7th IMA Conference on Mathematics in Defence and Security

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VARIETY DYNAMICS

A NEW APPROACH FOR TAKING CONTROL OF DYNAMICALLY-COMPLEX MULTI-ACTOR SITUATIONS

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Challenges for defence and security using conventional mathematical modelling

- Situations with large numbers of dynamically-changing feedback loops
- Coercive systems
- Multiple and changing dynamics of power and control
- Asymmetric power where manager/controller has less power
- Unresolvable conflicts between multiple key stakeholders
- Systems with discontinuous behaviours
- Situations that do not comply with standard system structure assumptions

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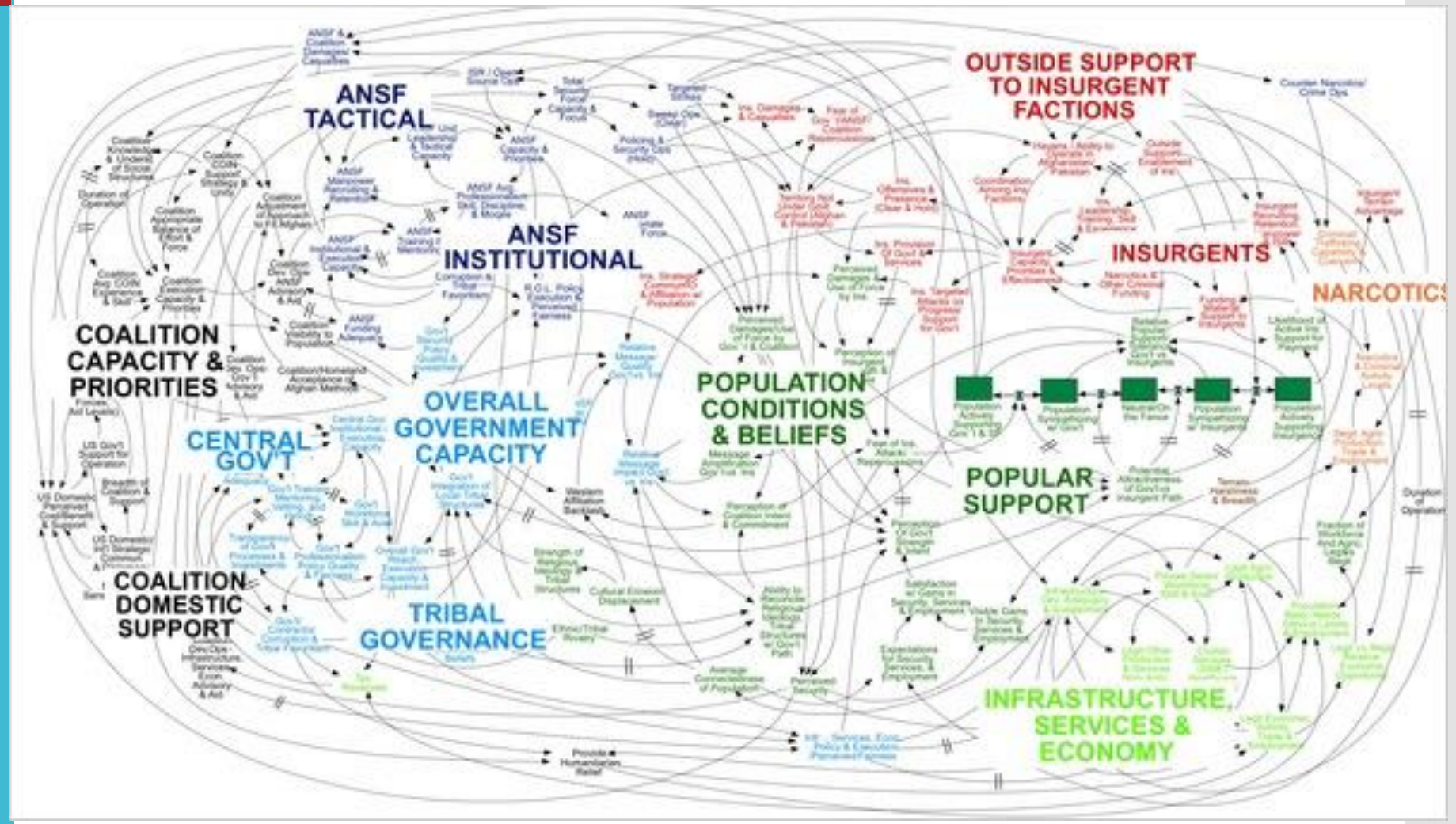
Typical complex power and control context



Causal loop diagram Afghanistan Stability – Coin Dynamics Source: US Military 2010

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Hyper-complex systems

Most problem situations in defense and security are **hyper-complex** s

Causally-based mathematical modelling has difficulty producing predictions for hyper-complex situations

Two Feedback Loop Limitation Axiom means **hyper-complex** systems are not amenable to mental understanding, intuition and collaborative/participatory group decision-making methods

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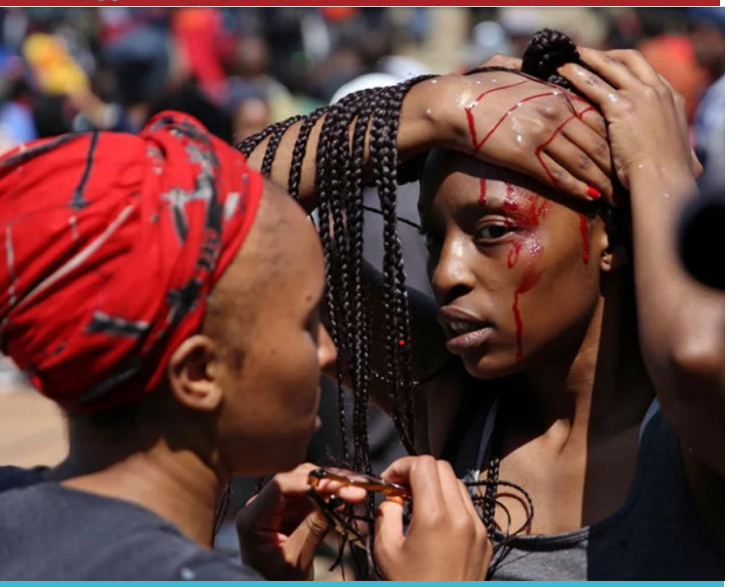

Characteristics of hyper-complex systems

- System behaviours, purpose, ownerships, subsystems, subsystem relationships and control mechanisms vary continuously.
- System boundary(ies) do not separate system elements of interest from each other and from environment
- System boundary(ies) not static and not necessarily always owned and controlled by system owner
- Sub-systems are not static in ownership, purpose, roles or relationships
- Control is dynamic and exerted through a variety of changing subsystems and factors; some outside the system
- Multiple feedback loops exist with changing structure, dynamics, purposes, causal relations, existence and ownership
- Coercive situations involving multiple asymmetric power relations unaligned to subsystems
- Control and system behaviours operate outside of the variables being addressed
- Parts of system and environment are chaotic
- Most of the situation and its causal relations are unknown

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Examples of hyper-complex systems

- US –Afghanistan and similar wars
- Epidemics with associated disasters and social breakdowns
- Middle East (Saudi, Iran, Israel, Lebanon, Palestine, US, Russia)
- Climate change control and politics
- Health systems in impoverished countries with low levels of governance or conflicted governance
- Large-scale international business competition
- Improving the government of countries captured by criminal cartels or industry lobbies
- Any system with large number of feedback loops in which the systems structure and ownerships of system elements changes
- International political tension between elites (wars by any means)
- National systems subject to hidden control via psyops or similar

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Variety Dynamics

- **Variety** is the number of **options** possible of any aspect of a situation
- **Variety Dynamics** focuses on **distributions**, **dynamics**, **ownership** and **control** of the **dynamics** of **varieties (options) by different elements of** hyper-complex systems
- It does **NOT** address **causal** relations between elements
- The reason for not addressing **causal** relations is that causal prediction is ineffective, misleading, invalid, or in error for hyper-complex situations

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Creation of Variety Dynamics

Dr Terence Love

Dr Trudi Cooper

Variety Dynamics developed by Professors Terence Love and Trudi Cooper starting around 1972 and includes:

- **Concepts** (systemic and mathematical)
- **Axioms** describing patterns of control influence and outcomes (currently 46 to date)
- **Practical strategies** for achieving control in hyper-complex coercive situations
- **New mathematical field** interacting with set theory, function analysis, combinatorics, topology of variable spaces, and hyper-complex vectors etc.

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Variety

Variety is the number of different possible options for elements in a situation

Variety and its dynamics can be represented in a dynamic multi-dimensional variety space

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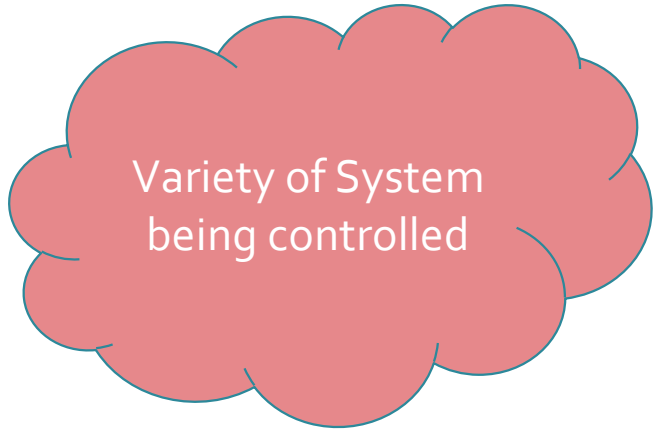
Early historical variety axiom:

Ashby's Law of Requisite Variety

For control must be LARGER THAN ->



The variety available to the controller to control the system must be larger than the variety able to be generated by the system.

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Example: Variety in simple power and control context - school

Variety available to teacher must be greater than that generated by pupils

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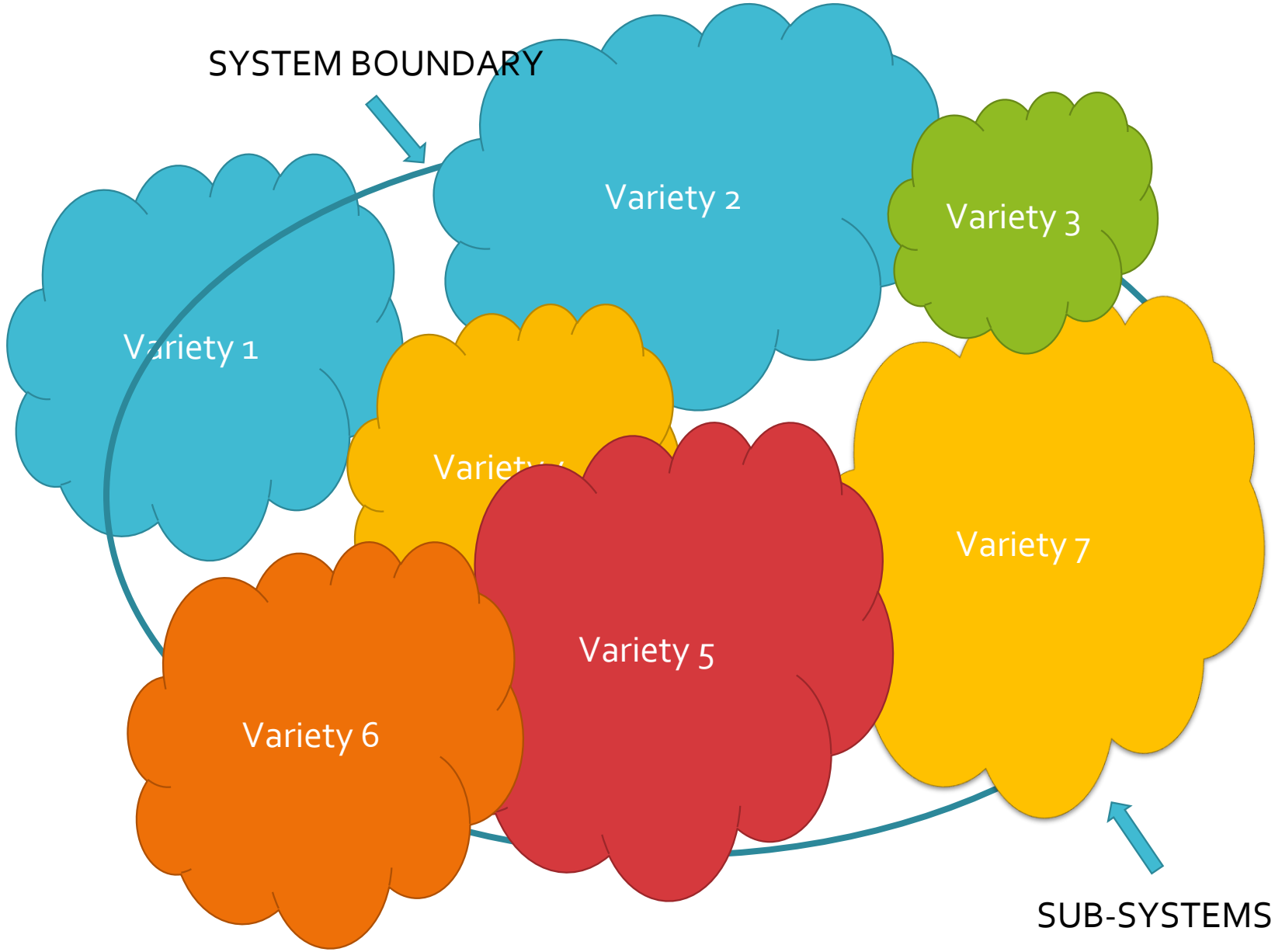
Real situations with dynamic variety distributions



- Distributions of variety and control and ownership are changing continuously in highly interrelated ways

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Variety Dynamics Axiom

Axiom 1:

For complex, layered and hierarchical systems involving multiple constituencies in which the distribution of variety generation and control is uneven across the system

THEN

The differing distributions of generated and controlling variety result in a structural basis for differing amounts of power and hegemonic control over the structure, evolution and distribution of benefits and costs of the system by particular constituencies.

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Practical example of use of Axiom 1:

Activists vs motor industry

1. Activists asked motor industry to implement strict emission control standard - motor industry refused
2. Activists persuades different states to implement **different** emission control standards (i.e. increased the variety to be addressed beyond motor industry's ability to control)
3. Offered to resolve via a single national emission standard
4. Motor industry agrees new national emission standard

Management of changes of variety resulted in power transfer TO the activists FROM the motor industry – without use of force or power

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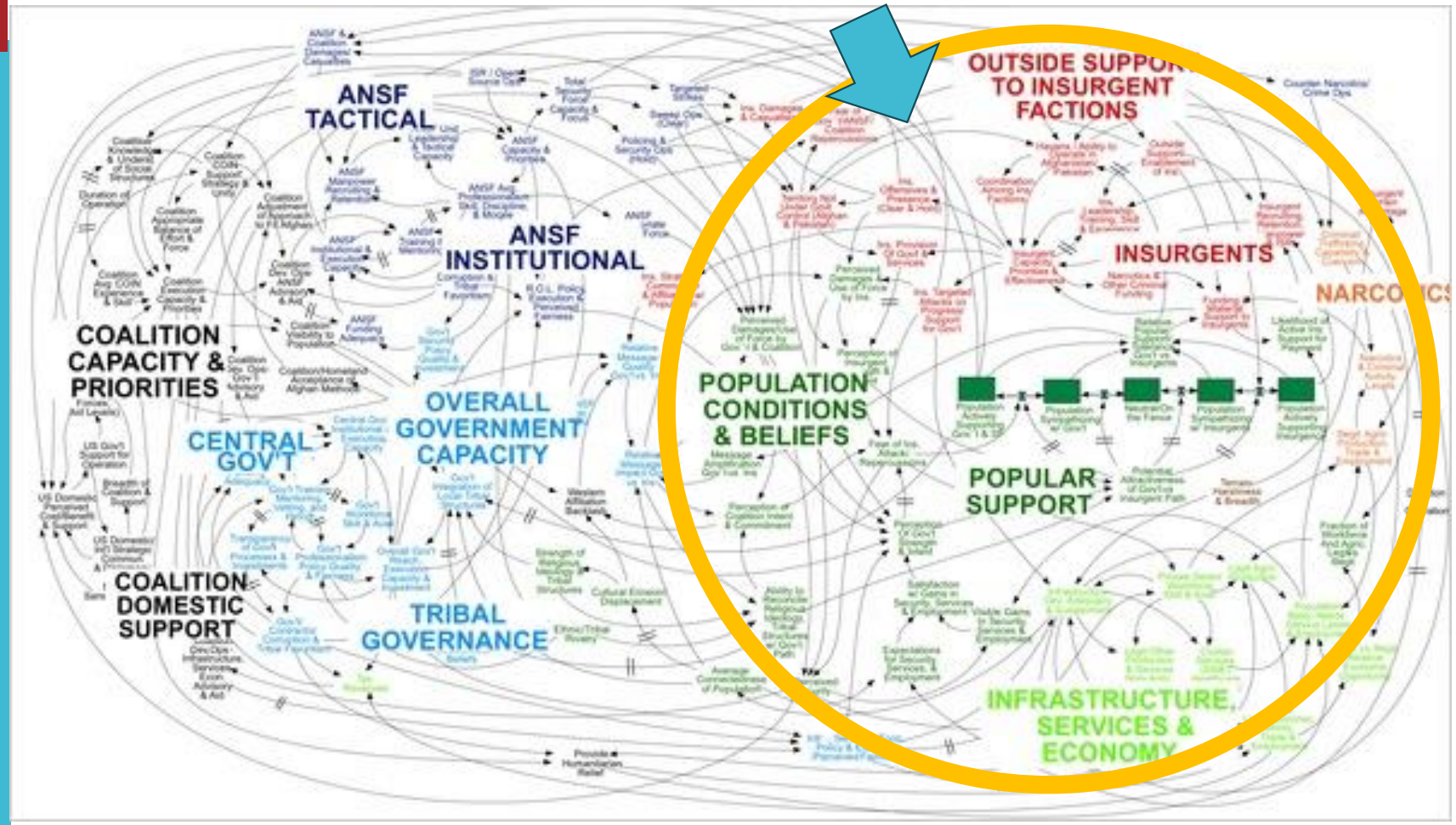
Variety analysis of Afghanistan and US=

Insurgent variety



Insurgent variety potentially larger than US military variety hence US would be expected to lose ownership of control – regardless of availability of force (Variety and its distribution and dynamics is more important than force)

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Variety space elements

Variety spaces contain a wide range of variety types concerning, e.g.:

- **Rules** (e.g. plates have knife and fork, sorbet dishes have small fork and spoon, Chinese food has chopsticks, Malaysian food has no knife, Korean food has scissors)
- **Dynamics** (changes with time)
- **Boundaries** (functionally defined rather than fixed)
- **Relationships** (including causal)
- **Projections in time and space**
- **Boundary porosity functions** (the way things change things across boundaries)
- **Agency abilities**

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Mathematics of variety 'spaces'

- Mathematically, a **space** consists of selected **objects** (of any sort or type) that are treated as points and vectors along with selected **relationships** between these points.
- The objects can be of many types including:
  - **Characteristics**
  - **Functions**
  - **Restraints (boundaries)**
  - **Classification systems**
  - **Other spaces**
- 'Spaces' can be considered as:
  - **Geometric** spaces (with ***m*** dimensions)
  - **Algebraic** spaces (of order ***m)***
  - **Communication** languages of order ***m***
  - **Feedback loop systems** of abstraction ***m+n***
  - **Hyper-complex vectors**

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Variety Dynamics and Hyper-complex vectors

First used as part of Variety Dynamics in 1972

Advantages of hyper-complex vectors include:

- Can be combined via dot product
- Provide an alternative to neural net AI / data mining/machine learning
- Can be decomposed and hence reveal reasoning (unlike AI etc.)
- Use around 1/25 of the energy needed for predicting complex outcomes compared to AI/machine learning and also uses less computer power
- Are around 25 times faster than conventional AI

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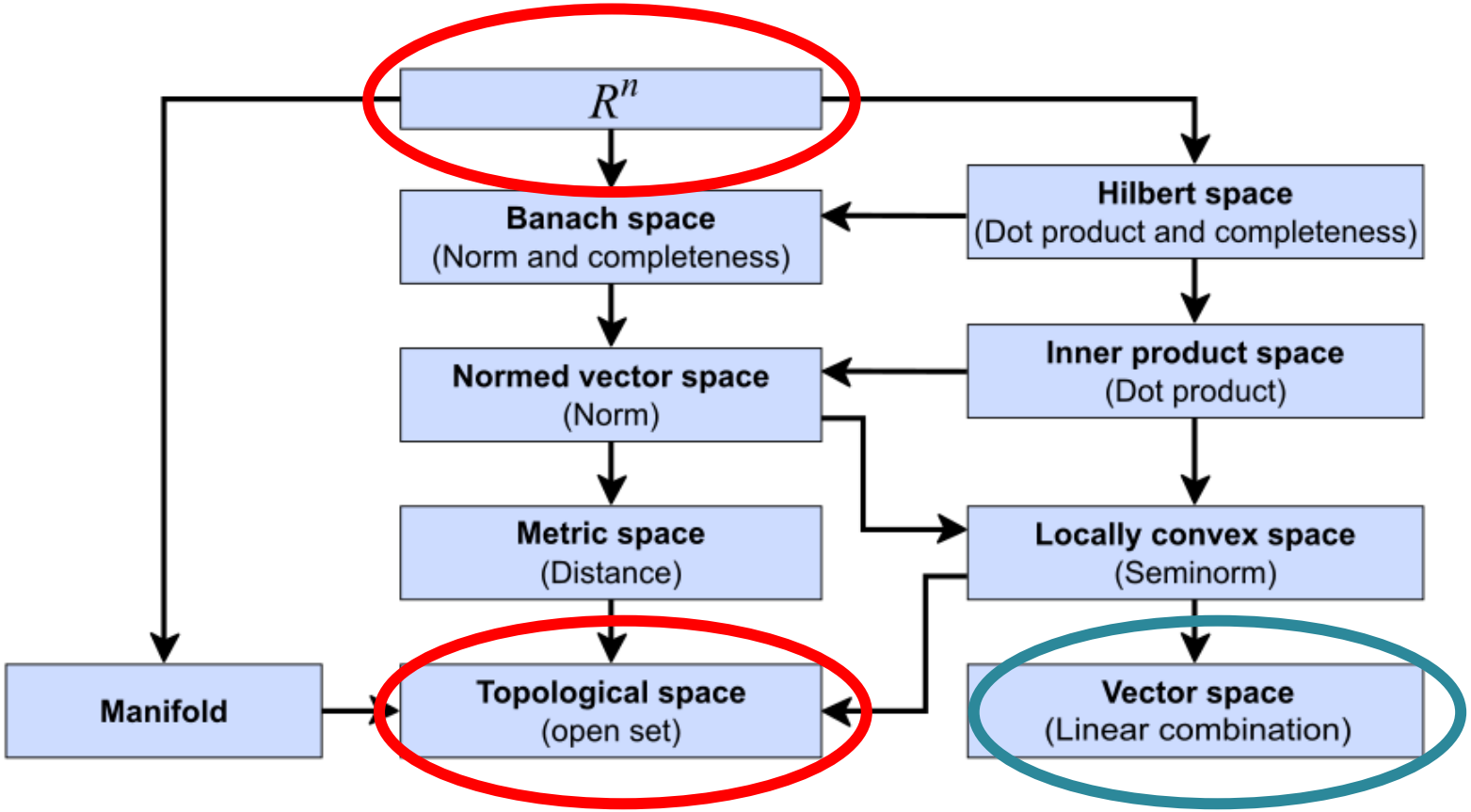
Variety Dynamics in different abstractions of mathematical variety spaces



- Conventional **systems modelling** operates in ***causal* vector space**
- **Variety space** is at the boundaries of R^n where ***n*** is a function of the **maximum variety of any one variety sub-space** and the **variety of subspaces** themselves – or as combinations of different R^n
- **Variety space** can be envisaged as **topological space** of order ***n***.
- **Variety spaces** can also include **probability spaces**

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