Assessing C2 System Vulnerabilities in Underdeveloped, Degraded and Denied Operational Environments

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Content outline

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- **Command and Control**

- **Degraded and Denied Operational Environments**

- **Cognitive Work Analysis**

- **System Dynamics**

- **Example – Border Safeguarding**
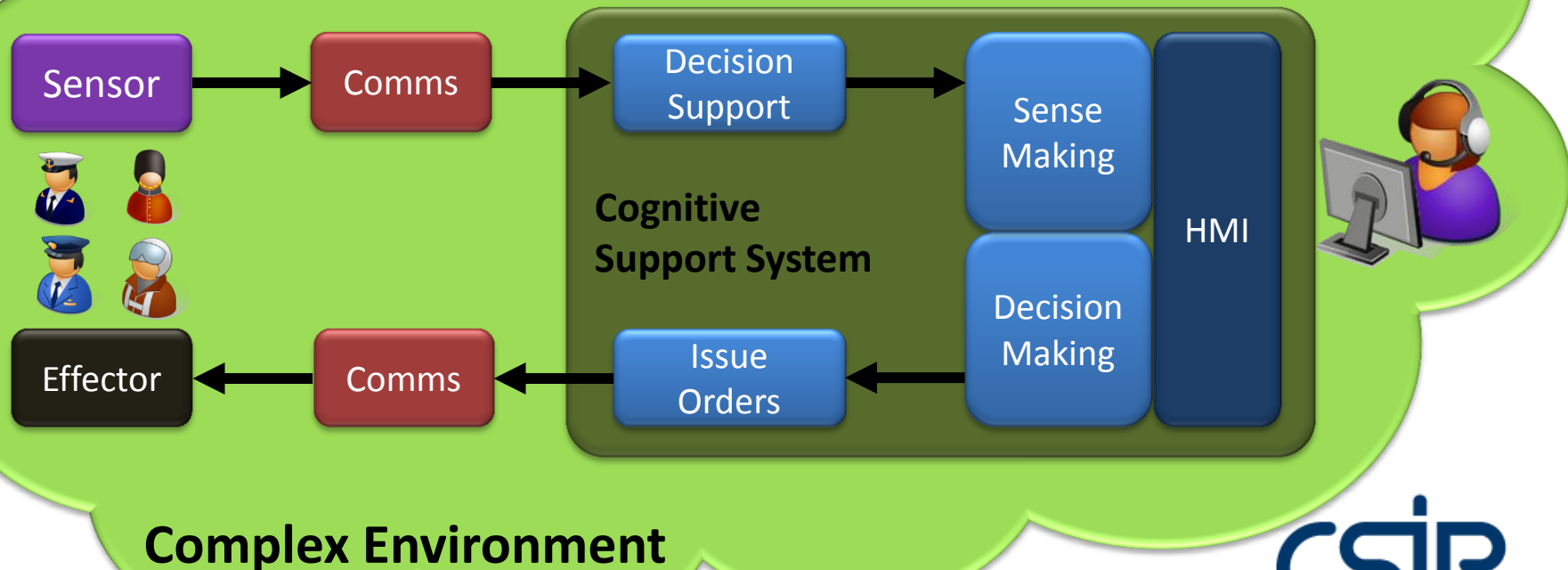
- **Conclusion**

Introduction

- C2 is a complex sociotechnical system
  - Humans part of the C2 system, make sense of the situation to support decision making

- In underdeveloped, degraded or denied operational environments systems may fail
  - The effect of lost capabilities on work may not be clearly understood
  - Humans have ability to adapt in the absence of some technical supports

- Adverse conditions to be considered in design and development of C2 systems

- Cognitive Work Analysis (CWA) and System Dynamics modelling and simulation provides a framework for analysis

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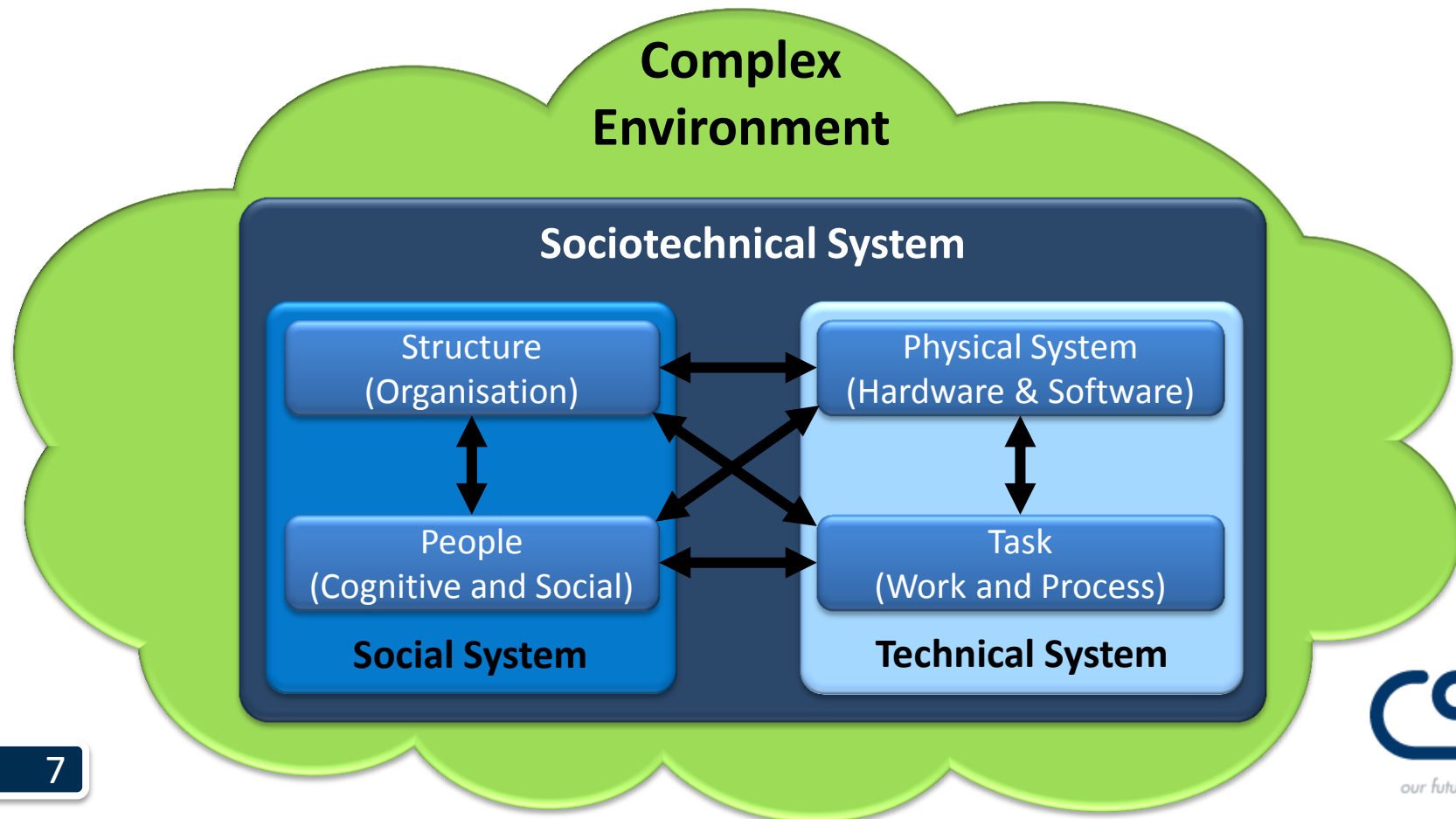
Command and Control System

- The purpose of C2 is to bring all available information and assets to bear on an objective to ensure the desired effects

- C2 system is integrated within larger military system to support decision making

- C2 support making sense of complex situations
  - Situation awareness of what has happened, is happening and may happen

- C2 is iterative and cyclic process with continuous updating of decisions as the situation change
  - Control through feedback of actions and information from sensors
  - Delays present complex dynamic problems
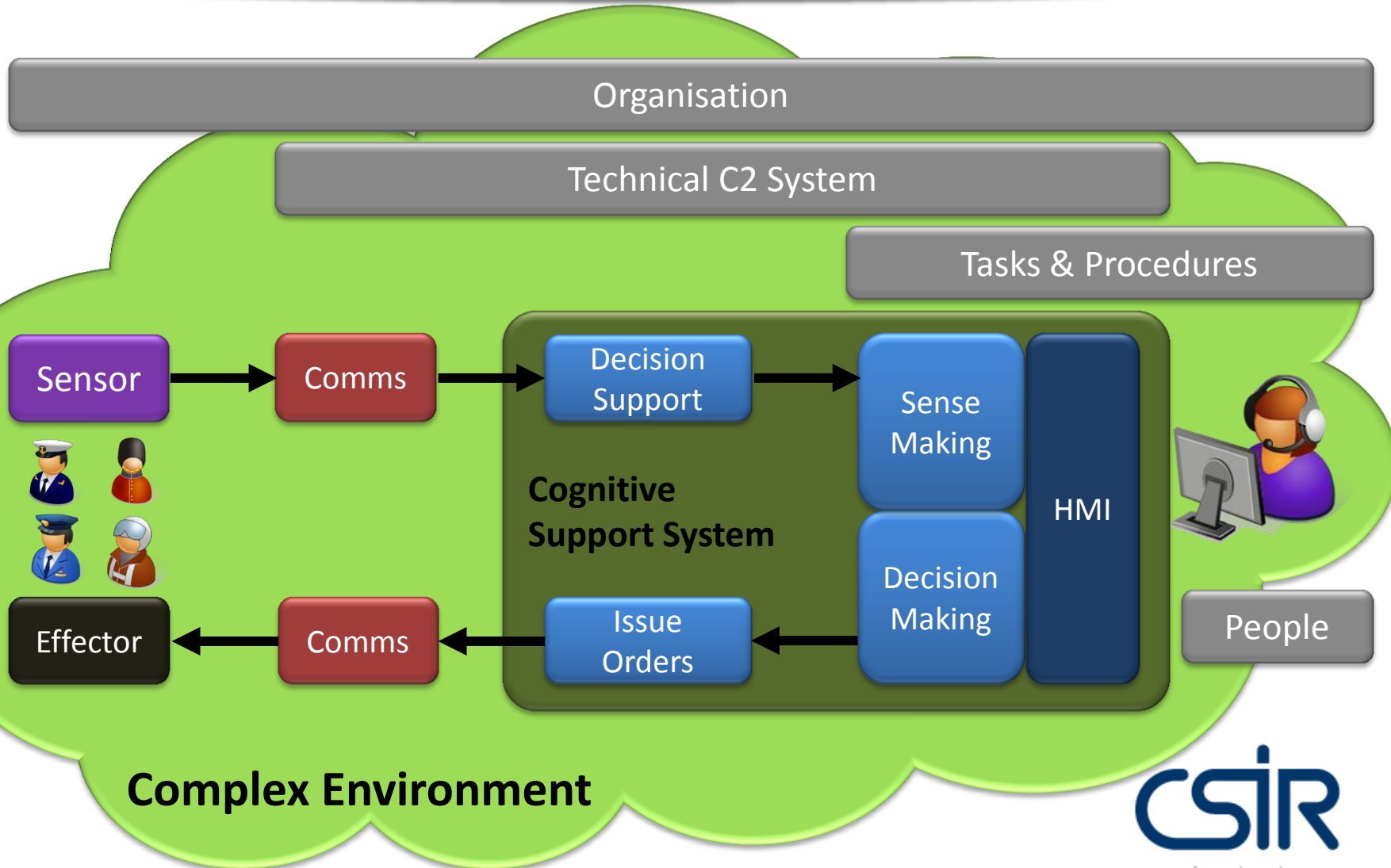 - C2 is hampered through loss of communication

Command and Control as Complex Sociotechnical System

- C2 is a sociotechnical system
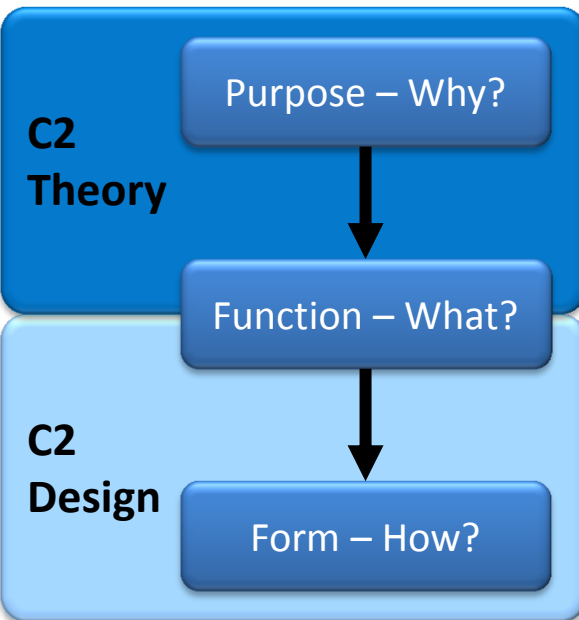 - Equipment and people organised in a structure to execute tasks

Command and Control as Complex Sociotechnical System

Command and Control as Complex Sociotechnical System

- Combat is a complex system
  - Opposing forces influence successful execution of plans
  - Environment with uncertainty, risk and time pressure

- Law of Requisite Variety
  - Variety of states within C2 must be similar to the combat it control
  - C2 must be a complex system

- The C2 system requires agility
  - Cope with changes to enable the solving of complex problems
  - Responsiveness, versatility, flexibility, innovativeness and adaptability

- Harness ability of human operators for agility
  - Enhance versatility, flexibility and adaptability in use of technical artefacts

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Command and Control Analysis and Design

C2 Theory

| Purpose – Why? |

↓

| Function – What? |

C2 Design

↓

| Form – How? |

- Consider Purpose, Function and Form levels of design
  - Means-to-ends relationships of why, what and how

- C2 is "Function" of military system is to produce effects through the direction and coordination of resources
  - "Purpose" of C2 is direction and coordination of resources
  - "Function" of C2 include Data Collection, Sense Making and Planning
  - "Form" of C2 include organisation, methods, procedures and technical elements
  - Ability to adapt in the absence of some technical supports

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- C2 system requires information to make sense of the operational environment for planning and control

- C2 system affected when technical elements become unavailable or degraded
  - Criminal or Military Action
  - Forces of Nature
  - Technical Capability and Serviceability
  - Lack of Infrastructure

- Degradation or denial of systems can occur before or during the mission

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Command and Control Analysis and Design

- Classic System Engineering approaches are not suited
  - System Engineering address human as outside of the system
  - Human performance is complex and difficult to predict
  - Depend on fixed and stable system requirements
  - C2 system performance is context dependant
  - C2 is a Complex Sociotechnical System

- Humans have agile and flexible ability
  - Effect of lost capabilities on work may not always be clearly understood
  - Humans can adapt in the absence of some technical supports

- Cognitive Work Analysis (CWA) and System Dynamics (SD) modelling and simulation provides a framework for analysis

- Analyse structure and dynamic behaviour of C2 system

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Command and Control Analysis and Design
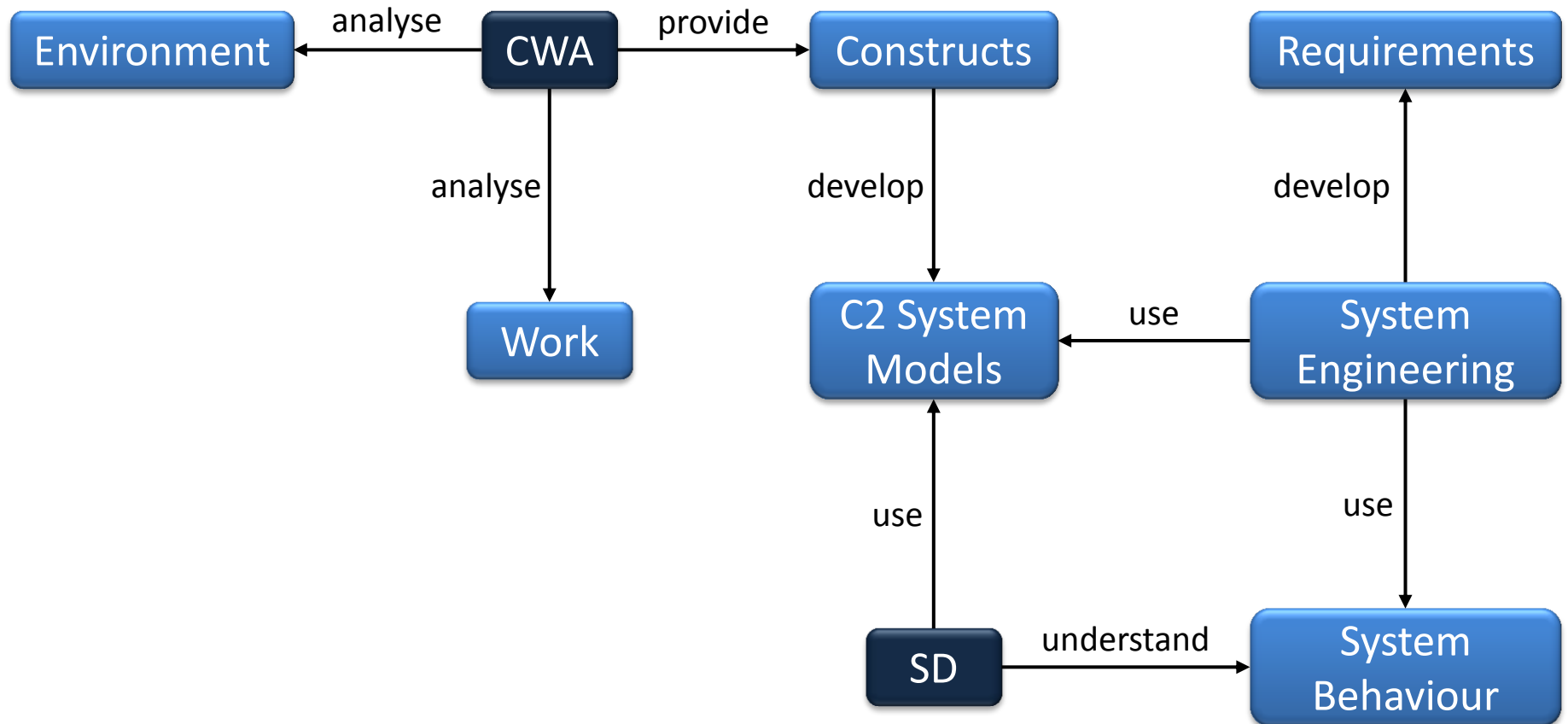
Cognitive Work Analysis

- Based on Systems Thinking, Adaptive Control Systems and Ecological Psychology

- Formative analysis and design of cognitive systems
  - People adapt to changes in the environment to solve unexpected problems
  - Assess C2 system in loss of technical means on ability to achieve the aims

- Define cognitive system information requirements and application context
  - Support cognitive strategies and competencies for in the sense making and decision making process
  - Define the information display and distribution requirements

Cognitive Work Analysis
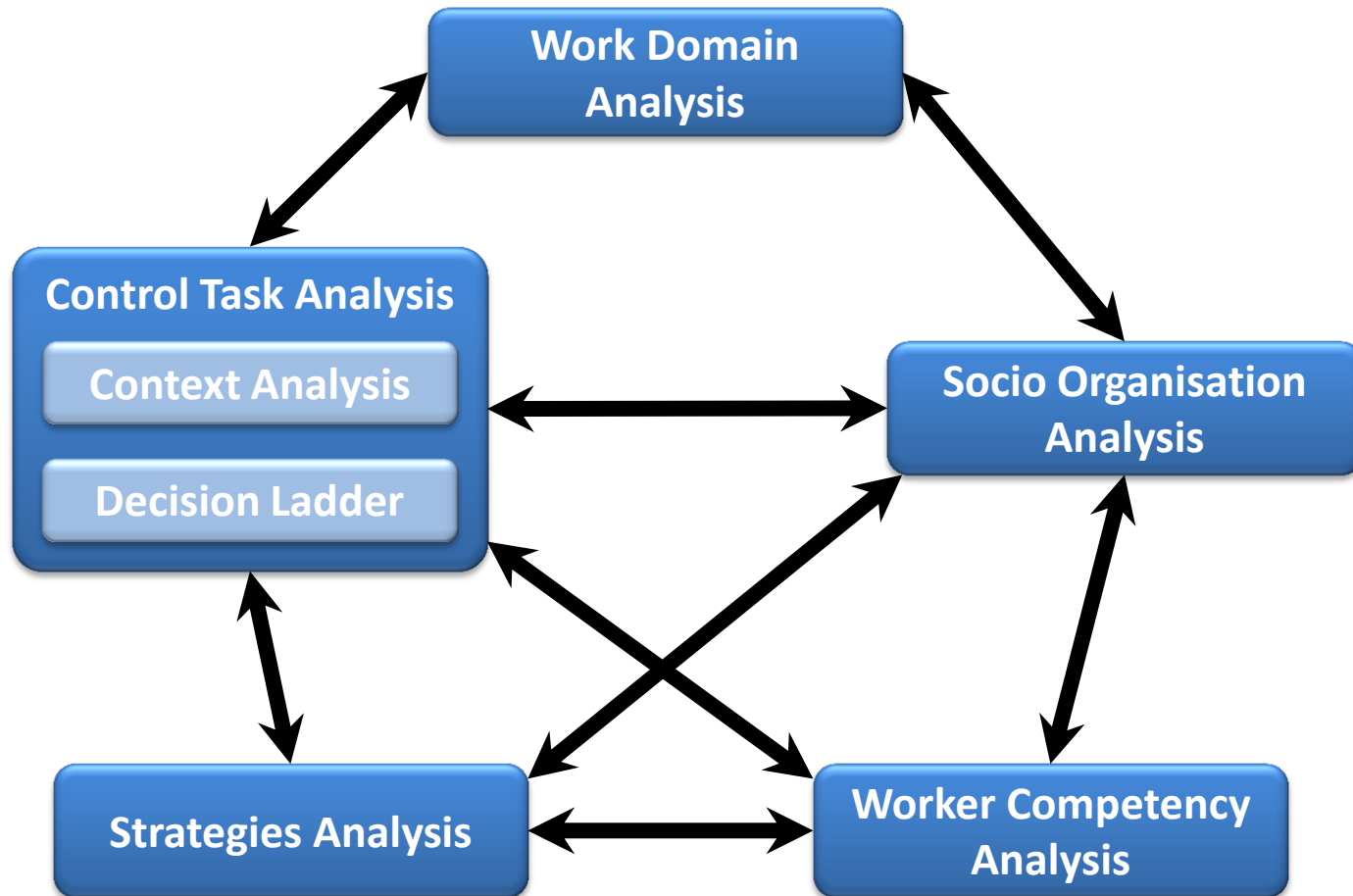
Work Domain Analysis

- Support understanding of the functional and physical structure of the system
  - Assess affect of environmental constraints

- Abstraction Decomposition Space (ADS)
  - Organise and present information and knowledge about a system
  - Identify and model goals and purposes of system relative to ecological constraints
  - Provide constructs and reasoning space (problem and solution)
  - Event independent
  - Integrates a global, top-down view (purposes) with the bottom-up view of physical resources
  - Many-to-many relationships indicate many options for action in order to achieve the objectives
  - Support the means-to-ends analysis required for C2

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System Dynamics

- Learn about the dynamic nature of a system
  - Behaviour is a result of the structure of the system
  - Behaviour is function/action over time
  - SD does not predict future behaviour
  - SD improve knowledge of the underlying system structure

- Feedback in the system causes most of the complexity
  - In simple systems interaction may be complex
  - Delays in decisions and feedback increase complexity

- SD Modelling
  - Causal loop diagrams – Feedback structure
  - Stock and flow diagrams – Physical process of resource accumulation

- SD Simulation
  - Develop mental models through understanding the system

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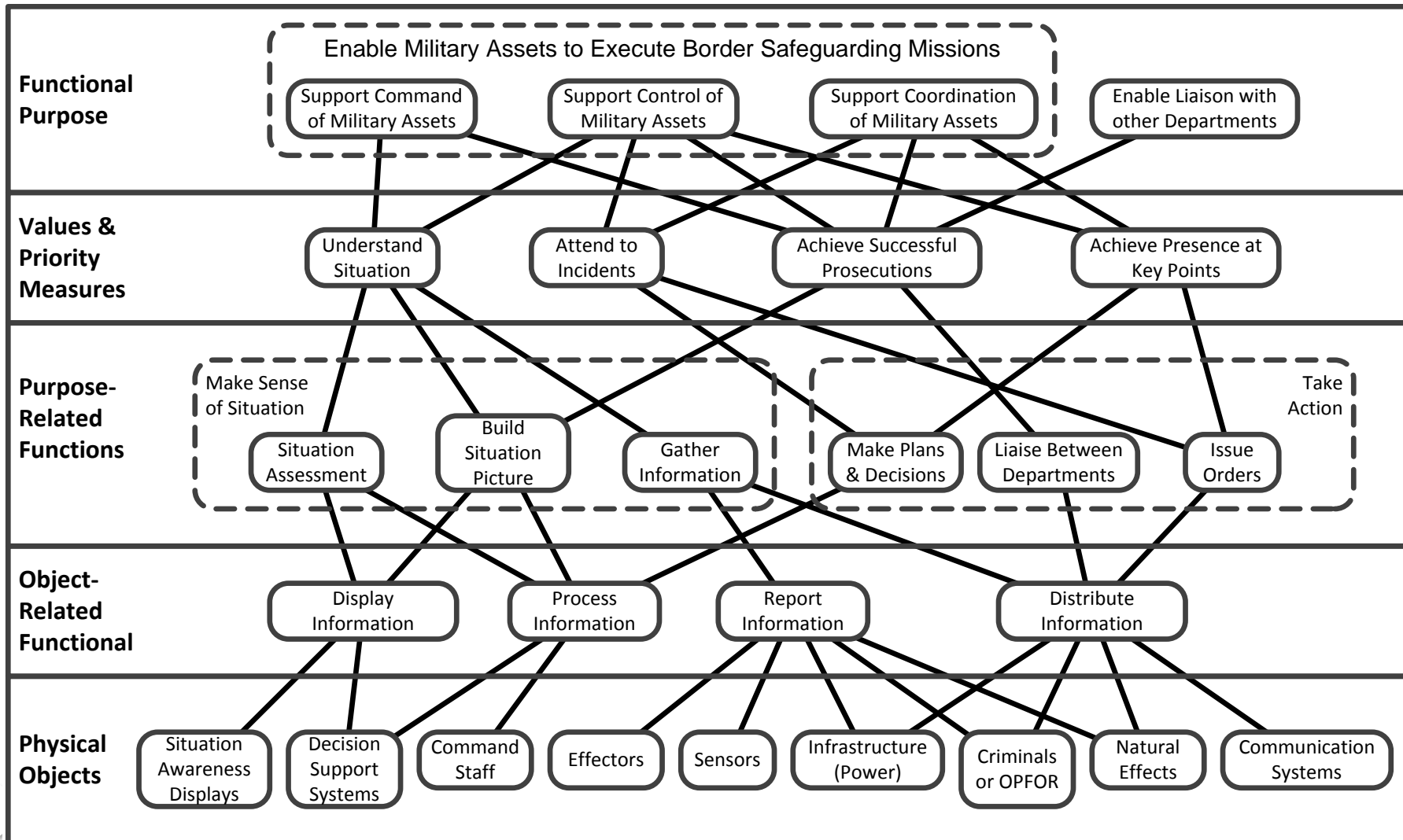
Example – Border Safeguarding (ADS)

- Priorities
  - Cross-border crime such as rustling of livestock
  - Firearms & Drug smuggling
  - Smuggling of stolen and untaxed goods, often part of organised crime
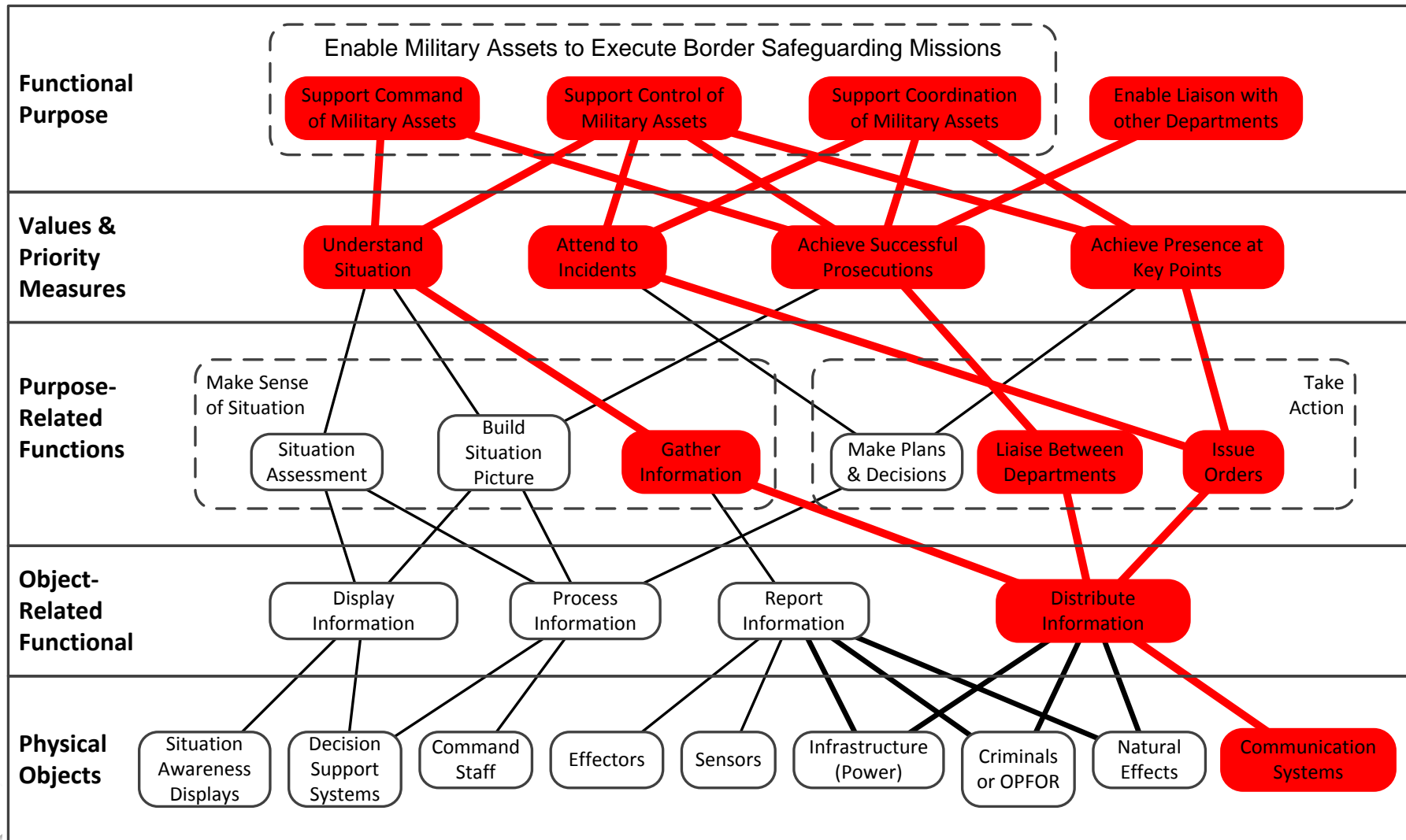 - Illegal immigration
  - Human trafficking

- Tasks and activities
  - Deployment of sensors and barriers
  - Patrols on the border as well as in depth
  - The arrest, transport and guarding of suspects
  - The search of areas or buildings looking for illegal immigrants or contraband
  - The recording of evidence for prosecution
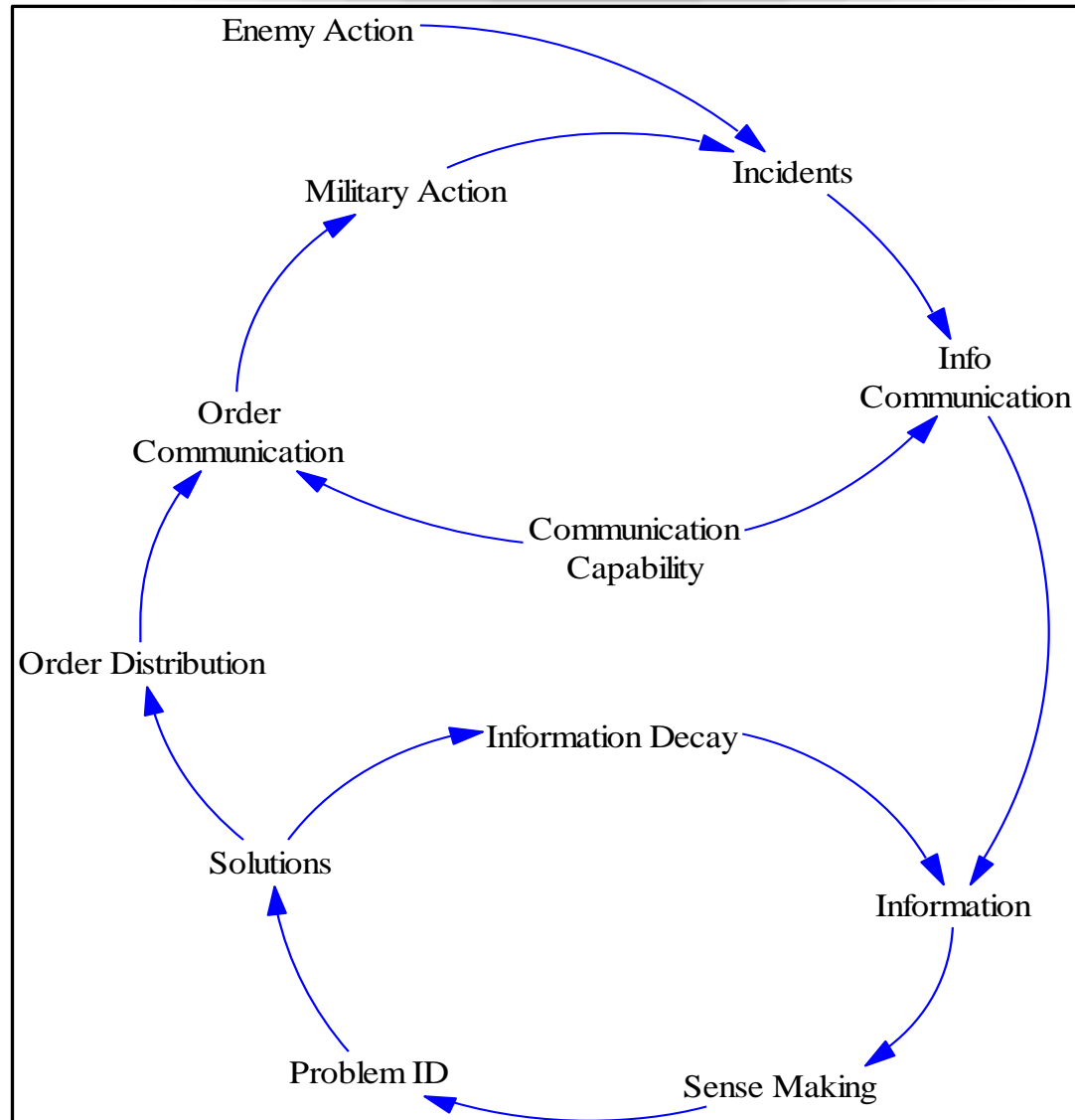 - The seizure of illegal goods

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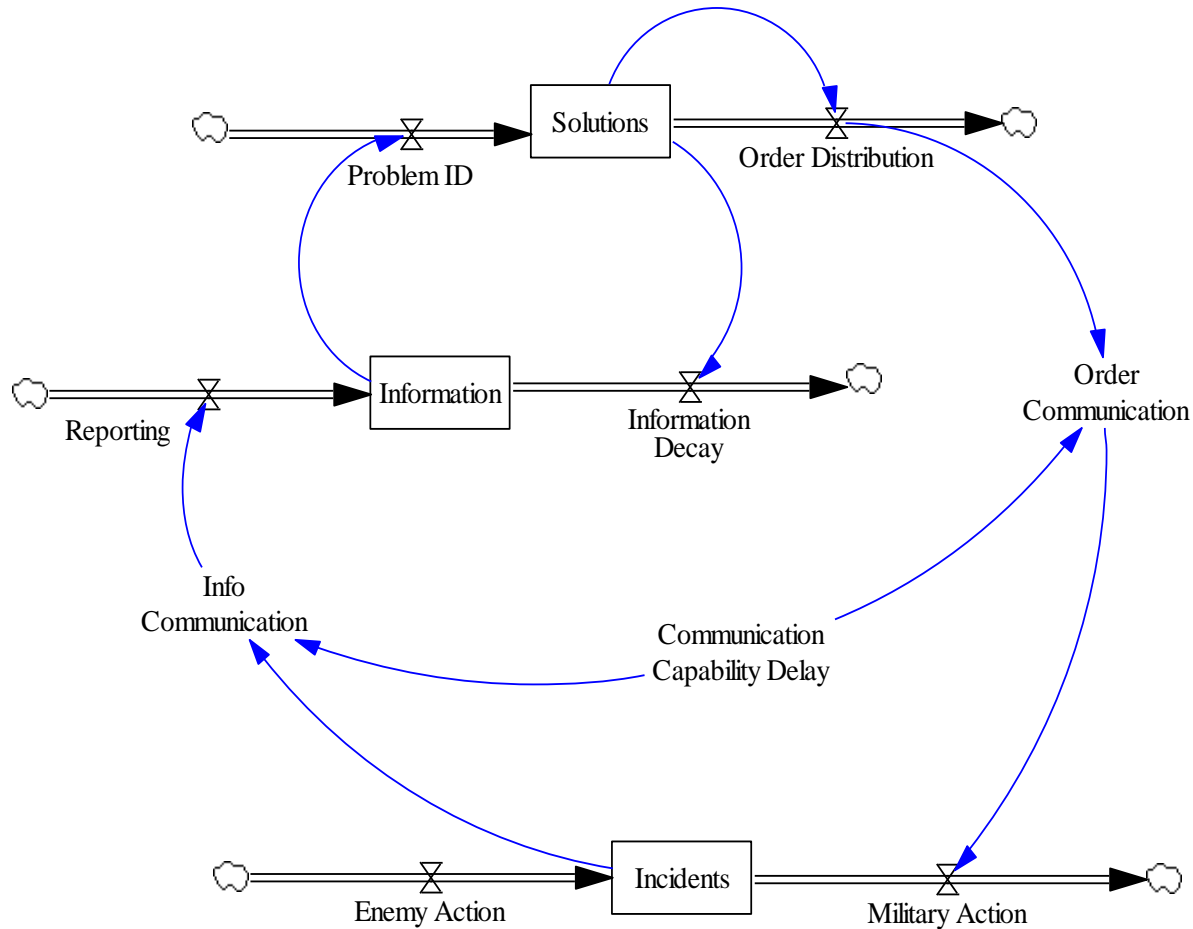
Example – Border Safeguarding (ADS)

Functional Purpose

Enable Military Assets to Execute Border Safeguarding Missions
- Support Command of Military Assets
- Support Control of Military Assets
- Support Coordination of Military Assets
- Enable Liaison with other Departments

Values & Priority Measures
- Understand Situation
- Attend to Incidents
- Achieve Successful Prosecutions
- Achieve Presence at Key Points

Purpose-Related Functions

Make Sense of Situation
- Situation Assessment
- Build Situation Picture
- Gather Information

Take Action
- Make Plans & Decisions
- Liaise Between Departments
- Issue Orders

Object-Related Functional
- Display Information
- Process Information
- Report Information
- Distribute Information

Physical Objects
- Situation Awareness Displays
- Decision Support Systems
- Command Staff
- Effectors
- Sensors
- Infrastructure (Power)
- Criminals or OPFOR
- Natural Effects
- Communication Systems

Example – Border Safeguarding (Output)

- Communication system vulnerability
  - Delays inhibit C2

- Implement alternative communication technologies dependant on different and robust infrastructures
  - Architectures with different routing

- Inform commanders on information they don't have

- Employ different C2 approaches as fall-back
  - Establish proper intent
  - Better use of available information
  - Awareness of information age
  - Autonomous and procedural execution of tasks

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Conclusion

- Effective C2 is required for border safeguarding operations

- C2 is a complex sociotechnical system

- Design and analysis have to consider the human
  - CWA provides models and constructs to assess vulnerabilities
  - SD support assessment of dynamic behaviour
  - Understanding the problems to support system design

- Using these methods to plan field experiments should result in better complex sociotechnical systems

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Thank you

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