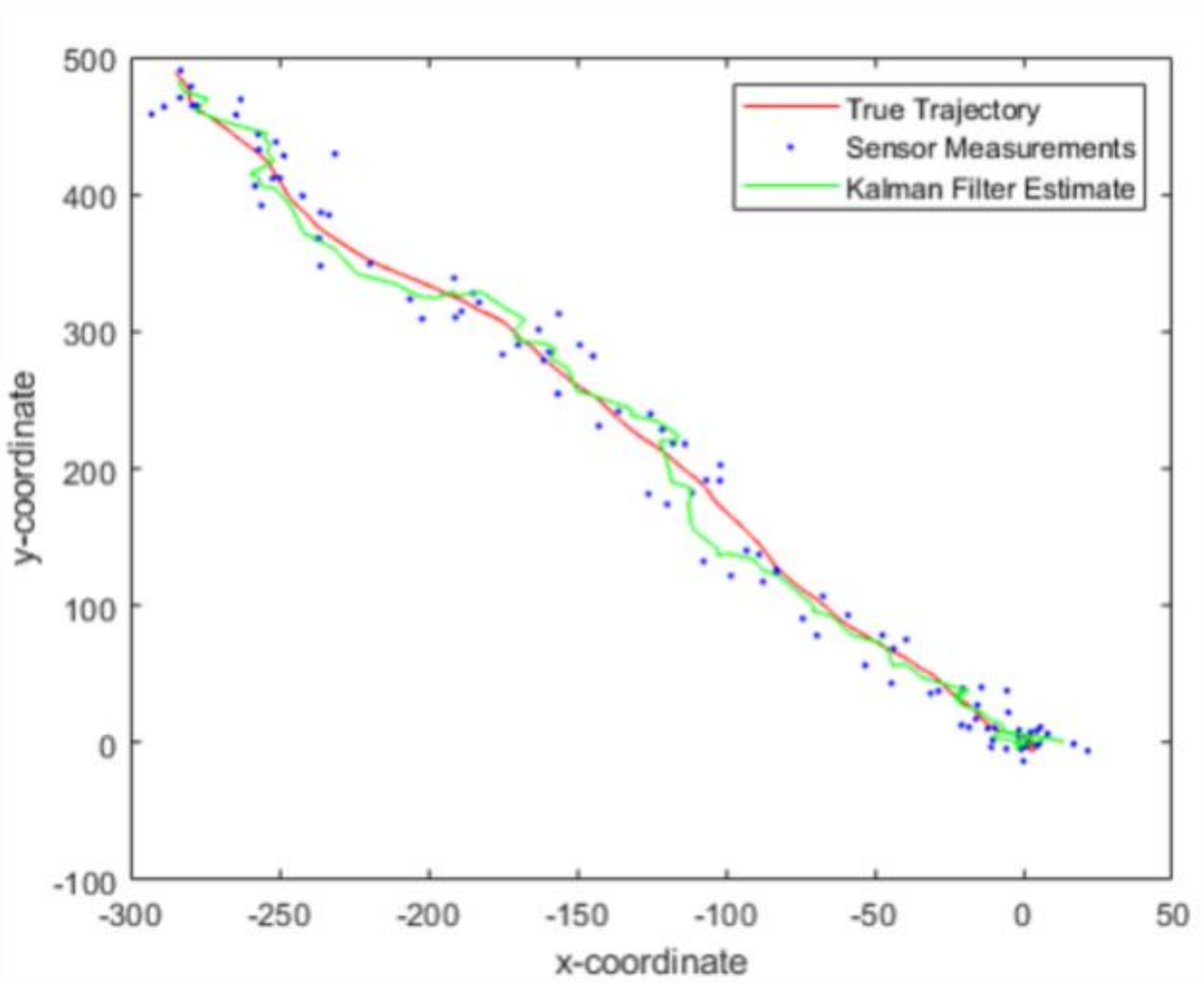
- Sensor fusion is often broken down into a number of different levels, depending on what data you are using, and what it relates to
- These are often referred to as the **JDL levels of fusion** in the literature – Google search will turn up quite a lot on this!
- As we move up through the different levels, the physical scale of the problem increases
- Because we are constantly refining our data using various algorithms along the way, the amount of data will likely get smaller at higher levels
- It would take a lot longer than this session to cover all the levels in detail. For now, we will focus mainly on **Object Assessment** and **Situation Assessment.**





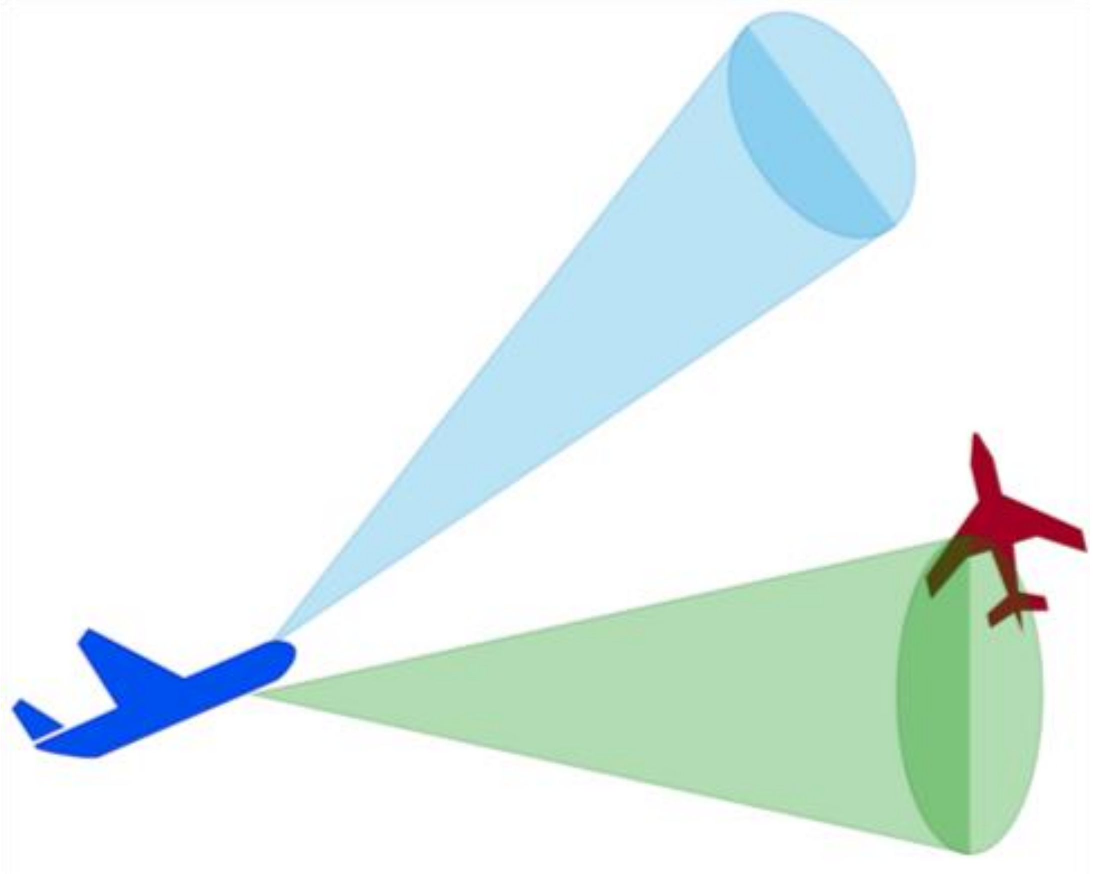
Background

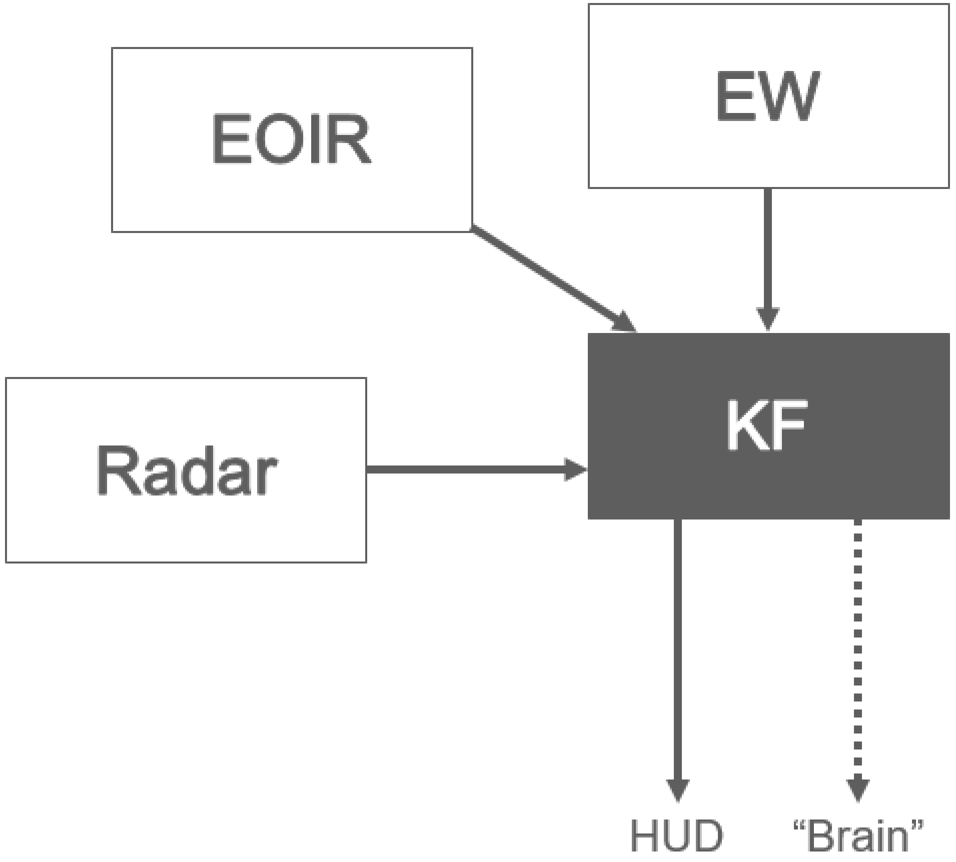
- Sensor fusion often works closely with state estimation and tracking steps to refine the track picture
- As we have seen today, there are a plethora of tracking techniques available to us, each with their own relative benefits and drawbacks
- To keep things simple, let's assume for the purposes of tracking (and possibly the fusion itself), that this is carried out using a **Kalman filter (KF)**
- Let's now take a look at some of the different architectures, starting with the **Object Assessment** level



Fusion architectures

Centralised Fusion





Centralised Fusion

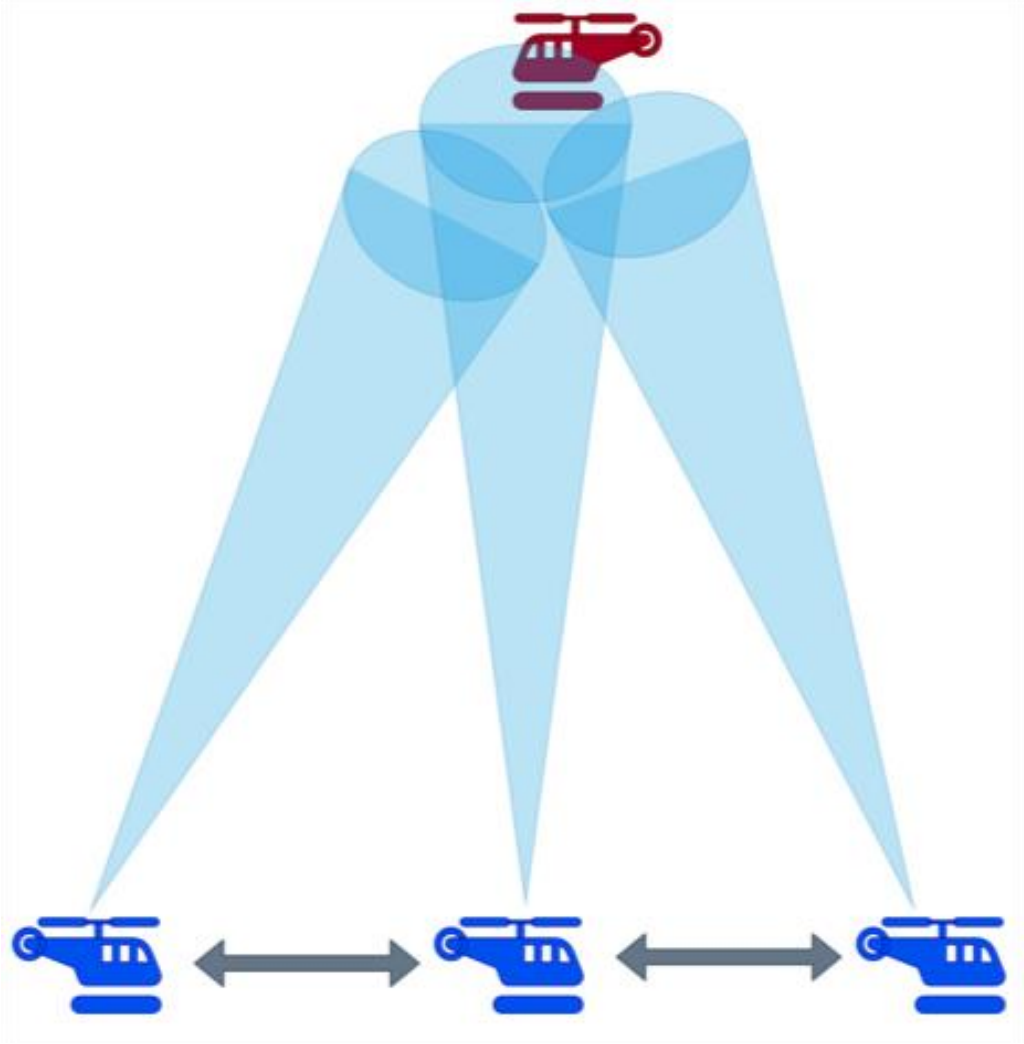
- In centralised fusion, we are typically working at the **Object Assessment** level where an object(s) have been detected by different sensors using appropriate signal/image processing.

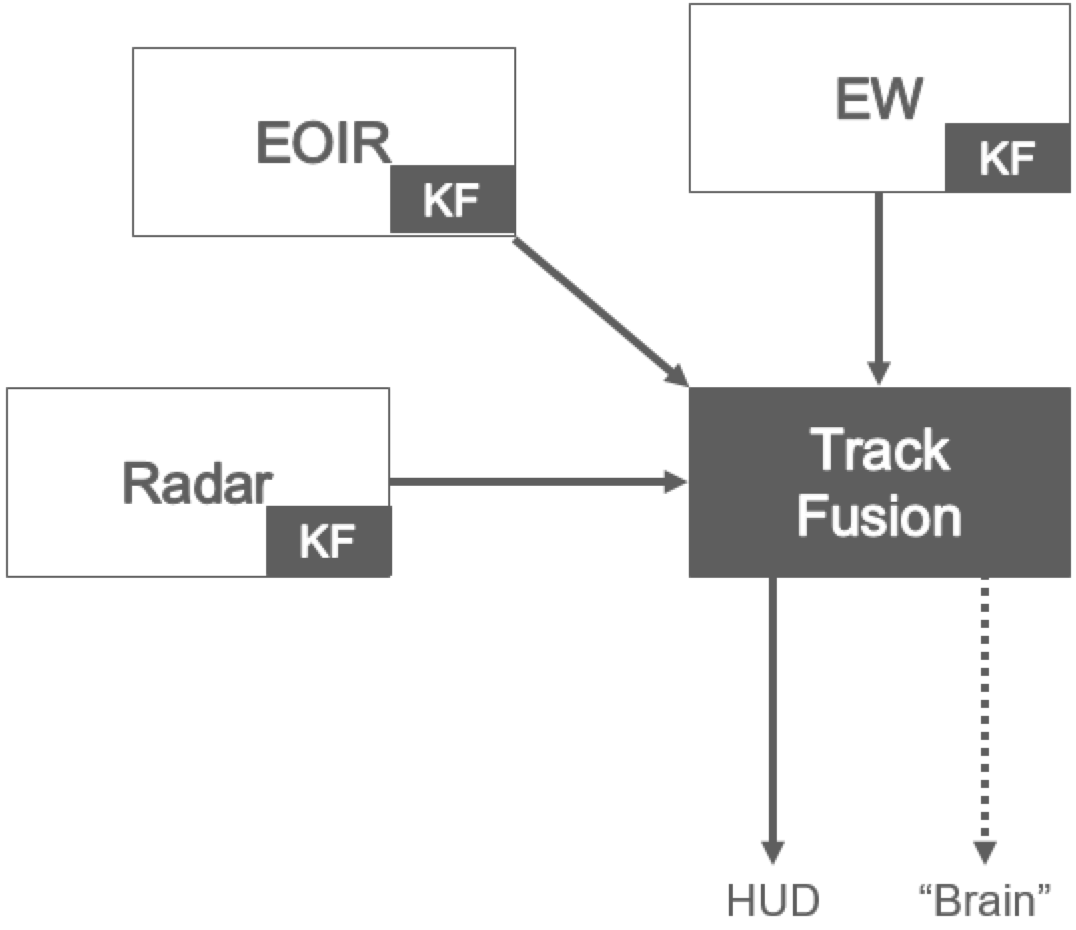
- Sensors can then pass their plots/detections to a centralised tracker, which will then form a track on each individual object in the scene.

- Tracks can then be displayed appropriately, and potentially passed on to some form of sensor management to make decisions about what to do, and where to look next.

Pros	Cons
"Optimal" solution	More data being sent
Usually easier to tune parameters	Can be more computation hungry
Single track picture of whole scene	Lack of redundancy
Data stored in one place	
Increase in track confidence	

Decentralised Fusion





Decentralised Fusion

- In distributed fusion, we are moving towards the **Situation Assessment** level of the diagram, where objects have already been detected and tracked within an individual sensor or platform, and you are now attempting to combine or fuse data across them.
- Tracks from each individual sensor or platform are brought together in a central location and fused using a different type of algorithm e.g. covariance intersection.
- As with the centralised fusion, we still end up with a track picture that should incorporate information from the whole region.

Pros	Cons
Computation distributed through network	More reliance on underlying assumptions
Single track picture of whole scene	Requires more tuning in each KF
Possibly easier to “retro-fit” to legacy	Often lower track confidence
	Limited redundancy

Real-world challenges

(Im)perfect fusion

- So far, I have painted a picture that sensor fusion is relatively simple, where we just plug everything into the same tracker, or connect my various tracker outputs to a black box algorithm.

- Alarmingly, quite a lot of the tracking/fusion literature would have you think that this is the case.

- In practice, there are a number of overarching or system-level problems that are only discussed in more select areas of the literature. These problems really come to the forefront when we start discussing using multiple sensors or multiple platforms.

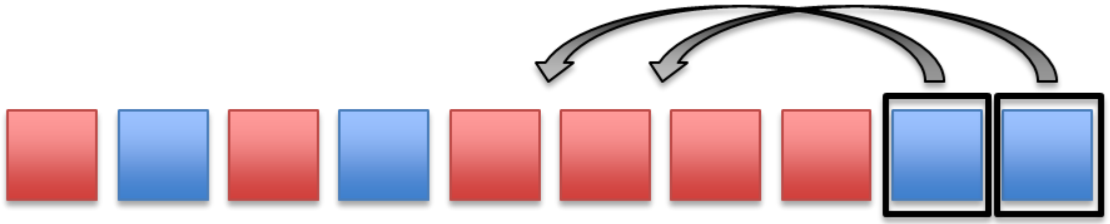
- For convenience, let's group them into three main strands –
  - Timing
  - Communications
  - Navigation

Timing

- When you open up a fusion-related paper on your preferred literature searching tool*, quite often you will see the assumption that the given sensor network is synchronised, and measurements/tracks will be available in all places at all times.

- Each sensor will likely have its own clock or timing hardware built-in, but can we guarantee that each of these clocks is synchronised?

- If the answer to that is no, we could end up with the following. Assuming that the sequence of measurements should be repeating red-blue, we may actually observe this sequence instead

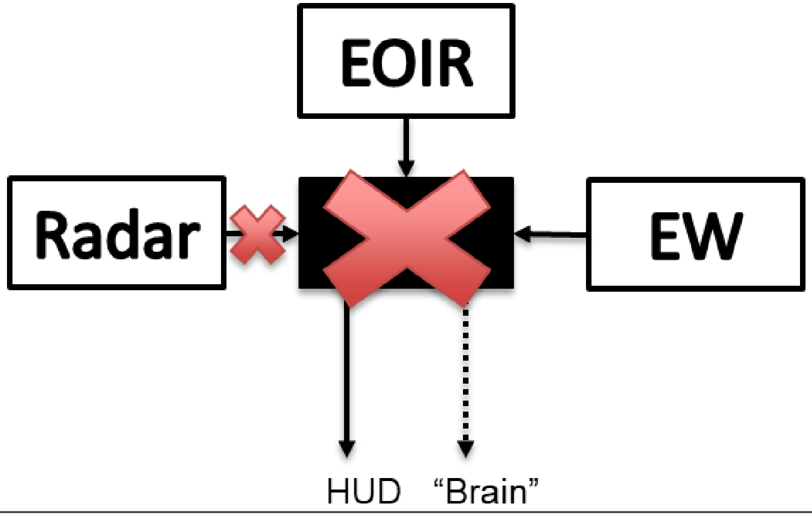


- You can imagine that if we process this sequence in the wrong order as above, we could end up with a bit of a mess where tracks could split, or we start multiple tracks on the same object!

- In the literature, these problems are often referred to as **out-of-sequence data** and/or **network latency.**

Communications

- Next, in the communications area, we could run into a number of different limitations.
- The first of these could be network bandwidth. When considering centralised measurement fusion, there is likely to be a lot of data being passed around, as typically the number of measurements is greater than the number of tracks. If we have any system “bottlenecks” or pipeline issues, the overall system could slow to a crawl!
- Another main concern is system redundancy. Consider the diagram and situation below. If for any reason we were to lose a link to a specific sensor, or if it is carrying out a different task, another sensor can hopefully take over; this is not a complete disaster.
- However, if we lose the main fusion engine for some reason, you can imagine that this puts us in a more difficult position.



Navigation

- This is a topic I know a bit more about; my PhD was most aligned to this area!

- Trackers often rely on a large amount of accurate navigation data to support a number of tasks:
  - Localising the platform;
  - Reference frame conversions;
  - Bias/registration compensation

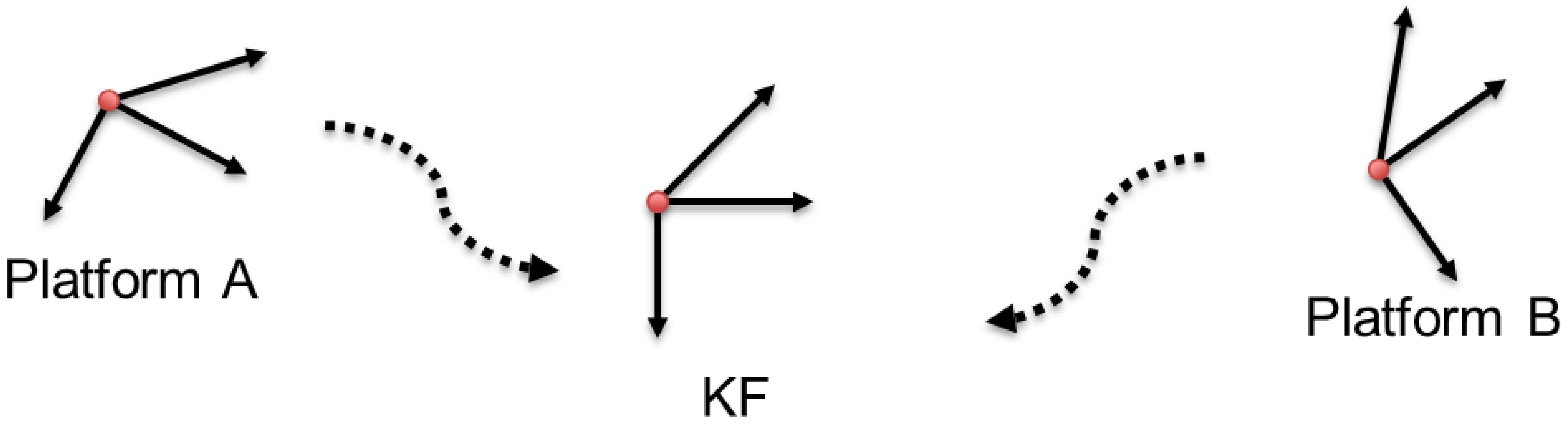
- It is clear to say that if this data is not available, or is incorrect/incomplete, we can start running into deeper issues with tracking and fusing data.

- Something like a GPS-denied environment would be an extreme case; but there are some more “boundary” cases where biases or reference frames may slowly change over time, which can be more difficult to spot and correct for.

- Now consider this example -

Navigation

- In order to perform fusion, data needs to be referenced to the same frame or point in space.
- For simplicity, I have only shown a rotational difference below, but you can imagine there may also be translational differences. In the literature, this is sometimes referred to as the sensor registration problem.
- Having issues with GPS could make the translation, or localisation, part of this problem much more difficult.
- Also, by having issues with some onboard navigation equipment, e.g. a gyroscope or IMU, could cause issues with the rotational part of the problem.



Conclusions

- I hope this has given you all at least a short introduction into some potential architectures that we could find in parts of a fusion system.
- With the overarching issues we face in practice, fusion systems take careful design which go beyond just “combining or fusing” the data as it were.
- For the types of fusion shown, there are of course lower-level design and implementation issues we will likely face which I haven’t had time to cover here.

Any questions?

CONTACTS

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FOR YOUR ATTENTION

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