CYBER-PHYSICAL SYSTEMS SECURITY: RESEARCH CHALLENGES AND OPPORTUNITIES

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Systems Security Group Mission

How do we **build** secure cyber-physical systems?

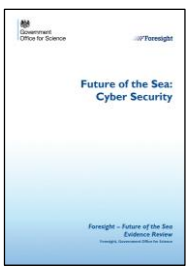
- Essentially, what are the methods for rigorous design, and qualified tools to deliver on such design?
- Once deployed, how do we analyse such systems to detect and monitor for stealthy threats?
- Finally, what national policy instruments are needed to ensure safe and secure operation of such systems?

The primary goal of the group is research excellence across a number of disciplinary themes that converge on the engineering of secure cyber-physical systems for transport, engineering, and critical infrastructure.

Systems Security Group Mission (2)

Research and technological excellence across disciplinary themes.

- Scientific and technological underpinning for CyberOwl technology, providing protective monitoring system for vessels;



- Authored the maritime cyber threat evidence review “Future of the Sea: Cyber Security” for the Government Office of Science (UK);

- Part of the ‘Cyber Readiness for Boards’ initiative to work with maritime boards on cyber risk governance, funded by the UK’s National Cyber Security Centre and Lloyds Register Foundation.

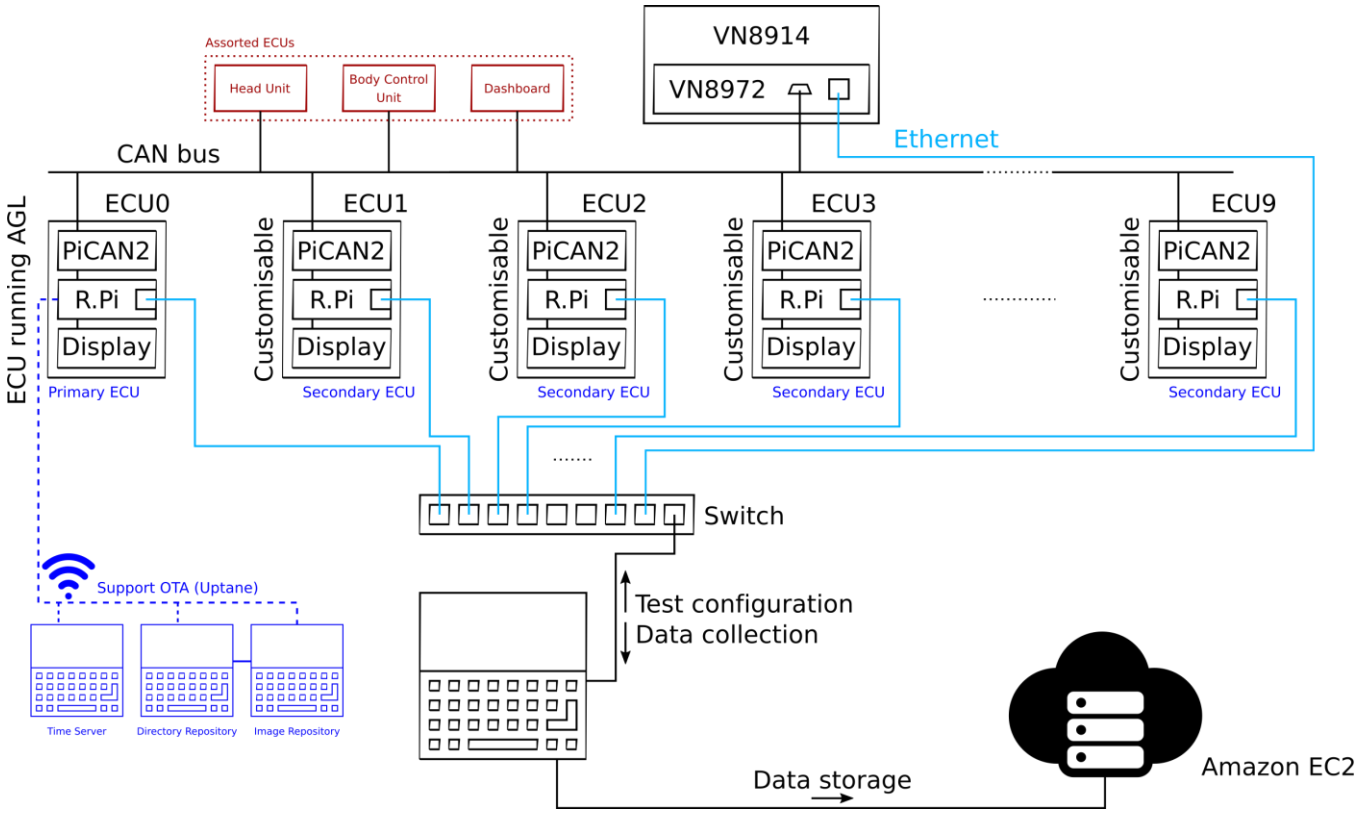
IoT Security Demonstrator (Automotive)

- **The world's first on-chip monitoring solution to rapidly detect cyber security threats in Connected and Autonomous Vehicles (CAVs)**
  - **UltraSoC Technologies** offers in-silicon modules for unparalleled and unique insight into what's happening inside a chip.
  - Machine-learning experts from **University of Southampton** will develop algorithms and code to intelligently identify security and safety issues both on-chip and off.
  - The Systems Security Group at **Coventry University** will develop a testbed demonstrator representing a full-scale automotive functional architecture in which the UltraSoC solution can be proven.
  - **Copper Horse**, a leading cyber security company, will model known and potential cyber-attacks and security test the solution.

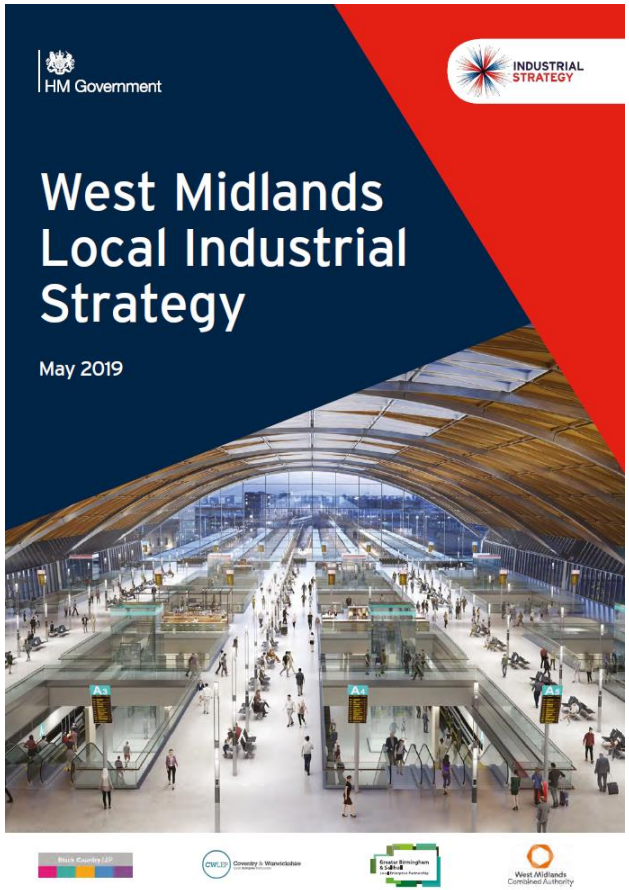
IoT Security Demonstrator (Automotive) (2)

Full-scale automotive functional testbed which:

- Supports multi-bus, multi-component configurations;
- Provide a plug-and-play ECU interface for telematics, sensors, infotainment, in-cabin & body modules as part of test configurations;
- Underpinned by a high-powered multi-core computing for scalable and parallel data processing and analysis, with a cloud-supported interface at the backend to allow for elastic storage and computation.



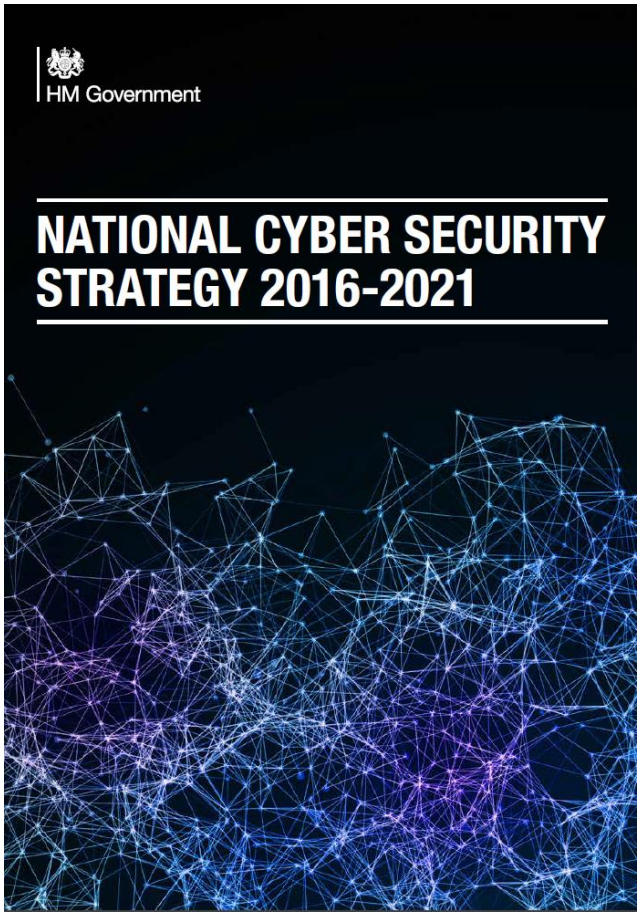
Systems Security is a (UK) Regional Priority



"Changes for which the West Midlands is well placed to take advantage include AI, automation, cyber security and machine learning."

- West Midlands Local Industrial Strategy
- Published in May 2019
- Future of mobility identified as a major new market;
- Transport technology, rail, automotive and innovative supply chains identified as key sector strengths;
- Infrastructure as a foundation of productivity;

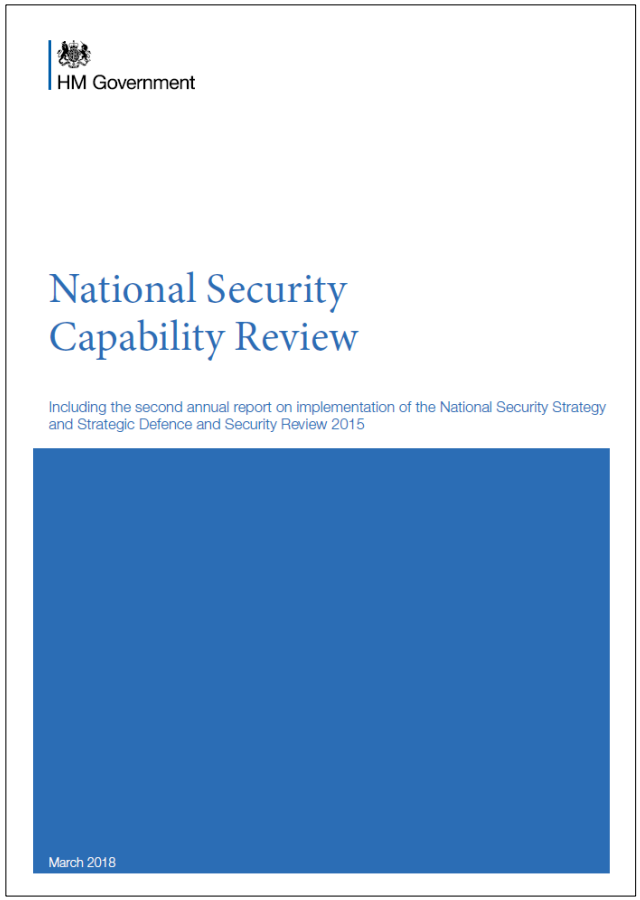
Systems Security is a National Priority



"Systems and technologies that underpin our daily lives – such as power grids, air traffic control systems, satellites, medical technologies, industrial plants and traffic lights – are connected to the Internet and, therefore, potentially vulnerable to interference."

- National Cyber Security Strategy (November 2016)
- It acknowledges UK's critical national infrastructure and industrial control systems are threatened;
- A commitment to develop an innovative, growing cyber security industry, underpinned by world-leading scientific research and development.

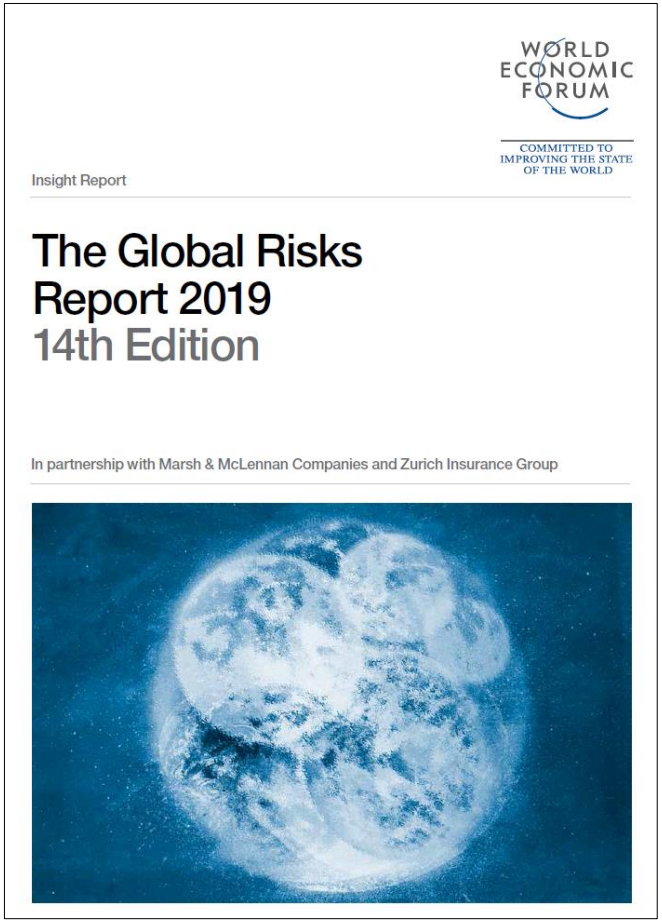
Systems Security is a National Priority (2)



"In an environment where major threats are largely technologically driven, so too must be our response."

- National Security Capability Review (March 2018)
- National resilience involves the effective coordination of capabilities and approaches;
- The government is committed to
  - Integrating economic goals and capabilities throughout national security;
  - Ensuring our development capability responds to changes in national security challenges.

Systems Security is a Global Priority



Global Economic Risk: "Failure to adequately invest in, upgrade and/or secure infrastructure networks (e.g. energy, transportation and communications), leading to pressure or a breakdown with system-wide implications."

- World Economic Forum's Global Risks (January 2019)
- Resilient transport infrastructure is identified as a key underpinning to addressing risks arising from environment disasters, rural-urban divide, and food security issues.

“The necessity of procuring good intelligence is apparent and need not be further urged.”

General George Washington
Letter to Colonel Elias Dayton
26th July 1777

Some challenges for maritime cybersecurity..

- **How do we bridge across IT and OT systems?**

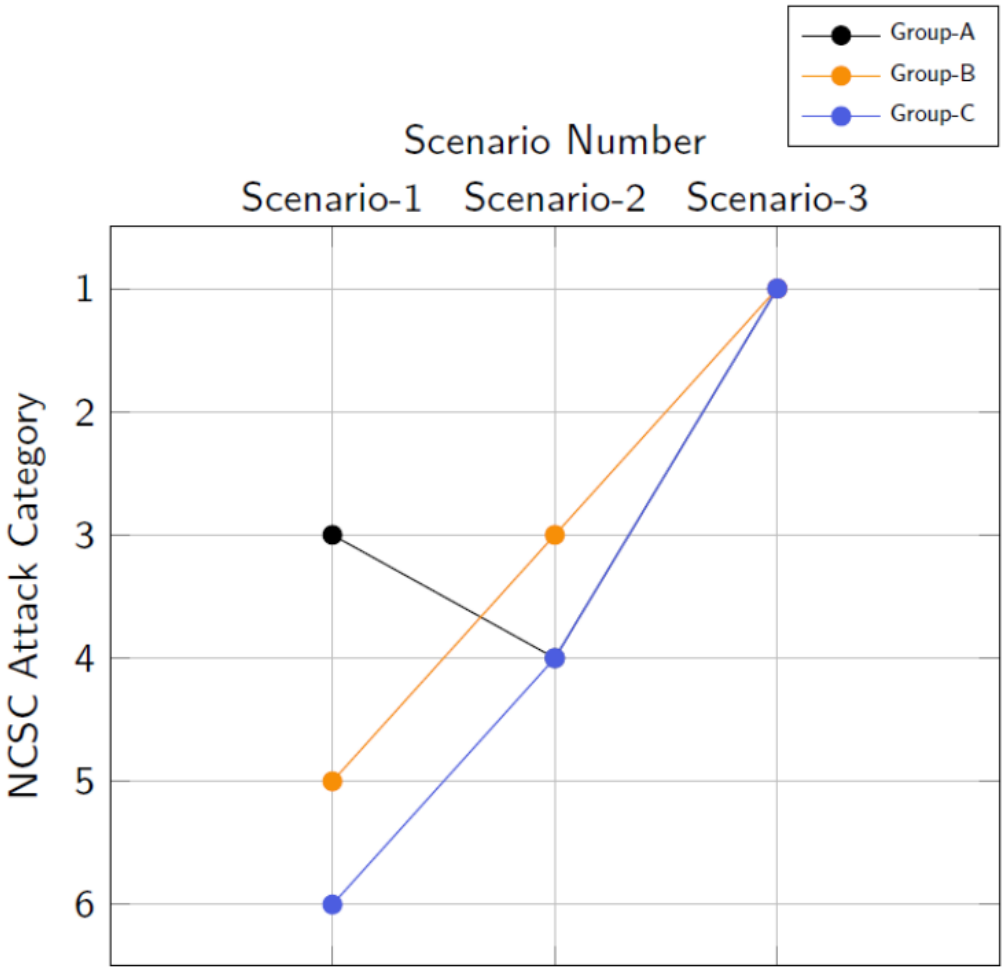
  Example: For planned maintenance systems (PMS) – increasingly integrated with sensors and telemetry across the vessel or an intelligent remote asset management system (iRAMS) – which are often run on on-board workstations, how do we ensure we detect for malicious attempts across our IT/OT systems?

- **How do we detect cyber incidents?**

  How effective is our current situational awareness and actionable intelligence capability? Typical malware dwells in the target system for well over five months (FireEye). Supply chain infiltration means that vulnerabilities remain hidden and threats remain stealthy.

Lessons from other sectors (automotive industry)

- We have run a policy game with cyber analysts to understand threat assessment and risk perception
- Three escalating scenarios, from keyless theft, to remote telematics hacking, to autonomous vehicle ramming attacks
- NCSC attack categorisation goes from local incidents (6) to tier-1 threats to the nation (1)



Monitoring challenges for cyber-physical systems

- As opposed to layered enterprise systems, such systems…
  - are assembled in a component-driven bespoke fashion, where attack signatures are not obvious;
  - where design is asset and process centric, with critical functionality earmarked.

- Learning on behaviours on data/io and traffic/interface is not straightforward because…
  - diverse data domains, where malicious behaviours are predicated across multiple domains of learning;
  - baselining across multiple domains for threat anomalies is a challenge for current generation of ML/AI.

Where do we go from here?

- A different monitoring approach is needed where…
  - Asset-sensitive health indicators, both at local and system level, need to be identified
    - Indicators, atomic in nature, falling under early phases of kill chain, are the core;
  - Risk-sensitive approach to monitoring to detect for threshold violations.
  - Aim is not to signature-detect or rule-match but to detect
    - Potential physical safety violations (physical assessments are key therefore);
    - Potential cyber safety violations (in terms of data-flow or control-flow violations).
- Domain-agnostic early-stage threat estimation for risk profiling
  - Low-tier sensor alert processing (reducing cognitive load) to direct human-in-the-loop decision making;
  - Automation of risk-sensitive low-level orchestration (in case of an ‘active’ early warning system).

We need a shift to..

Shift 1

- From attribution to early warnings: towards protective monitoring of assets

Shift 2

- From signatures to indicators and symptoms: looking for ‘unknown unknowns’
  - Needs to be achieved through horizontal integration across purpose-built sensors needs to aggregate on multi-domain visibility.

Shift 3

- From isolated predictions to system judgements: alerts and indicators to aggregated threat estimation
  - Human-in-the-Loop decision cycles, underpinned with risk-sensitive active defence.

Thank you