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Mission Data Support in the AI Age

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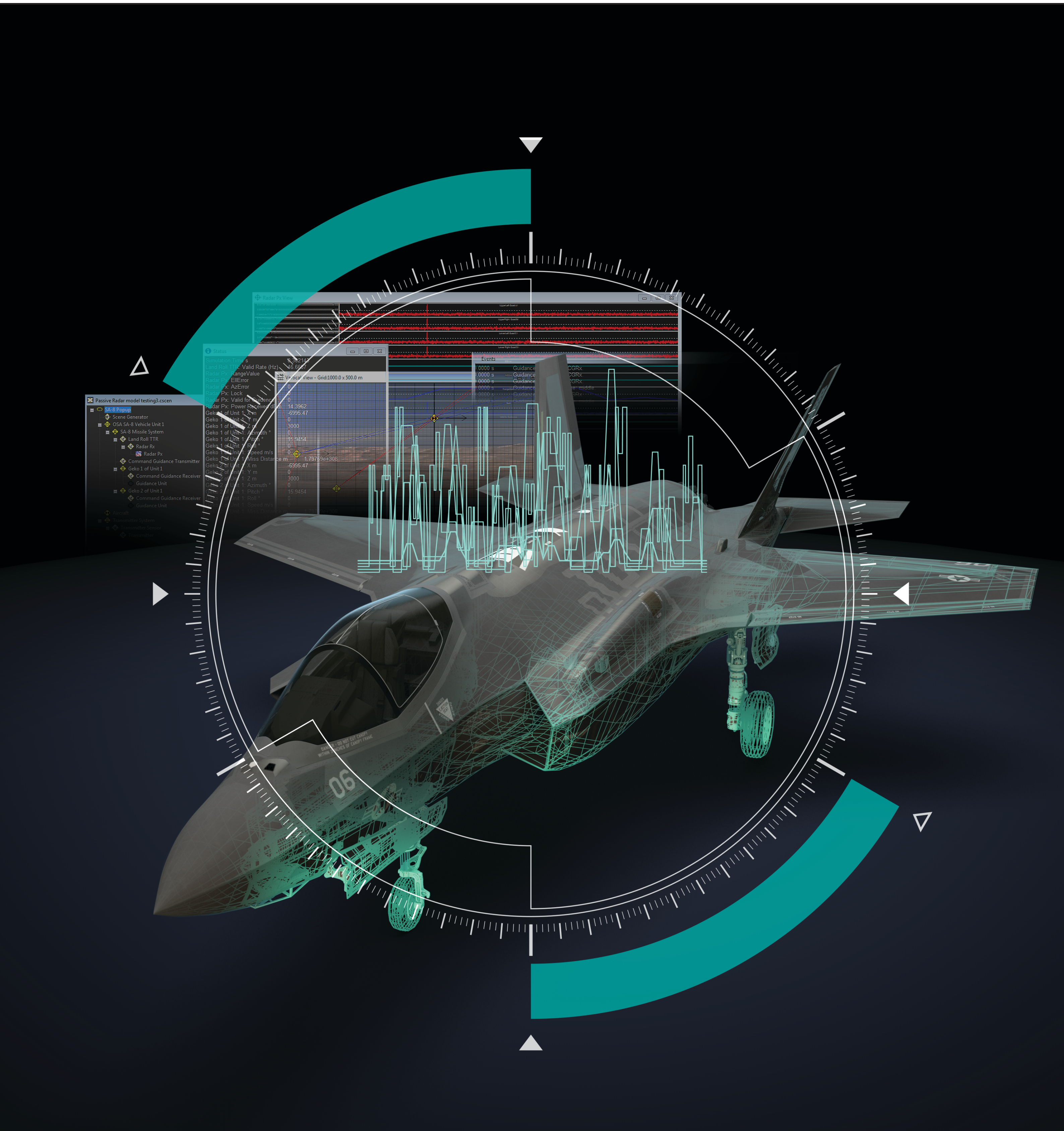
Mission Data Support in the AI Age

MASS is currently working on technologies that will support the next generation of Electronic Warfare (EW) equipment. As acknowledged experts in the EW Data Management arena, and as an independent leader in EW Operational Support (EWOS), MASS is thinking ahead to the challenges of supporting Mission Data in an era when Artificial Intelligence and Machine Learning become game-changers.



Here and now: legacy EW Operational Support

Legacy EWOS has been centred, quite sensibly, around a multi-source reference dataset, from which are built equipment-specific Mission Data Sets (MDS). Because the reference set is often multi-disciplinary (platforms, weapons, emitters etc), it is almost inevitable that these constituent parts of an engaging weapon system will have been analysed and described by separate analysts.

MDS are constructed from a set of highly-defined parameters that represent the threat system, very often contextualised to a specific geographical operating area. Furthermore, these parameters are likely to have been 'colourised' towards the specific EW equipment, quite probably rolled-up or summarised, and possibly with parametric 'notches' intended to mitigate ambiguity with other emitters.

After some hardware-in-the-loop testing, and some final tweaking to the parameters, our MDS is deployed into the real world. The real RF environment then interacts with our MDS, and a number of things happen depending on the aim of the system: a radar warner function (e.g. part of a Defensive Aids Suite) would seek to identify threats unambiguously (potentially at the cost of ignoring less threatening emitters) and then prompt further EW actions, whereas an Electronic Support Measures (ESM) function would seek to intercept all emitters, ideally identify and locate them, and almost certainly record them for later analysis and possibly to update the reference data set.

Whether it is a DAS or ESM function, the aim would be to match against known emitter parameters, investigate things out-of-match, and optimise the MDS library plus its equpment-specific dataset and the main reference dataset. Then, reprogramme the EW hardware and start the cycle again.

Why has EWOS developed this way?
Well, EW equipment architectures (i.e. receiver and processor, hardware and algorithms) have driven the data requirements, and hence the data analysis and MDS production processes that provide it. Furthermore, it has shaped the overall approach to data management, and probably some unintentional stove-piping. Our EW and EWOS policy and Concept of Operations (CONOPS) have driven the data update and refresh cycle, the supporting practices and processes, and the ownership, organisation, and manning of EW centres and their products.

What position does this leave us in now? In data preparation terms we've concentrated on filtering, selection, and avoiding ambiguity. As the environment and threat systems have got more complex, the filtering, selection and ambiguity resolution has got harder. Furthermore, we've tended to ignore confounding features in the environment (a good example is offshore windfarms) because they're not really 'EW', or because we don't have enough resource to analyse and database them – after all, it's hard enough keeping on top of threat emitters and weapon systems. On the plus-side for legacy EWOS, regardless of how the data are selected and filtered, its ownership, whilst prized and guarded, is mostly uncontested: OEMs own the data format and algorithms etc but their customers (i.e. the military) own the data.

Figure 1: Modern platforms such as Typhoon are still employing a traditional EWOS cycle for producing and maintaining Mission Data Sets. Yet as we see Artificial Intelligence permeating into EW equipments, EWOS structures and processes will have to adapt.

We could conclude that for legacy EWOS we've evolved skills, structures and processes which are effective (albeit, imperfect)…but we shouldn't assume they will be fit for purpose in the AI age, because there are some fundamental differences.

The times they are a changin'

For Command and Control (C2) systems designed against Cold War threats, modern hypersonic missiles like BrahMos are already very hard to defend against. More recent developments like Zircon will fly even faster. Whilst the problem is relatively new, our way of characterising and mitigating it goes back to lessons learned in aerial combat in Korea in the 1950s: Colonel John Boyd's OODA loop (Observe, Orient, Decide, Act) has lost none of its relevance in helping us understand the challenges we face.

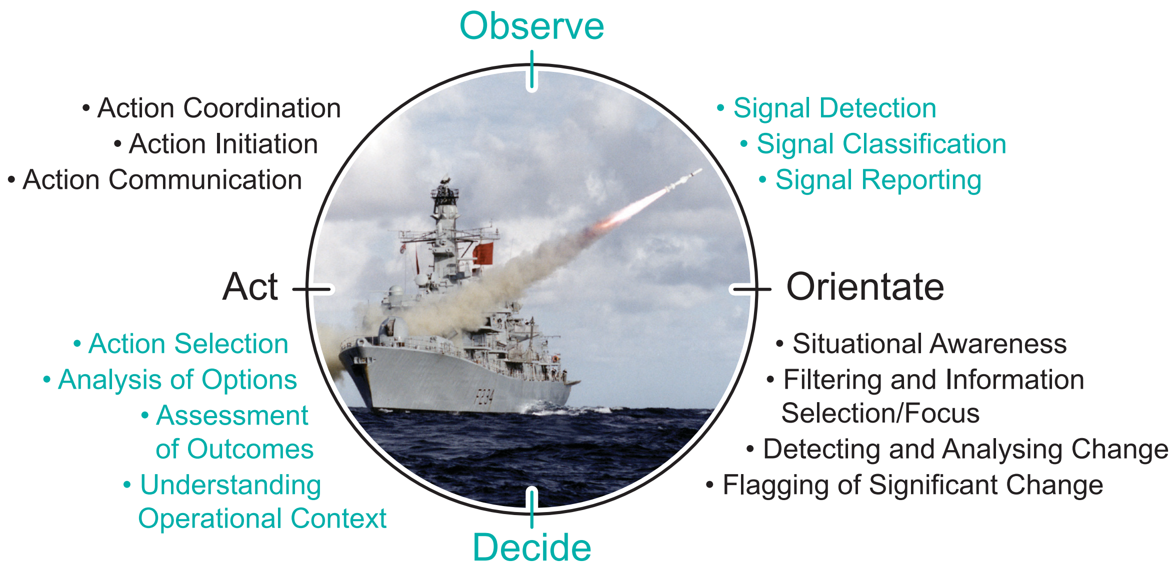


Figure 2. Colonel Boyd's OODA loop is still a powerful way of characterising the challenges we face in a modern weapon system engagement.

It is clear that a human-dominated C2 loop isn't responsive enough to deal with hypersonic missiles; by the time a hypersonic missile has been detected, its speed of closure compresses the OODA loop to such a degree that there is insufficient time to decide, communicate and execute a response. It is also clear that leaving all of the defensive action until the 'end-game' (i.e. once the missile is inbound) is a risky and life-threatening strategy.

Whilst new technology (e.g. the hypersonic threat) is the villain of the piece, perhaps too it will be the saviour, in that advances in Artificial Intelligence (AI) and Machine Learning (ML) can help us to overcome some of the constraints of our legacy, human-dominated defences.

Artificial Intelligence (AI) =
The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision making, and translation between languages.

Machine Learning (ML) =
An application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience, without being explicitly programmed. Machine Learning focuses on the development of computer programs that can access data and use it to learn for themselves.

Although sometimes seen as a mixed blessing, particularly in its applications like driverless cars, Google and Facebook, the truth is that AI is now an everyday practicality as opposed to laboratory-based research and development. From an EW perspective we could use ML to deal with some of the information challenges that are difficult for humans to work through quickly enough; think of it as AI helping humans to make quicker, better decisions. Considering how ML categorises things, EW could use ML in three distinct levels: signal, pattern, and event:

- Signal: Using attributes to arrange and identify signals by certain characteristics.
- Pattern: Looking for patterns and sequences of signals.
- Event: Learning what is routine, and therefore detecting abnormal events.

At a hardware level, ML could be used to improve the way that signals are dug out of a noisy and congested RF spectrum. Equally, ML's suitability for learning and recognising sequences and patterns means that we could see improvements in how we detect anomalous behaviour and then prepare for an optimal response with AI-led decision support. Of course, to get an effective ML decision-making engine will require suitable data and information from which to learn and make assumptions;

this presents a new challenge in terms of data support in the AI-age because we will need to focus on a broader, all-inclusive 'Kill Chain' view of an engagement sequence (from strategic intent all the way down to the final missile guidance and fusing). The Kill Chain view is essential because it allows ML techniques to recognise a pattern of events, and then predict what should be coming next; in essence, this is exactly what an experienced human operator does, but computer-based ML allows us to 'train' for far more events, and to produce results more quickly and more consistently. However, Kill Chain analysis is a niche activity at the moment, and putting emphasis on a co-ordinated view of the total Kill Chain is likely to be quite different to current stove-piped analysis we see in legacy EWOS.

If we can meet the demands and challenges imposed by ML, there is potential for it to intervene positively across the OODA loop, as figure 3 below illustrates.

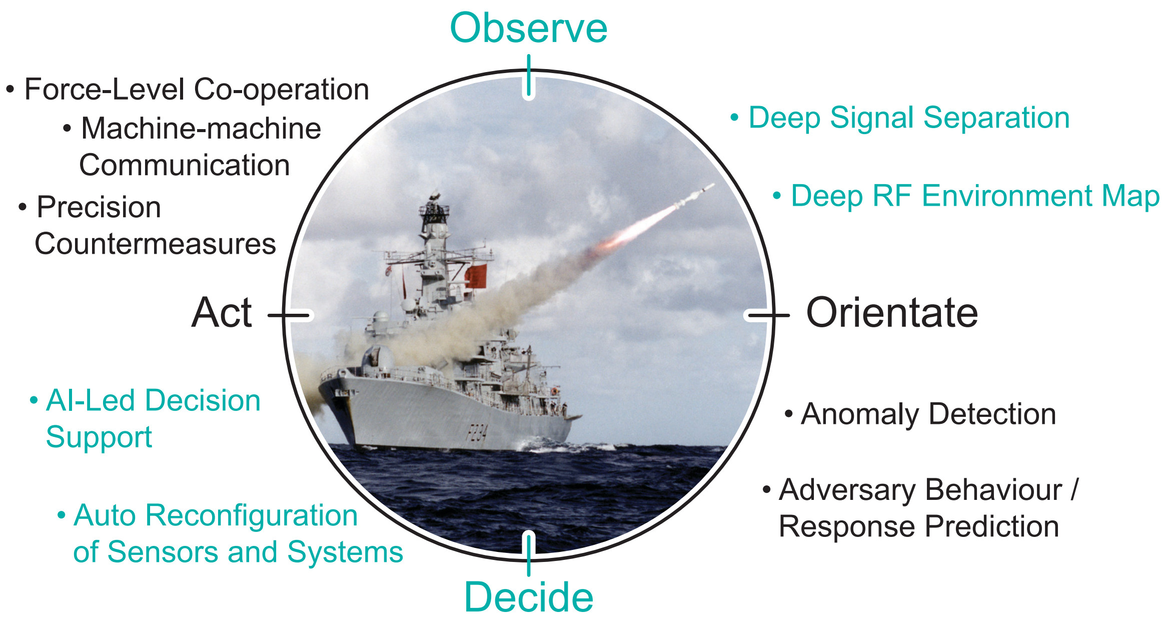
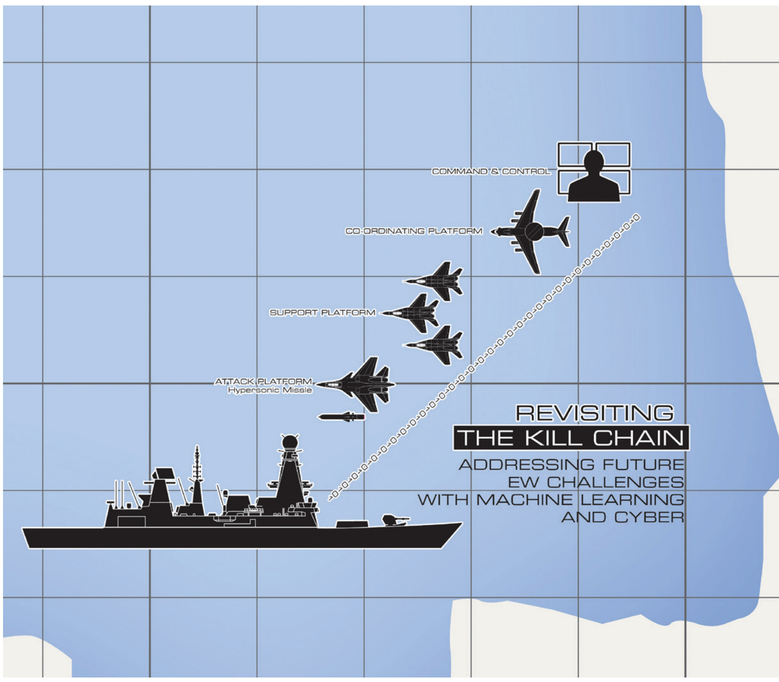


Figure 3: ML could contribute across the OODA loop by better separation of signals and identification of threats, faster decision making and increased machine coordination of responses.

At the start of this article, one of the features of legacy EWOS was that it had evolved a dominant focus on emitter parametrics. As we step towards the AI-age, and use machine learning to locate our position on someone else's Kill Chain, our notion of Mission Data will have to broaden.

The changing face of Mission Data (MD) will see an expansion in Electro Magnetic terms away from predominantly the radar bands to include other aspects in the environment such as acoustics, 4/5G communications, Wi-Fi, windfarms etc. Further to that, we'll see the importance of whole Kill Chain data which includes: systems integration, modes and sequences, datalinks, command chain, adversary tactics, degrees of autonomy, and engagement timelines. Finally, we'll see the inclusion of Cyber/CEMA elements such as: operating systems, processor types, software and firmware, network switch type, IP addresses, security enforcing functions, social media accounts etc. MD support in the AI-age will be a far cry from the simplistic 'RF, PRI, PD and Scan' that has served us well for so long.



A new paradigm for Data Management

The likelihood of AI-age MD being significantly different in content to legacy EW isn't the only change we'll have to face; the way we manage AI MD will be very different too. Whilst some of the data management activities will have broad similarities to what we do now (e.g. pre-processing, secure sharing, and data guarding), the employment of ML techniques means that we must not be too predictable in our responses – which means we'll need to introduce a degree of 'randomisation'. Equally, as a set of techniques and an operating medium which thrives on diversity, we'll have to acquire new skills regarding how data from one domain can be useful
to another: learning by (different) experiences. In the AI-age, a new breed of Data Engineers will be just as much a part of the EWOS cycle as emitter analysts and weapon system experts.

Another shift in the MD paradigm will be how we handle ownership of AI knowledge. Thus far, ownership in the legacy EW domain has been largely uncontested: the OEMs own the de-interleaving and processing algorithms, and the users (typically the military) own the data. Easy. Yet in a world where the AI decision making will be heavily developed by (and invested by) Industry, but contextualised and optimised by an operational user (the military), dividing lines of ownership may not be so clearly defined as present; this is because of the blurring between sampled operational data, pre-deployed knowledge, and because decision-making actions will evolve dynamically from both of them. It is hard to imagine this as a red-line show-stopper; the point is, it is a subtly new paradigm which surely warrants early consideration and discussion.

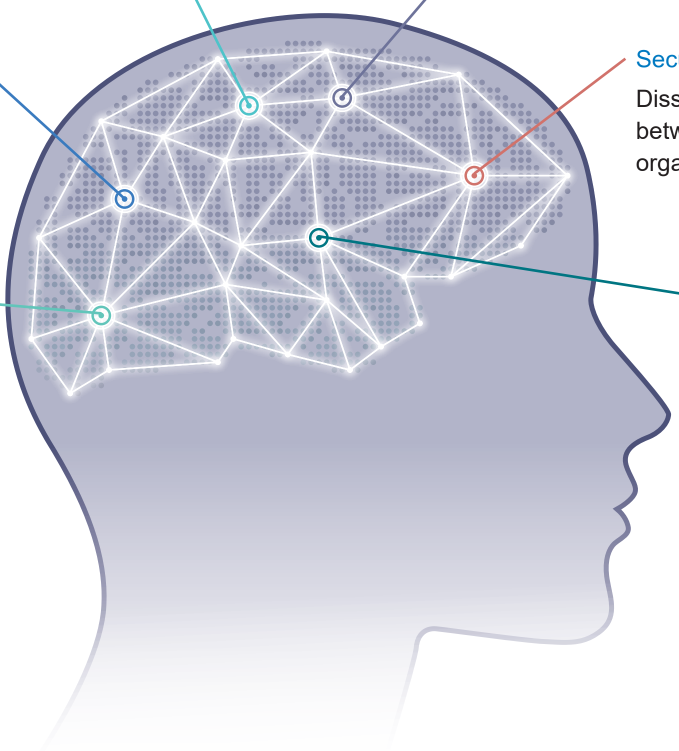


Figure 4: Mission Data support in the AI–age will be supported by 'data engineers' working in complex data factories; they'll develop new techniques such as 'randomisation', 'AI pipeline protection', and 'AI knowledge transfer'.

Summary

Our existing notion of EWOS and MD has evolved with decades of operational use, and has been shaped by the equipment architectures of our current generation of EW equipment. Even so, our focus on traditional RF parameters has meant that we haven't necessarily kept track of new, confounding, contributors to the electromagnetic environment, and whilst we continue to see strong support for joint-Service EW, we haven't yet de-silo'd some components of Intelligence Mission Data.

New threat weapon systems will render legacy EW and C2 systems obsolete, because their rapid delivery is complete well within the defending platform's OODA loop; for things to improve, future EW and C2 systems will need to harness some of the benefits that AI and ML have to offer. That said, Mission Data Sets in the AI-age will not only have different data to legacy mission libraries, but their production and maintenance introduces new paradigms for data management, and will necessitate new skillsets within our EWOS lifecycle.

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