Research topics 2024

Topic 1	**Exploration to determine the positioning accuracy of mobile devices using the 5G cellular networks**
Topic 2	**Detection of deep fake videos with audio**
Topic 3	**Distributed High Frequency Over-The-Horizon radar**
Topic 4	**Detection of obscured forensic or biometric markers at crime scenes or from objects**
Topic 5	**Countering deception in Intelligence, Surveillance and Reconnaissance (ISR) networks**
Topic 6	**Flexible solid-state batteries**
Topic 7	**Detection of genetic engineering and/or synthetic biology**
Topic 8	**Anticipating complexity in a modern world**
Topic 9	**Light weight metamaterial ultrawideband frequency absorber**
Topic 10	**Machine learning trained fingerprinting of the near field measurement**
Topic 11	**Analysis of non-western emerging technology**
Topic 12	**Detection of low volatile materials**
Topic 13	**Understanding AI enhanced biotechnology risks**
Topic 14	**Development of techniques to assess data aggregation**
Topic 15	**Utilizing a modern mobile to provide a level of TSCM capability**
Topic 16	**Simulation of emerging sensor technologies**
Topic 17	**The influence of air quality on cognitive performance and behaviour in secure environment**
Topic 18	**Using homomorphic encryption for machine learning sensor data and privacy**
Topic 19	**Developing techniques to enable analytic teams to make accurate judgments**
Topic 20	**Quantum engineering for quantum sensors**
Topic 21	**Materials informatics for rapid and efficient design of new systems**
Topic 22	**Synthetic aperture RADAR automated exploitation**
Topic 23	**Integrated multimodal facial recognition technologies**

Topic 1
Exploration to determine the positioning accuracy of mobile devices using the 5G cellular networks

Unclassified key words: telecommunications, 5G, Location Based Services, LBS, spatial accuracy, 3GPP standards.

Unclassified research topic description, including problem statement:
There is a lot of speculation and theory on the internet about the spatial precision of the 3GPP 5G telecommunications standards. This topic is to explore, prove or disprove what is actually achievable (in terms of location accuracy of a 5G mobile device) in the UK when using similar technologies to those used by the UK telephone operators.

Unclassified example approaches:
Location Based Services in 5G introduce a range of possible capabilities. Since these are not yet deployed commercially and involve new interfaces and network functions to deliver these, two phases of work are being proposed to be carried out – the first is to carry out exploration of technology, capabilities and possibilities for user location presented by 5G and scope the second phase – operational use-case validation and scenario exploration for a rural and urban scenario.

Phase 1 – technology and capability exploration:

- Understanding the impact of the deployment of 5G Non-standalone (NSA) into existing telecoms networks, and the possibilities and impact for user location arising from the deployment of 5G NR cells over an existing 4G core network (as is being/will be deployed in urban and suburban environments).
- Testing the introduction of an LMF function into a 5G SA network and evaluating functionality and feasibility of use of LBS capabilities in the network, and compatibility with core network components for 5G SA networks.
- Identify supported modes of operation with available 5G radios (i.e. what location-based services can actually do today, based on the features implemented by radios today), compared with the 5G standards, and exploring the extent to which the location standards are actually implemented in 5G network equipment at present.
- Exploring handset support for location-based services, and 5G location capabilities more broadly (since not all handsets fully implement all areas of standards) and evaluating the possibility of device location through passive means, based on routine uplink traffic generated by the device itself and apps/operating system installed on it (which would remove the need for the handset to cooperate and provide reporting on its observations of the PRS position reference signals).
- Exploring potential afforded by a roll-out of small cells for user location, and what this could offer in urban settings.

- Exploring whether devices implement and send sounding reference signal (SRS) signals within their uplink transmissions if requested.
- Exploring the likely realistic precision of location in 5G, based on experimentation, to investigate claims of 3 to 5m location precision, and claims around height / "Z-coordinate" positioning, and identify and understand the technical requirements on a network and radios which would be needed to achieve these.
- Exploring what different radio technical choices may afford around user location, including the potential use of urban mmWave FR-2 radios, and massive MIMO, which both have potential to enhance location precision or better support Z-coordinate height in positioning.
- Understand what a "vanilla" 5G network is likely to yield by way of user location capability, before addition of "over-the-top" enhanced location technology which would need to be re-developed for a 5G core network.

Phase 2 – operational use-case validation and scenario exploration:

- For a rural scenario initially, based on the available 5G location capabilities which can be used, determining the accuracy of user location.
- For an urban scenario, carry out a similar test scenario, to assess the viability of relevant urban goals, including 3-dimensional positioning, and precision.
- Other use-case validation and scenario testing which may arise from the findings in phase 1 (i.e. different radio technologies, options arising from small cells, etc.)

Technical 5G location-based technology of relevance to phase 1 evaluation:

- Testing functionality of 5G LCS (location services) via LMF (location management function) for regulatory use-cases outlined in Rel 15 standards.
- NR Cell-ID support for coarse conventional location of devices and exploring manual options akin to eCellID in a 5G network where a mix or alternative of low and high frequency cells are available (to compare urban and rural scenarios based on basic RF signal strength data).
- Testing for MT-LR (mobile terminated location request) support, and ability to trigger deferred (i.e., triggered, UE available, periodic, area-fenced) location reporting via LMF.
- Bulk (multi-UE) support for device location requests via the LMF.
- Time difference of arrival (TDOA) location method support and accuracy.
- Round-trip time (and multi-base station multi-RTT) if supported and exploring requirements for time sync in networks to enable this to work.

- Angle of Arrival (AoA) and/or Angle of Departure (AoD) measurements if supported on beam-forming capable massive MIMO radios.
- Exploration of whether Es are implementing support for UE-based NR native position, privacy settings on devices (as these are implemented by vendors), and options for GNSS-based assistance on the location reported to the network.
- Exploration of uplink-based positioning, based on the UL-PRS, which uses the Sounding Reference Signal that is already transmitted by the handset – potentially establishing positioning beam pairs, and allowing for device location from an uplink signal, just based on a passive uplink signal. Exploring if devices transmit the necessary SRS, and whether this can be enabled via MAC layer control protocols.

Topic 2
Detection of deep fake videos with audio

Unclassified key words: AI, generative, deep fake detectors, video, audio, speech, multimedia.

Unclassified research topic description, including problem statement:
The rapid advancement in generative AI technology has brought many new opportunities for content creation, but at an expense that malicious deep fake content can be easily created and then distributed. In the coming years it is anticipated that deep fake video complete with audio will mature, bringing another wave of advancement but again opening another angle for malicious or manipulated material that can be distributed at large.

The pace of open-source research in generative AI makes it incredibly challenging to keep track. Such pace also means that specialist research tools are being packaged more quickly than ever into software applications accessible to almost anyone, and usually before protective processes and legal understanding can be put in place. Development of deep fake video with audio detectors will become an urgent necessity sooner rather than later.

The topic here is the desire for detection systems to both quickly check large quantities of video with audio, and conversely, to provide explainable techniques on a fine-grained level to provide assurance and likely provenance.

Unclassified example approaches:
Possible routes to develop detectors could include:

- Exploring existing deep fake detection video with audio challenges, considering participation, and understanding the benefits and limitations of such common systems.
- Investigating deep fake video jointly with audio detection as well as separate video and audio detection research.
- Review deep fake video with audio research identifying key methodologies to understand their limitations.
- Consider forensic angles where lighting, occlusions, and possible statistical artefacts as an explainable alternative to any automated countermeasures.
- Exploring use of identity recognition of deep fake videos with audio for detecting deep fake content.
- The choice of language and emotion, and whether it is consistent with the scene or not.

Topic 3
Distributed High Frequency Over-The-Horizon radar

Unclassified key words: HF radar, ionosphere, data assimilation, inverse problems, signal processing, multistatic, distributed RF, MIMO, Beyond-Line-Of-Sight, Over-The-Horizon Radar, OTH.

Unclassified research topic description, including problem statement:
Over-The-Horizon (OTH) radars operate in the High Frequency (HF) band (3–30 MHz) and exploit signal reflection from the ionosphere to detect and track airborne and surface targets at ranges an order of magnitude greater than is possible with conventional line-of-sight radars. More than half a century of international research and development in this area has resulted in the fielding of mature OTH radar systems capable of cost-effective early-warning surveillance over wide areas. In particular, the ability of OTH radar to persistently monitor remote geographical regions where microwave radar coverage is not feasible or convenient represents an important advantage of such systems. The high performance achieved by state-of-the-art operational OTH radar systems is the outcome of a great deal of theoretical and experimental research in the areas of ionospheric propagation modelling, hardware system design, intelligent resource management, and digital signal processing. The knowledge gained and shared through joint programs of international collaboration has played a key role in the deployment of successful OTH radar systems worldwide.

Current trends dictate that for several Intelligence Surveillance and Reconnaissance (ISR) applications, the requirement is to push the boundaries on distributed OTH radar. Conventional OTH radar use large transmitter antenna arrays (typically 100-200 metres long) and even larger receiver antenna arrays, extending to many kilometres. The arrays each comprise many antenna elements and evidently a conventional OTH radar cannot be considered to be mobile or easily relocatable. The transmitting and receiving systems are usually located 50 km to 100 km from each other to provide radio frequency (RF) isolation of the transmitter from the receiver. Although a conventional OTH radar is formally a bistatic radar, it can often be considered monostatic at typical detect and track ranges; consequently, a conventional OTH radar transmitter and receiver can only measure the speed of a target along the look direction.

The scope of this research topic is to innovate next-generation and generation-after-next distributive OTH radars which would give added performance advantages for ISR applications by providing proposals which could advance theoretical and experimental research in the areas of ionospheric propagation modelling, hardware system design, intelligent resource management, and digital signal processing.

Unclassified example approaches:

Distributed high frequency over-the-horizon radar system:

The invention relates to the technical field of radar systems, radio physics, and the like, and, in particular, relates to a distributed high frequency over-the-horizon radar system. The distributed high frequency over-the-horizon radar system comprises a shore-based high frequency ground wave radar netted subsystem, a fixed/mobile ground wave over-the-horizon radar subsystem in other forms (float type, vehicle-mounted and shipboard ground wave radar), a high frequency sky wave emission subsystem, an environment guarantee subsystem, a control subsystem, and a data processing subsystem. The distributed high frequency over-the-horizon radar system can work in a ground wave netted and sky-ground wave hybrid netted mode, by virtue of distributed ground wave radar netted and sky-ground wave integrated netted detection, breaks through the limit that the conventional ground wave radar only can be distributed along coastlines, obtains more comprehensive physical quantity information at the original signal level by organic integration and mutual complementation multiple work modes, can improve accuracy of detection on wind, wave and current to a greater extent, greatly improves detection range of the high frequency radar system, and realizes far-shore ocean dynamics elements detection and near-shore fine detection.

Research Paper:

The article raises the problem of fine tuning over-the-horizon radars with relevant information about the parameters of the ionosphere. To improve the accuracy of the radar, it is proposed to create a system of remote positions, which are ionosondes of vertical and inclined sensing. The results of the operation of such ionosondes serve to adjust the global model of the ionosphere. Thus, the quality of the radar is significantly improved, allowing us to more accurately determine the coordinates of air targets.

Topic 4
Detection of obscured forensic or biometric markers at crime scenes or from objects

Unclassified key words: forensics, DNA profiling, fingerprint analysis, human identification, attribution.

Unclassified research topic description, including problem statement:
Deposition of friction ridge detail and/or human DNA through skin barriers including disposable gloves, re-usable gloves, and other hand/skin barriers. Can forensic or biometric markers be visualized and/or identified from crime scenes /objects when such barriers are in place?

Deposited friction ridge detail (i.e., finger or palm marks) and human DNA are often recovered from crime scenes and/or objects, in order to assist with forensic investigations. The use of gloves and/or other physical hand/skin barriers may impede the recovery of friction ridge detail and reduce the amount of DNA deposited on a surface. Despite the use of a barrier, modern fingermark visualization techniques may be able to capture glove prints or possible friction ridge detail that could be used for forensic intelligence or evidential purposes. An evaluation of different glove types, textures, materials, and use methodology (e.g., double gloving) will provide important information on whether intelligence or evidential friction ridge detail can be recovered despite hand/skin barriers. There is also an opportunity to evaluate these types of barriers on their effectiveness in reducing touch DNA deposition.

Unclassified example approaches:
An artificial finger pad, previously developed at Dstl for Covid-19 transfer research, could be used to test deposition of glove marks onto a variety of surfaces such as polymers, metals, and porous materials. The finger pad allows for controlled pressure deposition and can be adapted to also be used with artificial and real human fingerprints to test deposition with gloves or other skin barriers. Similar mechanisms could also be used to test for deposition of DNA. This is only one example of an approach, with more in-depth studies using human volunteers being envisaged.

Topic 5
Countering deception in Intelligence, Surveillance and Reconnaissance (ISR) networks

Unclassified key words: Intelligence, Surveillance and Reconnaissance (ISR), sensing, situational awareness, deception, strategy, game theory, bayesian Inference.

Unclassified research topic description, including problem statement:
Military sensing and intelligence gathering is complicated by the fact that our adversary's objective is, more often than not, in direct conflict with our own. Adversaries will work hard to obscure their state and their intent from observers; they may also undertake activities designed to give a false impression of this state or intent, which could involve, for example, hiding, mimicking benign targets, manipulating signatures, or deploying decoys and countermeasures. All of this is designed to complicate our inference, and means any decision based upon the ISR picture we compile must be robust to such tricky activity.

Behaviour designed to confuse the ISR picture is not confined to a single domain or sensor modality, and techniques found in certain scenarios have analogues in others (e.g., radar jamming/optical dazzle). The IC is looking for methods of quantifying the effect of such deception, and furthermore to develop strategies to recover the information which has been obscured or changed. The ultimate goal is that decisions based upon an ISR picture should be robust to deceptive activity, or at least aware that deception has taken place.

Unclassified example approaches:
Deception of sensing can take many forms and occur in many situations. We are interested in general aspects of the problem space such that we may draw conclusions and provide mitigations in multiple domains (e.g., Air, Land, Space, Maritime) and across a full range of sensors (e.g., radar, electro-optical, sonar, text-based, social media, to name a small subset). We want research to build toward a mathematical description of the deception of sensors. This description should thereby point to development of strategies to counter types of behaviour designed to deceive sensors. This may begin from general-purpose human-centric theories of deception and specialise them toward sensing and inference, or it may build from models of sensors and target intent. Whichever way is chosen, the research must develop a general mathematical framework characterising multiple and varying types of deception. These may encompass hiding, dazzling, decoying, mimicking, inventing real and fake targets, repackaging, and distraction among many other examples. Solutions to single and overly specified problems are not of interest here.

We will not be prescriptive regarding solutions; all techniques are welcome. We are, however, looking for methods which can be engineered within future ISR and autonomous systems and will eventually deliver benefit to the intelligence community. Preference will therefore be given to research which shows strong potential for exploitation in this direction. Cross-disciplinary research is encouraged.

Current component methods of sensor counter deception research cover modelling of intent, efficient optimization, game theory, Bayesian inference, scalable inference on graphs, and high-dimensional sampling methods. This list is neither complete nor prescriptive.

Topic 6
Flexible solid-state batteries

Unclassified key words: energy storage, batteries, Li-ion, solid state, flexible, wearables.

Unclassified research topic description, including problem statement:
Solid state batteries are at a maturity where they are commercially available. This is typically limited to use in devices that require low power levels, such as wireless sensors (marketsandmarkets.com), this is due to higher resistance that is typically exhibited compared to Li-ion cells utilizing liquid electrolytes. There is significant research in reducing internal resistance, and if achieved could unlock a much greater market share in the EV market for example, as solid-state batteries are typically significantly safer to use than liquid electrolyte-based batteries and more energy can be packed into the same space.

Related to this topic, is the growth of wearable technologies and specifically flexible batteries that can enable wearable electronics (Deng and He, Energies 2023). This is still an emerging market and although there has been research in the area of flexible batteries, uptake in the commercial market has been limited (marketandmarkets.com).

By combining developments of solid-state batteries, and flexible batteries, it is believed a viable battery could be developed for the wearables market that can store significant amount of energy and have increased safety for the user. There have been developments in flexible electrodes by utilizing non-metallic current collectors, printed materials and increasing binder content, but there is a lack of research on developing the solid electrolyte/separator material that can also offer a degree of flexibility.

Therefore, this research topic should focus on developing and proving that a solid-state electrolyte can be manufactured which can also be bent and flexed and is appropriate for use in a wearable scenario.

Unclassified example approaches:
Early approaches to solid-state batteries have been demonstrated using solid polymer electrolytes (SPEs) or inorganic solid electrolytes (ISEs) based on sulfides or oxides. They often suffered from low rate due to poor ionic conductivity or poor electrochemical stability compared to liquid electrolytes. The rigid structures also required high levels of compression to ensure good electrical contact to suppress lithium dendrite growth during extended cycling. These requirements are incompatible with wearable or flexible structures and so a new approach is required.

Recently, hybrid systems have been created that benefit from the increased ionic mobility of a solvent trapped in a polymer, such as hydrogel electrolytes (Xin Li, *Chem. Eng. J., 2022*). However, these formulations can be semi-solids / quasi-solid-state and so require thick layers or separators. The structures can provide higher performance and flexibility but rarely are evaluated using wearables and accept lower operating voltages to overcome limited environmental protection.

Other approaches avoiding liquids have included blending the polymer and ceramic together through either a polymer in ceramic or ceramic in polymer structure (Kun Zhang, *Adv. En. Mat., 2022*). They often will have extremely strong structures but suffer from lower ionic conductivity. These demonstrated a secondary benefit of the electrolyte providing an environmental protection layer in addition to active electrolyte.

Flexibility has also been achieved by imparting the ISE into a fabric-based substrate (Yunhui Gong, *Materials Today, 2018*). The addition of carbon conductive additives and more flexible anode/cathode elements has further refined this approach (Changmin Shi, *Energy Storage Materials, 2023*). Hierarchical designs can enable the sharing of physical properties and enable the use of rigid ceramics into a woven structure that is perfectly adaptable to wearables.

The flexibility can also be gained from utilising thin structures, such as drawn fibers. A team at MIT demonstrated that multi-layered structures of battery elements could be drawn simultaneously to achieve a fiber battery (Tural Khudiyev, *materials today, 2022*). This extremely thin structure wouldn't necessarily require the flexibility of a classical sheet electrode due to the narrow structure. The design will struggle with stress and strain if using inflexible elements but shows a novel approach.

Topic 7
Detection of genetic engineering and/or Synthetic Biology

Unclassified key words: genetic modifications, synthetic biology, biosecurity, detection, attribution.

Unclassified research topic description, including problem statement:
The timely detection and identification of a biological hazard is critical to minimizing the impact of an event, whether that be a natural event (e.g., emergence of a new viral strain such as SARS-Cov-2) or a nefarious release (e.g., intentional dissemination of material such as the Amerithrax attacks). Microbial forensics represents a new and emerging area of science which goes further than simply detecting an organism is present in a sample, by determining the material's provenance and whether there are any signatures of nefarious release (e.g., evidence of laboratory growth, changes in the genome). The identification of genetic modifications (GM) of an existing pathogen and/or the creation of new organisms with the potential to be pathogenic to human health represents key attributable intent (i.e., nefarious). Approaches that enable the detection of these signatures will therefore be crucial to improving government preparedness against the misuse of GM and/or SynBio microorganisms.

The detection of the use of GM and/or SynBio represents a significant technical challenge. Traditional bioinformatics tools that interrogate genome sequencing data are limited with respect to the complexity of data that can be analysed (e.g., cannot interpret metagenomic data) and often require significant lengthy onward human intervention (e.g., lack automation, AI). New bioinformatics approaches are required – potentially involving artificial intelligence and data science fusions – in order to interpret complex genomics data and also identify the presence of genetic engineering.

This proposal seeks the generation of completely new approaches to this problem, benchmarking these newly developed techniques against traditional bioinformatics pipelines used in genomic analysis and demonstrating performance improvements with respect to the detection of the use of genetic engineering and SynBio.

Unclassified example approaches:

A possible approach may include:

- Assessing the current "market" with respect to bioinformatics tools that could be used for the intended purpose.
- The development of curated reference database(s) of signatures of genetic engineering and/or the use of SynBio.
- Bioinformatics tools and pipelines that can map genomics data (both DNA and RNA) robustly to publicly accessible reference databases and are able to screen for the presence of indicators of GM and/or SynBio.
- Provide graphic user interface (GUI) that provides a preliminary interpretation of the result and/or highlights areas of interest within the genomics data for furthermore targeted investigation.
- Use openly accessible reference genomes as training data sets to apply AI-machine learning techniques in order to improve the efficacy of the tools for identifying markers of genetic engineering and/or SynBio.
- Undertake performance tests using pre-existing genomics data in the public domain to demonstrate the robustness of the technique to separate between natural organisms and genetically engineered or synthetic organisms.

Topic 8
Anticipating complexity in a modern world

Unclassified key words: microbiome, biosecurity, detection, attribution, disease, engineering biology, synthetic biology.

Unclassified research topic description, including problem statement:
The world is becoming ever more complex as physical reality is combined with the virtual world of cyber through the cyber-physical. Interdependencies of cyber-physical system components, either directly or via the virtual world of computing, are growing in intensity. At some point in the future, the technologies we increasingly rely on to live safe and fruitful lives will become complex systems with emergent properties in their own right. Soon, our relationship with the cyber-physical systems that surround us will be determined by the emergent properties of the collective and will not merely be the sum of what the developers of the individual devices intended. This affects the availability and reliability of smart cities, intelligent transport systems, supply chain logistics, smart buildings, industry 4.0, advanced military conflict, and wherever large collectives of disparate technologies sustain our lives.

How do we predict the technological tipping point to complexity? How do we prepare ourselves so that we understand the security implications of technologies with properties no one intentionally designed? How stable will the environment we live in be, and how vulnerable to attack? These are just some of the questions we are likely to face in the next few years.

This topic is to explore the representation of complexity in highly interdependent collectives of cyber-physical systems. We can assume that each member of the c ollective is a heterogenous intelligent agent, or a member of a guild, with a model of its situation (and potentially those around it), but without visibility of the collective as a whole. Individual mission goals drive behaviour (which may be prosocial or antisocial) with no guarantee of synergy or collaboration. The research is to define fundamental approaches to modelling complex systems. This may include (but is not limited to) the evolutionary dynamics: coherence in time (synchronization and coordinated dynamics), adaptation, levers and lever points; thresholds; critical behaviours; tipping points; stability; turbulence; sustainability; susceptibility; and resilience. The emphasis is on the connected technologies of tomorrow and their behaviours from a cybersecurity perspective. The aim is to create a mathematical model of complexity in collectives of cyber-physical systems that will lead to better understanding of security vulnerabilities, the corresponding defences, and the potential impact of cyber-attack.

Unclassified example approaches:

- Models of complexity in intelligent agency (e.g., emergent properties of Popperian intelligent agents, antifragile systems).
- Agent-based modelling of multi-agent systems (e.g., stochastic modelling of multi-agent behaviour and interactions; swam intelligence models).
- Generative self-organisation (and Finitely Generated Systems).
- Measures of complexity, such as entropy; intensive or extensive measures (of how the properties changes when the size or extent of the system changes); behaviour (such as measures based on the law of requisite variety).
- Revealed Dynamics Markov Model (Bramson, 2019 in Carmichael et. al. pp79-128).
- Other mathematical tools of complexity science: branching processes (and generator functions), statistical mechanics, network theory (and graphs), information theory and entropy, stochastic dynamics (and probability), intermittent dynamics (and differences in dynamics at the individual and aggregated scales), and co-evolutionary dynamics.

Ted Carmichael (Editor), Andrew J. Collins (Editor), Mirsad Hadžikadić (Editor), Complex Adaptive Systems: Views from the Physical, Natural, and Social Sciences (Understanding Complex Systems), Springer; 1st ed. 2019 edition (27 Jun. 2019), ISBN-13: 978-3030203078.

Topic 9
Light weight metamaterial ultrawideband frequency absorber

Unclassified key words: metamaterial, absorber, ultrawideband, polarized, acoustic, RF, technical surveillance, novel materials, attenuation.

Unclassified research topic description, including problem statement:
Metamaterials have been widely used in the past few years for RF as well as acoustic shielding applications. These are typically only applicable over a limited bandwidth, and there has been limited research in the metamaterial absorber design for combined acoustic and RF application, from a few Hz up to 30 GHz. There are additional research gaps that RF absorption effects suffer from the incidence polarization of its signal, meaning that shielding often does not fulfill the requirements in the IC's scenarios, as outlined in the last section.

In this topic we would like to explore the research and development of novel light-weight metamaterial absorbers to provide the frequency absorption over a wideband range from a few Hz to 30 GHz that is insensitive to the incident signal phase.

The development would help in providing an absorption and attenuation of various sound and RF signals emanating from multiple consumer devices and sources and bring new vitality into traditional approaches.

For further related reading, please see the following references:

- Zhang et al., 2020, "Engineering Acoustic Metamaterials for Sound Absorption: From Uniform to Gradient Structures", iScience.
- Yang and Sheng, 2023, "Acoustic metamaterial absorbers: The path to commercialization", Applied Physics Letter.
- Begaud et al., 2018, "Ultra-Wideband and Wide-Angle Microwave Metamaterial Absorber", MDPI.
- Tirkey and Gupta, 2019, "The quest for perfect electromagnetic absorber: A review", International Journal of Microwave and Wireless Technologies. from doors, lifts, etc.).

Unclassified example approaches:

- Computational modelling and calculation of the architectural design.
- Model and simulate the behavior of metamaterial absorber for its intended frequency range.
- Identifying candidate materials and novel composite structures with negative permittivity and permeability, potentially using conductor and dielectric sandwich materials.
- Optimise the design for the physical construction.
- Experimental verification of the physical design and its analysis for its application.
- Development of lightweight design for its integration within a physical space.

Topic 10
Machine learning trained fingerprinting of the near field measurement

Unclassified key words: machine learning, fingerprint, near field, electromagnetic, EM, RF.

Unclassified research topic description, including problem statement:
Electromagnetic (EM) shielding controls have widespread usage ensuring secure communication facilities do not emanate unintentional EM signals. Over the past few years near field measurement has been obtained with traditional multiprobe technique in combination with analytical functional evaluation to provide a measurement of the complex and dynamic EM field, however this approach introduces uncertainties in its measurement result due to dynamic field complexity within its surrounding. Recent advancement in Machine Learning (ML) with linear/non-linear mapping algorithms has exhibited novel techniques to solve complex analytical functions in real-time.

This topic looks for the development of fast and efficient ML integrated near field measurement within a dynamic and complex EM environment to provide fingerprinting of its surroundings for secure communication.

Unclassified example approaches:
- Literature survey for the near field measurement of EM signals.
- Near field measurement of an EM surroundings.
- Development and application of the ML algorithms integrated into near field measurements.
- Real time measurement and response accuracy enhancement within a dynamic EM environment.

For further reading please see following references:
Wen, J et al., doi: 10.1109/TEMC.2020.3004251
Alavi, RR et al., doi: 10.1109/APUSNCURSINRSM.2019.8888868
Deschriiver, D et al., doi: 10.1109/TEMC.2011.2163821.

Topic 11
Analysis of non-western emerging technology

Unclassified key words: AI, engineering biology, telecommunications, semiconductors, quantum, quantum sensing, advanced semiconductor manufacturing, hypersonics, internet of things, smart cities, digital twins, machine learning, robotics, patents, roadmaps.

Unclassified research topic description, including problem statement:
We believe that the emergence of hostile technology may be predicted from the comparative volume of patents and research publications, and the amount of investment by certain countries, on specific areas of novel technology. The timeline of emerging threats may also be predicted by considering how multiple technologies could be combined.

There is an increasing concern of reliance on non-western science, technology and manufacturing. This growing reliance may mean the UK is less resilient to shocks in the market, could impact long-term economic growth, and position technology in some more sensitive equipment in the national security arena, out of our control.

A recent publication in March 2023, The UK Science and Technology Framework, highlighted five critical technologies to the UK. These were Artificial Intelligence (AI), Engineering Biology, Future Telecommunications, Semiconductors and Quantum Technologies.

We would like an IC Postdoc fellow to deep dive into the emerging technologies in non-western countries undertaking a systematic review. This will inform strategy, policy, and future investment in the five critical technologies highlighted.

Unclassified example approaches:
We believe a fellow with a strong strategy and policy background, as well as a broad understanding of the five critical technologies will be well placed.

The emergence and development of the five critical technologies could be predicted from a systematic review looking into volume and trends of patents, interdependency with other critical patents, research publications (including impact and number of citations), commercial developments, and open-source future roadmaps. It should also be considered how multiple emerging technologies could be combined and what these threats may be.

Example Approaches:

- Compare the total number of patents, research publications and grant funding by country on each type of technology, over a period of time, to infer what the emerging threats might be and their timeline.
- Analyse in detail the patents and research publications on particular types of technology to predict what the emerging threats might be and their timeline.

Topic 12
Detection of low volatile materials

Unclassified key words: detection, explosives, quantum, nanomaterials, sensing.

Unclassified research topic description, including problem statement:
The solutions implemented for bulk and trace detection of explosives and other related materials have matured to a sufficient point that they are now widely accepted as the gold standard within the field, being capable of high levels of sensitivity. A useful augmentation to the arsenal of detection solutions would be a portable vapour detection system with optimised selectivity and sensitivity required to work outside of a laboratory environment. Current gas sampling and analysis techniques – such as gas chromatography, mass spectrometry and ion mobility spectroscopy – when used in the vicinity of particular materials allow for detection at a satisfactory concentration level. Whilst sufficient, many of the techniques used could benefit from reduced operational costs, easier sample preparation, simplified useability, and reduced need for re-calibration.

Many threat materials either have low volatility or are concealed in such a way that the amount of vapour available to detect is minimal. As well as the challenges imposed by commercial and military grade explosives, the diverse chemistries of homemade explosives (HMEs) pose an additional challenge. The complex vapour signatures of HMEs are not only highly variable, but their compositions vary with time and environmental conditions which requires additional consideration. The techniques for explosives detection should be non-invasive and based on direct detection at the source.

The successful development of a portable system with high selectivity and the sensitivity needed would potentially find application in finding the location of an odour source, to not only classify the material of interest, but also search for the threat.

Unclassified example approaches:
The utility of a sensor is dependent on many parameters, the most important of which is sensitivity and selectivity, which have been the focus of much research to date. Currently available commercial sensors do not demonstrate the level of selectivity required but many novel sensors have the potential to improve performance. Functionalisation of receptor materials has demonstrated improvement in selectivity demonstrating the capability to characterise materials of similar chemical groups, but performance improvements in the presence of many interferents and continuous change in background (e.g., temperature and humidity) would be beneficial.

The focus of this project is to leverage emerging technology in novel sensing such as quantum sensing, polymers or nanomaterials which have the potential to enable sensors to reliably detect and identify tiny amounts of chemical vapours. The realisation of accurate sensing devices would have potential applicability in the early detection and identification of airborne threats.

Approaches should include experimental methods and, where possible, comparison to existing solutions.

Topic 13
Understanding AI enhanced biotechnology risks

Unclassified key words: PNT (Positioning, Navigation and Timing), CNI (Critical National Infrastructure), resilience, threats, risks, mitigation, emergency services, technology.

Unclassified research topic description, including problem statement:
The latest generation of Artificial Intelligence (AI) models have the potential for broad applicability across science, with an associated set of opportunities and risks (Birhane et al., Nat. Rev. Phys., 5, 277-280, 2023). For example, researchers have identified the risk of AI giving enhanced access to dual-use biotechnology tools like DNA sequencing and gene editing, with associated potential for misuse (O'Brien & Nelson, Health Secur., 18(3) 219-227, 2020).

Soice et al. 2023 (arXiv:2306.03809) present a case study investigating the possibility of Large Language Models (LLMs) being used to cause a pandemic, finding they could suggest potential pandemic pathogens to a user, explain how they could be generated from synthetic DNA, supply the details of DNA synthesis companies who might produce the pathogen, and troubleshoot possible problems.

Sandbrink 2023 (arXiv:2306.13952) discuss the risk from Biological Design Tools (BDTs) like RFDiffusion and ProGen2, suggesting they likely increase the ceiling of possible harm from misuse of biotechnology.

Unclassified example approaches:
The researcher will first perform a literature review of a) possible engineering biology security risks enabled by AI (both LLMs and BDTs, but also other model classes), and b) the current landscape of AI safety research, before conducting novel research to identify which security measures are most appropriate to biotechnology and bioengineering AI risks – this is a global problem and the researcher will be expected consider global perspectives and possible global solutions. Possible measures could include novel improvements to Reinforcement learning from human feedback (RLHF), different pre-release evaluation approaches, more reliable DNA screening methods, controlled access/ authentication for BDT use, but the researcher is encouraged to develop new approaches, anticipating how the field may evolve in the future.

Topic 14
Development of techniques to assess data aggregation

Unclassified key words: data aggregation, re-identification, de-anonymization.

Unclassified research topic description, including problem statement:
Problem statement: development of a methodology to enable identification and repeatable assessment of risks arising from the aggregation of data sets. This issue is becoming more acute due to the existing volume of published information about national infrastructure produced at the behest of policy makers and regulators, but without adequate consideration of the potential intelligence value to hostile actors and risks associated with these aggregated information sets.

It is recognized that data aggregation arising from combinations of data sets can result in revealing or allowing the inference of information that is not contained in the aggregated data. For data that may be linked to an individual or groups of individuals, it is difficult to measure re-identification or de-anonymization risks that may arise in ways that are both general and meaningful. For data relating to physical assets, it can be difficult to assess what can be inferred about the criticality or sensitivity of the assets and their associated infrastructure.

There have been several publicized examples of anonymized data being de-anonymized enabling the identification or re-identification of individuals and locations. At present there is no published guidance defining how to assess the potential consequences of data aggregation, nor are tools available that allow testing or formal evaluation of combined data sets prior to their publication or disclosure.

While there is some understanding of the issue in respect of personal and travel data, the concept is poorly understood with regards to asset data, particularly relating to infrastructure assets, where factors such proximity, interconnection, and interdependence can create criticalities. A complicating factor with infrastructure data is the need to understand not only the geospatial relationships but also the significance of facilitating the disclosure or inference of links between sensitive or potentially sensitive physical assets/sites and the infrastructure that supports them.

Unclassified example approaches:

Examples of potential data aggregation threats include:

- Identity disclosure – associating individuals with specific records and/or locations which may arise from insufficient de-identification, re-identification by linking data from two or more sets, or from pseudonym reversal.
- Attribute disclosure – identifying an attribute in a dataset held by a specific individual, group of individuals, or by asset(s) with high probability, even if the data associated with the targeted entities are not identified.
- Inferential disclosure - making an inference about an individual, group of individuals, location(s) or asset(s) with high probability, even if the targeted entities were not in the dataset prior to de-identification/anonymization.

The latest draft of NIST SP 800-188 - *De-Identifying Government Data Sets* (https://doi.org/10.6028/NIST.SP.800-188) provides some background to the issue and an extensive list of references. The proposed research would build upon this to develop methods and, where practical, tools to assist users to identify and address potential aggregation issues.

Topic 15
Utilizing a modern mobile to provide a level of TSCM capability

Unclassified key words: TSCM, mobile phone, tablet, discrete.

Unclassified research topic description, including problem statement:
Current Technical Security Countermeasures (TSCM) tools are various, expensive and a range of physical sizes. All of them together make a useful tool set, but there are operational challenges such as logistics, ease of use, and discretion that are presented in their application.

The modern mobile platforms – i.e., mobile phones and tablets – are a high specification computer processor with a variety of measurement and communications sensors and transducers. These can be exploited to measure the physical world and collect information and measurement data equivalent to the TSCM tools, in a single device.

We are looking to find out how the sensors on a mobile phone (accelerometers, cameras, magnetometers, vibrometers for example) can be used in conjunction with software defined radio to be useful as a tool in monitoring an environmental for technical threats, such as hidden electronic devices.

Key questions – can a phone be used as a TSCM tool to detect hostile threats? Secondly, how effective is that tool when compared to the specific equivalent TSCM tool. Additionally, what are the benefits of collecting data simultaneously and aggregating it at scale?

Unclassified example approaches:
- Downloading and comparing commercial applications for example wifi scanning and ranking for performance.
- Utilizing a bespoke overarching application to manipulate and leverage the commercial applications.
- Utilizing external peripheral devices to exploit sensing not native to the phone. Infrared camera, lenses, borescopes, microphones.
- Utilizing a bespoke overarching application to manipulate and leverage the commercial applications.

Topic 16
Simulation of emerging sensor technologies

Unclassified key words: edge, IoT, cloud, compute, neural networks, post-CMOS, machine learning, cybersecurity, green AI, sensors, emerging technologies, simulated environments, modelling, imagery, audio, magnetic, RF, motion, quantum sensors.

Unclassified research topic description, including problem statement:
Scientific and engineering advances in areas such as quantum, photonic and manufacturing techniques are creating opportunities for the development of new types of sensors which may create as-yet unquantified opportunities (and threats) for the IC trying to operate in environments where currents sensors are ineffective.

For most use cases traditional methods of gathering environmental data from the commercial world are very mature, such as light (imagery/photos/video), pressure (audio), magnetics (object detection), RF, and motion (accelerometers and gyros). Capability upgrades are mostly in the processing of the output, not the sensing itself.

There are however still several areas where current sensors fail to gather useful information:

- Non-illuminated ultra-low light imaging.
- Speech detection in high noise, highly reverberant environments.
- Position in GNSS-denied environments.

The aim of this research topic is to investigate the use of simulated environments to quantify/qualify the effectiveness of novel sensing methods in environments where current sensors are ineffective.

Unclassified example approaches:

- Create a scenario within a simulated environment, model novel sensor techniques and quantify.
- Using information on novel sensors that can detect faint objects, or detect without the photons even hitting the object.
- Gravimetry sensors used to passively detect objects underground.
- Increase sensitivity of GPS receivers.

We are not overly prescriptive as regards solutions; all techniques are welcome. We are, however, looking for methods which could be practically used as technique matures.

Topic 17
The influence of air quality on cognitive performance and behaviour in secure environment

Unclassified key words: carbon dioxide, building environments, cognitive performance, memory, decision making, psychology of security breaches.

Unclassified research topic description, including problem statement:
The Foreign, Commonwealth & Development Office (FCDO) owns a complex global estate of buildings. Each building has its own unique qualities and they are located in major cities where poor air quality is a factor. The buildings are designed in a way to maximize security and often overlook the human factors associated with their users and how these users interact with their workspace.

It is well documented (Lowe et al, 2018), that when human beings breathe in air with increased levels of Carbon Dioxide (CO_2), the CO_2 levels in our blood increases, meaning the blood is less oxygenated and this impacts how our brains function. In turn this can lead to poor memory, impaired concentration and reduces our decision-making capability. Current research has not examined the specific impact this may have upon analysts or individuals who work in security environments. Often the solution is not merely introducing air conditioning and other building information management systems to regulate these secure areas. We have not taken into account the impact of exposure to pollutants and poor air before we even arrive at our place of work.

We would like some empirical evidence to be gathered to demonstrate the impact of decision making and concentration on tasks of varying complexity in enclosed spaces where there are enhanced levels of CO_2 in the atmosphere. These tasks should be undertaken by individuals AND small teams. Ideally the activity should examine tasks that involve making decisions based upon written information AND more mobile activity such as conducting security inspections (and creating reports afterwards). We would also like to study whether there is an association between air quality and the number of security incidents, for example, people not adhering to the security protocols of a building and inadvertently causing security breaches. We would like to compare individual behaviour with that of group behaviour. We would be interested to know about any other airborne particles that could impact human performance in an office space.

The research will help us better design secure environments and provide optimal workspaces for individuals who spend prolonged periods in secure spaces. It will inform security policy and guidance.

Unclassified example approaches:

- Inhalation of air with increased CO_2 levels leads to poor cognitive functioning.
- The impact of pollution on human respiratory systems.

Possible future impacts of elevated levels of atmospheric CO_2 on human cognitive performance and on the design and operation of ventilation systems in buildings - Robert J Lowe, Gesche M Huebner, Tadj Oreszczyn, 2018 (sagepub.com).

Topic 18
Using homomorphic encryption for machine learning on sensor data and privacy

Unclassified key words: homomorphic encryption, machine learning, Internet of Things, sensors, privacy of data.

Unclassified research topic description, including problem statement:
The concern and need to protect data and privacy continue to grow. Over the years, fully homomorphic encryption (FHE) has emerged as a possible solution and offers defence mechanisms that allows computations to be performed directly on encrypted data while maintaining confidentiality. However, high computational complexity on large ciphertexts had limited the capability for FHE to be leveraged. To address these challenges, there is a need for cryptographic accelerators that can expedite real-world application deployment. Thus, the objective of this project is to design and optimize the homomorphic encryption algorithm to enhance data sharing and confidentiality.

To accomplish the research objective, there is a need to develop a framework that leverages the benefits of homomorphic encryption (HE), and machine learning (ML), to protect information during data collection and sharing process against potential attacks such as data collected from supervised devices such as sensors, network flow, and camera systems that are encrypted using HE schemes.
Machine learning (ML) as a cloud-based service is growing rapidly and the growth of Internet-of-Things data have given rise to a significant concern for monitoring systems while maintaining the security of data during ML inferences. Cryptographic accelerators may reduce the computational burden of homomorphic functions, enabling faster and more efficient computations on the encrypted data. The proposed approach will advance new theories and methods for effective and efficient defence processes involving homomorphic encryption, ML, and optimization of data sharing and privacy.

Unclassified example approaches:
Develop a software architecture for integrating FHE into networks to collect data from devices such as sensors and sensing and camera systems.

- Provide a proof-of concept by developing a small data base using the software architecture.
- Implement the software design using simulated or real sensor arrays feeding FHE data to an encrypted data base where ML operations will be executed.
- Deliver a report that compares the results to the same data created in an unencrypted environment and demonstrates essential equivalence of the machine learning process and outcomes.
- Prepare a user-friendly set of tools and rules to apply homomorphic encryption to the problem of machine learning and privacy preservation.
- Explore how the FHE will perform at scale with large datasets/changing of resources and demand on the system.

Topic 19
Developing techniques to enable analytic teams to make accurate judgments

Unclassified key words: reasoning, informal logic, rational discussion, expert disagreement, expert elicitation, human-computer interaction, argumentation, cognitive psychology, Artificial Intelligence.

Unclassified research topic description, including problem statement:
Humans solve many cognitive problems better when they talk with one another than when they work alone. A rich tradition in psychology has demonstrated that that the benefits of group work are far greater than most people think and that they cover a great range of problems, from classic reasoning problems to real-world tasks. Recent research has found that disagreeing parties who engage even in brief discussion often substantially increase the accuracy of their answers. Chen (2019) used a structured discussion method to increase the rate of correct answers from 67% to 98.8%. Schaerkermann (2018) found that discussion among disagreeing workers leads to substantially higher accuracy than non-discussion- based aggregation techniques.

Research is needed to develop effective techniques that would further improve discussions, particularly between people with initially differing answers to complex, real-world problems. The techniques would enable online or in-person groups of people to rapidly make accurate analytic judgments on a wide range of questions, including but not limited to forecasts. The techniques should be easy and natural for busy professionals to use on the job. They should require no formal training or knowledge of logic. The software interface should be self-explanatory.

People with doctorates in these disciplines are particularly encouraged to apply: philosophy, cognitive psychology, informal logic, reasoning, and computer science (particularly AI/ML and human-machine teaming).

Unclassified example approaches:
- Techniques that make it easier for participants to acknowledge that their initial answer was incorrect.
- Methods to help people discover the sources of their disagreements more rapidly.
- Human-machine teaming that enables people to articulate their reasoning more clearly.

Topic 20
Quantum engineering for quantum sensors

Unclassified key words: quantum, quantum engineering, quantum sensors, atomic sensors, machine learning, control theory, quantum control, signal processing, enabling technology for quantum sensors, magnetometer, gyroscope, accelerometer, gravimeter, atomic clock, atom interferometer, NV diamond.

Unclassified research topic description, including problem statement:
This topic is about using quantum engineering to make quantum sensors easier to build and operate, both in the laboratory and in the field. Quantum sensors are devices that encode a physical quantity into a few quantum states of the system- for example, atomic magnetometers, atom interferometer gravimeters, atomic clocks, NVD magnetometers, and so on.

Quantum sensors may optionally utilize non-classical states to increase their performance. As quantum sensors become more sensitive and accurate, a key remaining challenge is to make them more practical outside of the laboratory. They need to be easy to operate, fast to turn on, robust against vibration and thermal changes, small and low power. The emerging field of quantum engineering can address these problems by applying standard and new engineering techniques to quantum devices.

Unclassified example approaches:
Example approaches will depend on the maturity of the quantum sensor and its intended application environment. Some interesting directions include (but are not limited to) using machine learning techniques to simplify the user experience, using quantum and/or classical control techniques to increase robustness against noise, employing digital signal processing algorithms to increase sensor speed or improve accuracy, and applying advanced packaging techniques to reduce sensor size. These techniques may also be used to improve the performance of enabling technologies for the quantum sensor, such as lasers, photonic integrated circuits (PICs) or photon detectors, but the proposal should then include the use of these enabling technologies in an actual quantum sensor. Proposals may include work on theory, modelling, or algorithms, but must apply these to a quantum sensor in the lab during the first year of the effort.

Topic 21
Materials informatics for rapid and efficient design of new systems

Unclassified key words: materials modelling, materials informatics, materials design, rapid R&D, smart manufacturing, reverse engineering.

Unclassified research topic description, including problem statement:
The rapid advancement of materials modelling has given rise to a new field, often called materials informatics or materials genomics. Descended in part from the Materials Genome Initiative, this line of research focuses on connecting the underlying physical and chemical properties of materials to their macroscale properties (i.e., hardness, corrosion resistance, melting temperature).

This information, in turn, can be used to design new combinations of materials to more rapidly iterate through the R&D process and achieve key performance metrics. Oftentimes, materials informatics studies incorporate some elements of machine learning to assist in quickly screening candidate materials and selecting possible combinations. Other key features, like cost and availability, are often considered as well.

This research topic would seek to advance the science of materials informatics through development of improved models, machine learning algorithms, and collection/aggregation of basic materials data. Current models have difficulty capturing the complexity of multicomponent systems under a variety of environmental and operating conditions and are often made via empirical observations and interpolative analyses. This research effort would seek to close these knowledge gaps and work towards development of a more comprehensive system for faster material design.

Unclassified example approaches:
One direction could be to focus on developing an informatics approach to enhance R&D for a specific system- i.e., a database of materials for satellite design. An alternative could be to develop an informatics-based approach to reverse- engineering of systems (i.e., if a component does X, then it could only be material Y or Z). Further approaches can include investigation of materials science properties in an attempt to strengthen current models and expand their use to more complex systems.

Topic 22
Synthetic aperture RADAR automated exploitation

Unclassified key words: synthetic aperture RADAR, SAR, AI, machine learning, computer vision, maritime domain awareness.

Unclassified research topic description, including problem statement:
Maritime Domain Awareness (MDA) is important to security. A key issue to enabling MDA is the ability to detect and classify an object, particularly in open water, in all weather conditions and in a timely manner. While space-based commercial synthetic aperture radar (SAR) could meet most of these criteria there is a high learning curve for human analysis which can require substantial time to analyse a single image. The ability to automatically exploit SAR imagery would facilitate the development of person-on-the-loop (i.e. automated) rather than person-in-the-loop (i.e. manual) approaches to collection and analysis for MDA.

This topic aims to develop algorithms to run over space-based SAR satellite data and provide confidence levels for the classification of any given detection for MDA. The predominant inhibitor to person-on-the-loop approaches to collection, using commercial systems (e.g. tipping and cueing), is the inability to recognise vessels of interest from SAR imagery. The NIC is interested in a scenario where broad-based tracking systems, such as the maritime Automatic Identification System (AIS), provide an overall maritime domain awareness, and then use commercial SAR systems to undertake automated analysis of specific vessels, or monitor specific areas of interest for vessels that are not emitting an AIS signal.

Specifically, automatically exploit SAR imagery to:

- From SAR imagery, recognise to some level of confidence: o a military vessel (at sea) of length 50m or longer. o a fishing vessel (at sea) of length 10m or longer o a commercial shipping vessel (at sea) of length 50m or longer or a military, fishing or shipping vessel (in port or harbour) on SAR imagery.
- Understand at what SAR imagery resolution (or other parameters) detections of different sizes or classes of vessel can no longer be classified to certain levels of confidence.
- Understand the optimal collection geometry and conditions to improve the chance of classifying vessels on SAR imagery.
  - For example, sea state, grazing angle, imagery resolution (IPR), displacement and smearing effects, etc.
- Understand common groups of confusers (vessel classes that are easily confused for each other).
  - For example, vessel classes X, Y & Z are often confused for one another, but are easily distinguished from vessel classes A, B and C.

Desired outputs would include algorithms to perform SAR analysis, as well as an account of the current limitations of such algorithms (e.g. see point 2 above) and exploration of potential future methods to overcome these limitations. Other outputs of interest include the characterisation of vessels that are not transmitting an AIS signal, but are transmitting other signals (e.g., radio frequencies associated with phones, or UHF/VHF radio).

Unclassified example approaches:

It is expected that access to, or development of, labelled SAR datasets will prove challenging. Thus, the first part of any approach will likely involve developing labelled SAR datasets.

Labelled data might be developed using some combination of the following methods:

- Synthetic data (including simulated motion-smearing and other relevant SAR imagery effects)
- AIS correlated with SAR imagery
- Commercial Radio Frequency (RF) signals collection correlated with SAR imagery
- Electro-optical imagery correlated with SAR imagery.

A combination of these methods could be used, for example, focusing on a smaller correlated data set for validation and a larger synthetic data set for testing. A method to develop and implement a confidence rating for different data sources may be useful to mitigate limitations of individual data sets. An option for unlabelled imagery might be to use Sentinel or NovaSAR data, or other commercially available SAR imagery. NovaSAR also has the ability to co-collect SAR and AIS data which could potentially be used to produce a limited labelled dataset.

Following the development of appropriate datasets, multiple modelling approaches might be taken. These will likely be influenced by the size and quality of the available data, but might include:

- Conventional computer vision approaches
- Analysis of pre-image formation data (i.e., SAR phase history data, before it is processed into an image)
- Deterministic/rules-based approaches
- SAR cross section for classification
- Combined approaches using multiple methods to filter detections with increasing confidence levels.

Topic 23
Integrated multimodal facial recognition technologies

Unclassified key words: facial recognition, vision transformers (ViT), machine learning, video sense-making, real time analysis, video multimodal fusion.

Unclassified research topic description, including problem statement:
Facial recognition technology has been a longstanding challenge in the field of computer vision, with existing applications struggling to achieve accuracy in diverse real-world scenarios. Despite recent advances, there remains a need for further research to overcome the limitations of current methods and improve their robustness, particularly in situations where faces are partially occluded, poorly lit, or exhibit varying expressions.

This research topic investigates the use of new models, such as vision transformers, for facial recognition, with a focus on developing techniques to accurately evaluate the confidence of matches and interpret the embedding space. A key limitation of current systems is that they do not scale into downstream use cases as their inaccuracies compound, limiting their applicability. The research might also explore the combination of multiple modalities, such as audio and face recognition, and the incorporation of video data to enhance the accuracy of systems. Finally, the project would examine the potential applications of the developed techniques for other embedding searches, such as sentence embeddings.

Unclassified example approaches:
Proposals are likely to approach this Topic from an applied vision transformers (ViT) perspective. A literature review with respect to facial recognition and recently emerging associated fields could inform experimental work, e.g., AI/ML enhanced ViT, may be relevant.