TECHNICAL INSIGHTS

COMPLEX SYSTEMS EVALUATION

COMPLEX SYSTEMS IN DEFENCE

The Contemporary Operating Environment represents a hostile complex socio-technical system. Uncertain outcomes, adaptation and emergent behaviours are expected from individual, group and political actors against a backdrop of diminishing resources across the globe[1].

Recent events in Europe and the Middle East have highlighted the unpredictability and volatility of the operating environment. The UK faces a significant challenge to deliver capability that can be responsive to this changing complex environment. The approach outlined here offers an opportunity to evaluate future UK capability (itself a complex system) in potential future operating environments.

WHAT DO WE MEAN BY A COMPLEX SYSTEM?

For our purposes we consider a complex system as one that has:

- Large ***numbers*** of and high degrees of ***variability*** in the elements, particularly if those elements include people.
- Large ***numbers*** of and high degrees of ***variability*** in relationships between elements. The system cannot easily be reduced to a number of distinct subsystems.
- ***Emergent properties/behaviours***[2] that are novel or unpredicted; ie where "the whole is greater than the sum of its parts"[3].
- ***Adaptation***: Elements within the complex system change themselves and their relationships in response to their environment.
- ***Outcome uncertainty***: cause and effect relationships within the system are difficult to establish.
- ***Non-additive effects*** or ***non-linearities***: the combined effect of two or more factors does not equal the sum of the two individual effects.
- ***Sensitivity to initial conditions***: where the same system can exhibit significantly different behaviours from near identical starting conditions.

HOW CAN WE EVALUATE SUCH COMPLEX SYSTEMS?

Traditional evaluation approaches that are focused on cause-effect relationships do not work well for complex systems. Specifically, the emergent behaviours, adaptation and outcome uncertainty in a real-world complex system mean that it may not be possible to predict the outcome and the risks of applying UK capability in a particular situation. In such cases the experiment environment and the real world are just not the same.In recognition of the shortfalls of traditional evaluation methods, Niteworks has recommended an exploration based approach that acknowledges these complex system characteristics[4].

A NEW APPROACH TO COMPLEX SYSTEM EVALUATION: HOLISTIC COMPLEX SYSTEM INTERVENTION[5] EVALUATION (HCSIE)

There are five key ideas behind the approach, as shown below:

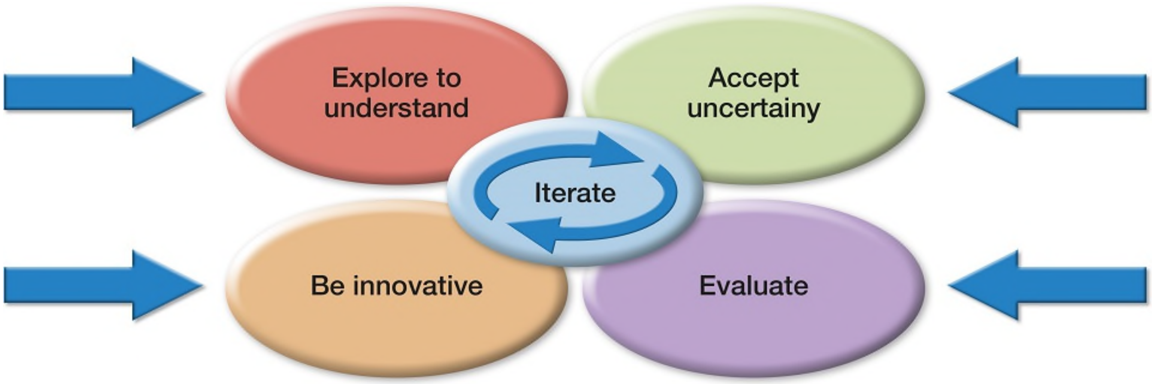

Figure 1: The HCSIE Principles

The fundamental tenet of this approach is iterative exploration of the extent to which interventions can reduce risk and contribute to UK operations. As a predominantly qualitative technique, the insights gained will increase understanding of the potential options available to UK MOD as it determines how to develop capability to deploy to highly volatile operational environments.

Explore to understand

Appreciation of the strategic intent is an essential first step: what has the military capability been asked to do and why? This intent should enable the operational aims and objectives to be developed. It should also establish the Political, Military, Economic, Social, Infrastructure, Information, Physical Environment and Time (PMESII-PT) context for the operational environment outlined in the strategic intent. An assessment of the likely impact of any of the PMESII-PT dimensions should provide a dashboard similar to Figure 2.

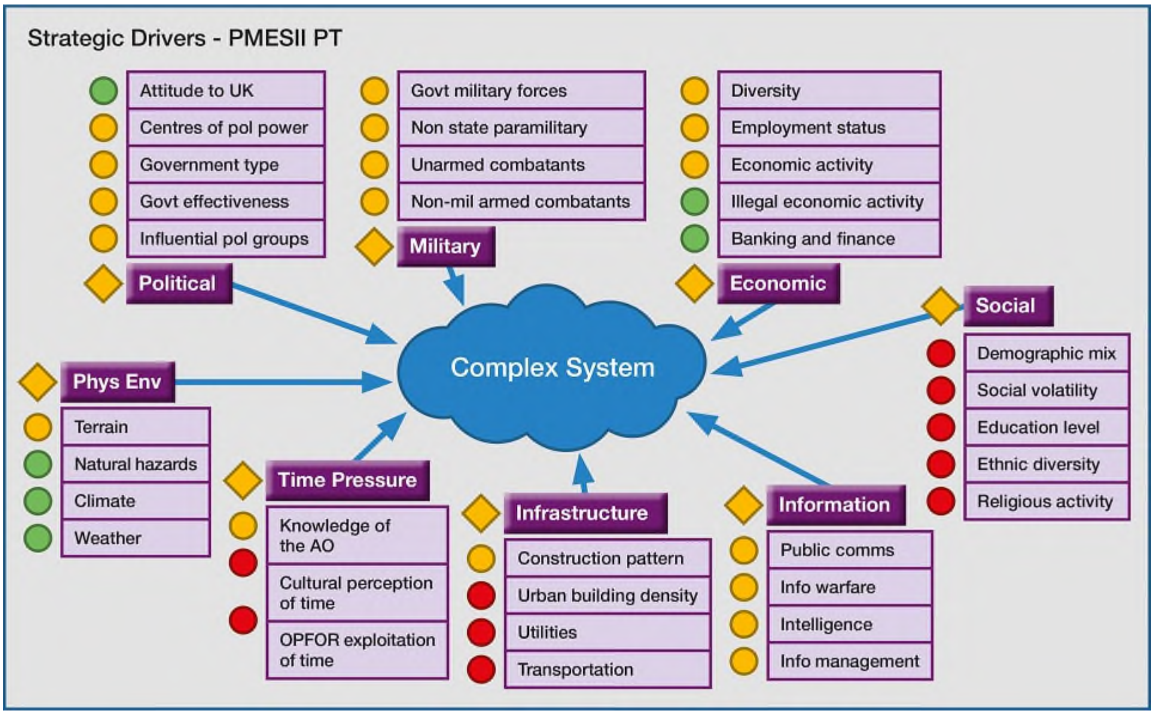

Figure 2: PMESII-PT Strategic Dimensions[6]

The colour coding in figure 2 reflects the areas that may present significant challenge to any UK capability (shown in Red or Amber circles). The diamonds represent a summary for each PMESII-PT factor. For example, indicators of high building density, poor transportation and utilities (shaded red) have led to an assessment of Infrastructure as Red; low education level, ethnic and religious diversity, social volatility and demographic mix have led to an assessment of the social dimension as Red. However natural hazards, climate and weather and the attitude to the UK are positive (shown in Green). The strategic drivers should be determined and captured as in Figure 1 for each operational environment under consideration. This helps provide the wider context and an understanding of the factors that will impact the UK Capability.

With this wider context established, the focus can shift to the UK capability. The capability requirements are described using the Defence Capability Framework (Command, Inform, Operate, Sustain etc) or alternatively the Tactical Functions (Firepower, Mobility etc). These requirements can be ascribed a Red, Amber, Yellow, Green, Grey (RAYGG) value that denotes the extent to which the particular capability under investigation satisfies the requirements (from Red (does not satisfy) to Green (can fully satisfy)[7]. The goal would be to be green against the requirements of the Defence Capability Framework as well as the operational aim and strategic consequence (see figure 3). In the example shown in figure 3 there is a limited amount of green against the requirements and the operational aim and strategic consequences have been assessed as falling short of the requirement.

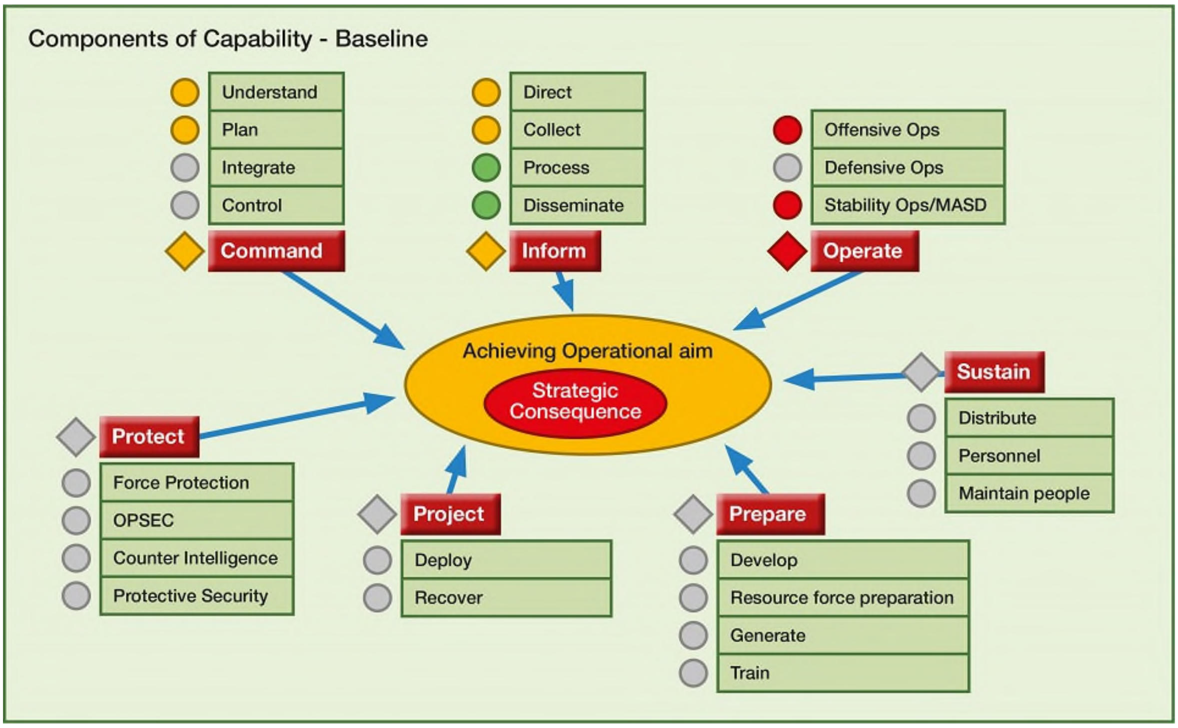

Figure 3: Defence Capability Framework components of capability[8]

Accept Uncertainty

As set out in this paper, evaluating complex systems is about exploring the way in which factors might interact. There is no suggestion in the approach that the specific relationships between factors, or the strength of association between particular requirements, should be mapped out in the same way as one might do for simulations or engineering models. This is because intensive and rigid modelling of the complex system is likely to lead to the wrong conclusions given emergence, adaptation etc. The lack of hard-wiring or direct connection between requirements allows what-if investigations to be conducted; for example, exploring the impact on UK capability if the opposing force was in possession of a new technology (eg increased detection).

This approach lacks a definitive or absolute outcome, however the emphasis on encouraging exploration with uncertainty present is just as it would be in the operating environment.

Be innovative

Interventions should be developed based on the gaps identified from the baseline assessment. Innovation in the identification of interventions is essential to keep up with our adversaries and consideration of innovative interventions (both equipment and non-equipment focused) that are not encumbered by current constraints, whether that be in relation to policy, technology or organisation, is recommended to ensure out-of-the-box thinking. Interventions should however be considered on a case by case basis as often the solution in one context might not be applicable in another.

Evaluate

The complex system should be evaluated with interventions applied to understand their contribution to capability. A fail-fast approach should be used that seeks to promote interventions that have promise and identify those that currently do not;

such an approach should prioritise those interventions that have greatest applicability. As in the baseline assessment, an estimate is made of the contribution of the intervention to the baseline to satisfying the requirement. This is about evaluating the whole system and not just component parts, particularly in relation to the achievement of the operational aim and the strategic outcome or consequence. The dashboard of the baseline capability components should be updated to reflect the impact of the intervention as shown in figure 4.

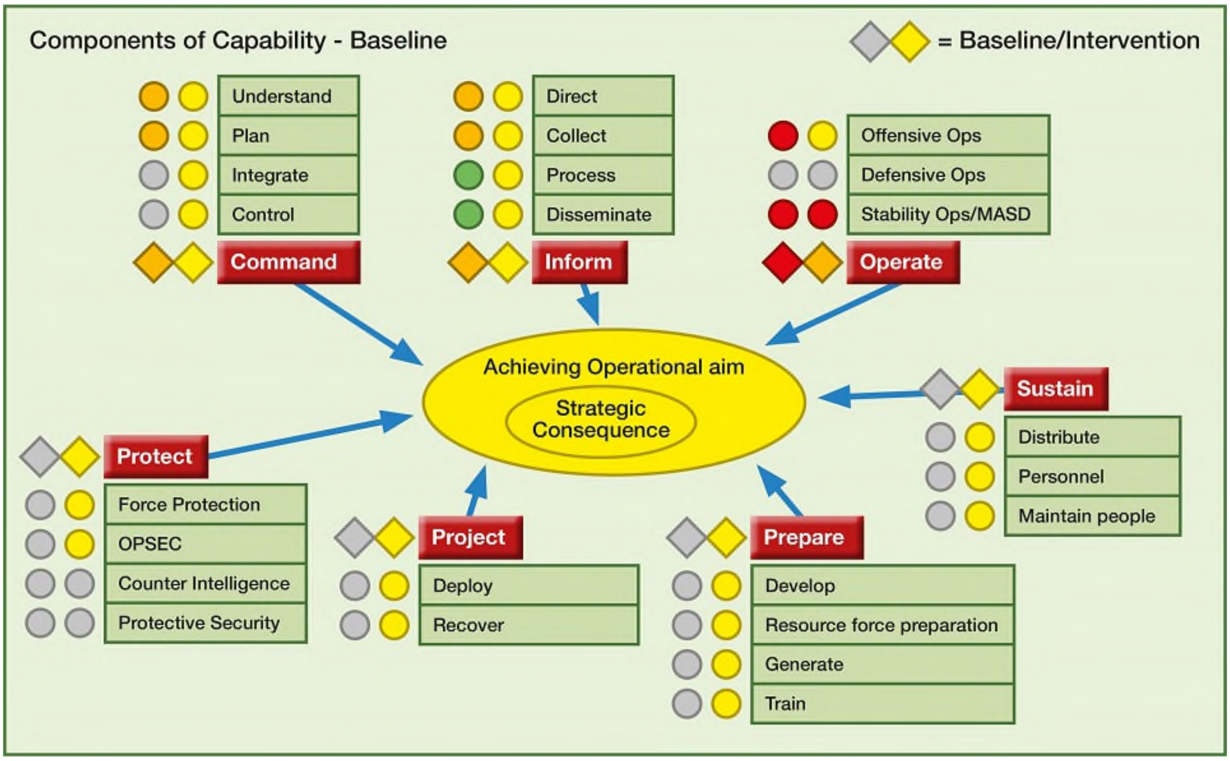

Figure 4: Impact of the intervention example dashboard

Iterate with small steps

The degree of iteration will depend on how successful initial interventions have been. A new baseline (intervention plus baseline) should be established and then additional interventions evaluated against that baseline. To keep pace with technology and adversary adaptation, the iterative approach is recommended, however the iterative approach may stop when interventions have closed the gaps against the requirement whilst minimising operational risk.

WAY FORWARD

To date, the HCSIE approach has been applied in Niteworks projects that include analysis and evaluation. The approach is particularly appropriate for evaluating the extent to which capability requirements are satisfied. The application of the approach and its integration with other techniques, particularly wargaming, is where the approach is being developed further. Within the context of a multi-sided wargame where players responsible for own force (blue force) actions propose actions that affect other players military forces (red force), an understanding of the current baseline can be developed and captured on a dashboard similar to figure 3. As the wargame progresses through a series of turns (blue and red action) it would be possible to develop dashboards for each stage of the wargame and capture the impact of any interventions that are played. This is one of the ways that the HCSIE approach could be applied and relates to figure 4 where the dashboard is an interface to a range of different analysis and experimentation techniques.

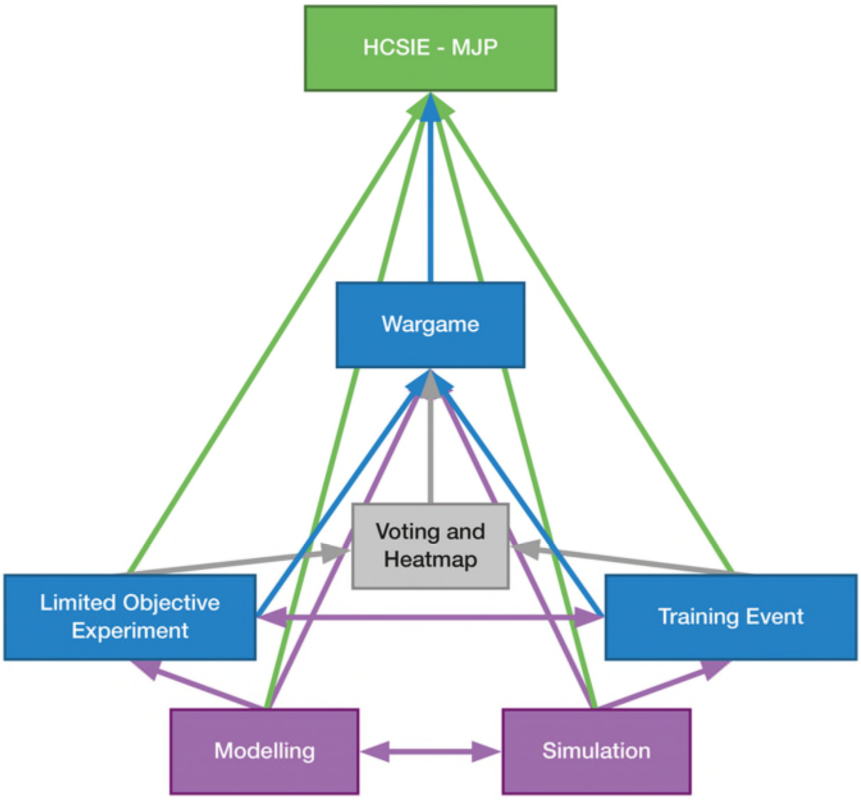

Figure 5: Contributory methods to the HCSIE approach

1. Future Operating Environment 2035. DCDC. MOD
2. The defining feature of a system is that a group of elements, when interacting with each other and their environment, can generate emergent behaviours and properties. For example, the minimum stopping distance of a car on a wet road is an emergent property of the car and its elements (including the type of tyres and their air pressure, the type of brakes and their condition, the mass of the car, etc), and the car's environment (properties of the road surface, surface contaminants, depth of water, etc).
3. Attributed to Aristotle.
4. The ideas behind this evaluation approach have been derived from the Niteworks White Paper on Holistic Complex System Intervention Evaluation published in November 2015.
5. Intervention is a managed change, which transforms the system from its 'current state' to the 'desired state'.
6. AO is Area of operation and OPFOR is Opposing Force.
7. Grey represents not applicable.
8. MASD is Military Assistance to Stabilisation and Development, OPSEC is Operational Security.

Author: Chris Jordan

Chris Jordan is the Chief Analyst for the Niteworks partnership and has worked on a range of analysis and experimentation projects to support military capability development through decision support.

This paper is an updated and abridged adaptation of the Niteworks White Paper 'Holistic Complex Systems Intervention Evaluation – Understanding the nature of defence capability', Jordan, C. and Wilkinson, M. first published October 2015.