

Systems of Systems Engineering and the Pragmatics of Demand

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The focus of the talk

Q1: How do we analyse systems of systems that do not have pre-defined boundaries?

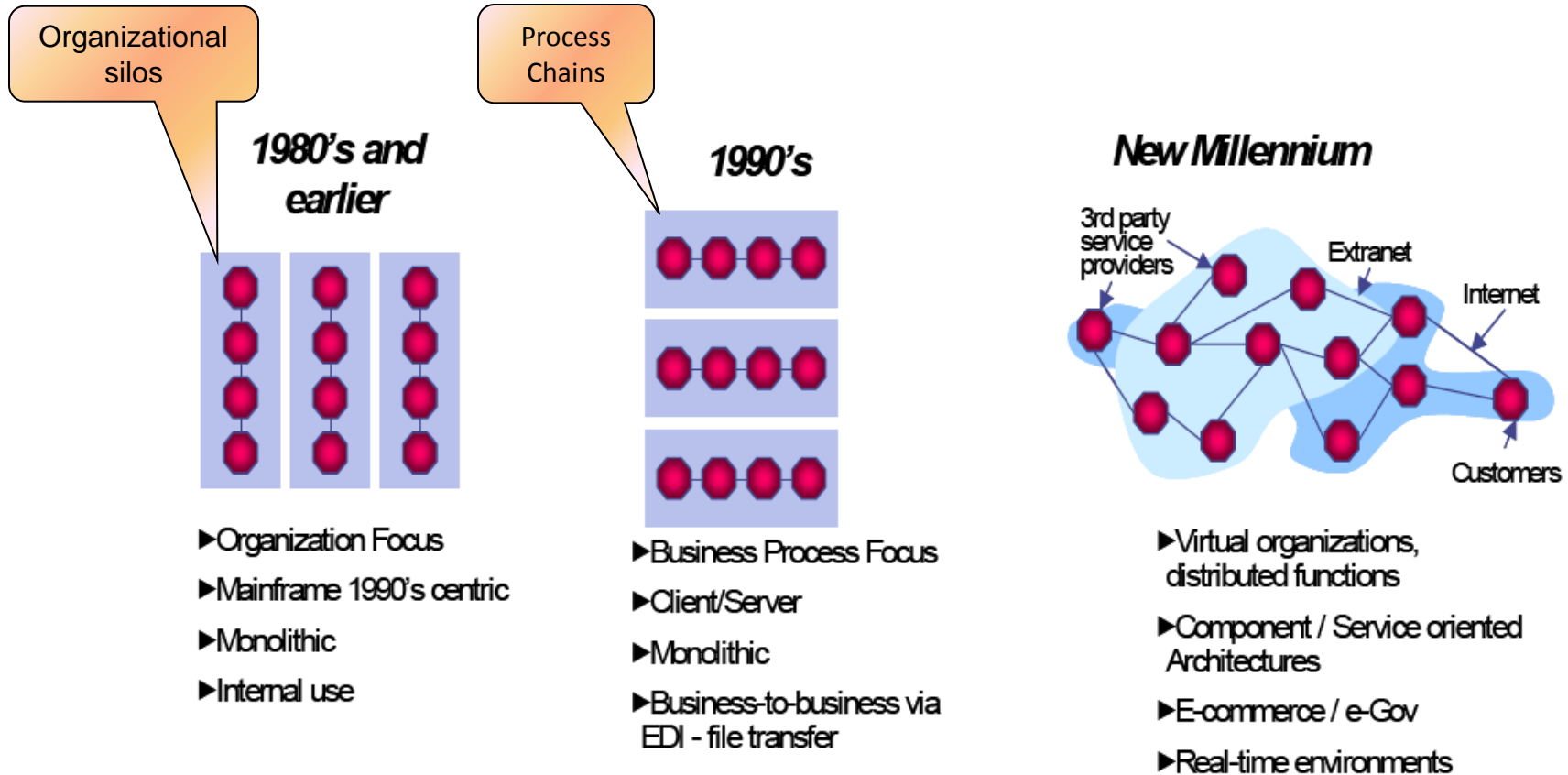
Q2: How do (socio-technical) systems of systems align themselves to changing varieties of demand?

- Healthcare systems
- Edge-driven military systems

A (1 and 2): By understanding how the pragmatics of demand translate into geometries-of-use

- Geometries-of-use are particular patterns of interoperation
- The agility of a SoS is a function of the variety of geometries it can support

The US DoD perception of the evolution of SoS



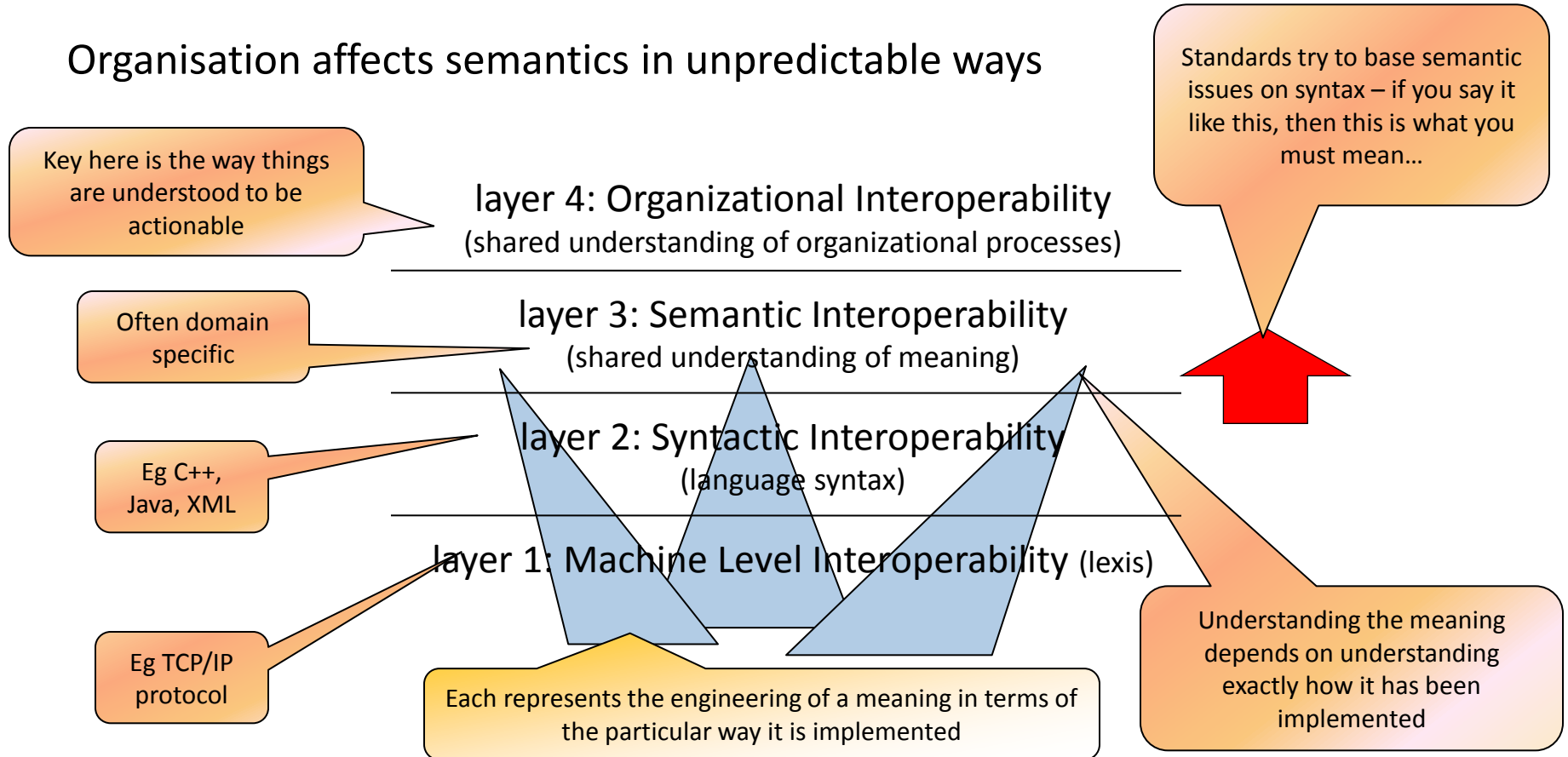
Source: US DoD Enterprise Architecture Technical Reference Model [v0.04 dated 20 August 2005, http://www.defenselink.mil/cio-nii/docs/DOD_TRM_V0.4_10Aug.pdf]

How are all these systems to interoperate?

CHALLENGE

Standards are not enough

Organisation affects semantics in unpredictable ways



Source: Why standards are not enough to Guarantee End-to-End Interoperability, Lewis et al, 2008

Stratification layers

We have some missing layers...

The layers read into a particular context

'demand-side'

pragmatic constraints



The size of this overlap depends on how over-determining are the engineering constraints

Engineering constraints

'supply-side'

6: Effects Environment
(the contexts-of-use in which effects are created)

5: Situational Interoperability
(the way a situation is engaged with)

4: Organisational Interoperability
(shared understanding of organizational processes)

3: Semantic Interoperability
(shared understanding of meaning)

2: Syntactic Interoperability
(language syntax)

1: Machine Level Interoperability
(lexis)

effect
decisive moment
composite capability
operational capability
fielded capability
equipment capability

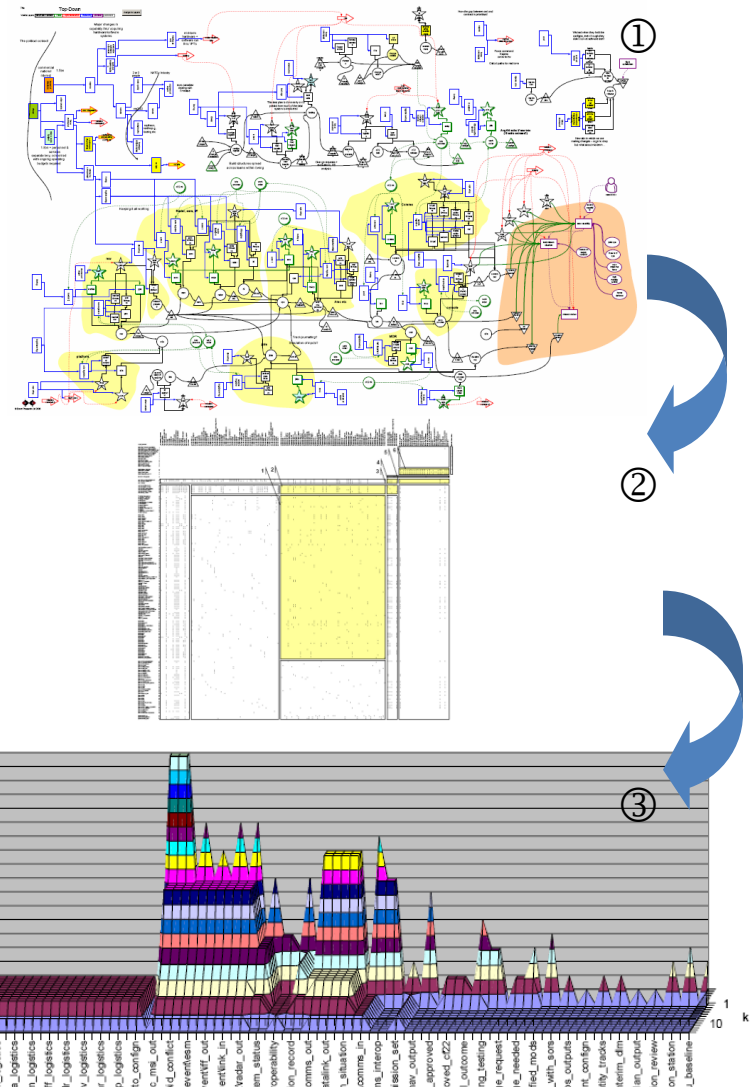
Modeling SoS Complexity in Context

Defining this stratification involves modeling the forms of interoperability defining a system of systems (SoS) involved in the launch of a NATO modernization program....

... Including the many ground and airborne systems and diverse organizations (as virtual systems) required to operate and sustain the NATO AWACS fleet.

Analysis is done in Three Stages:

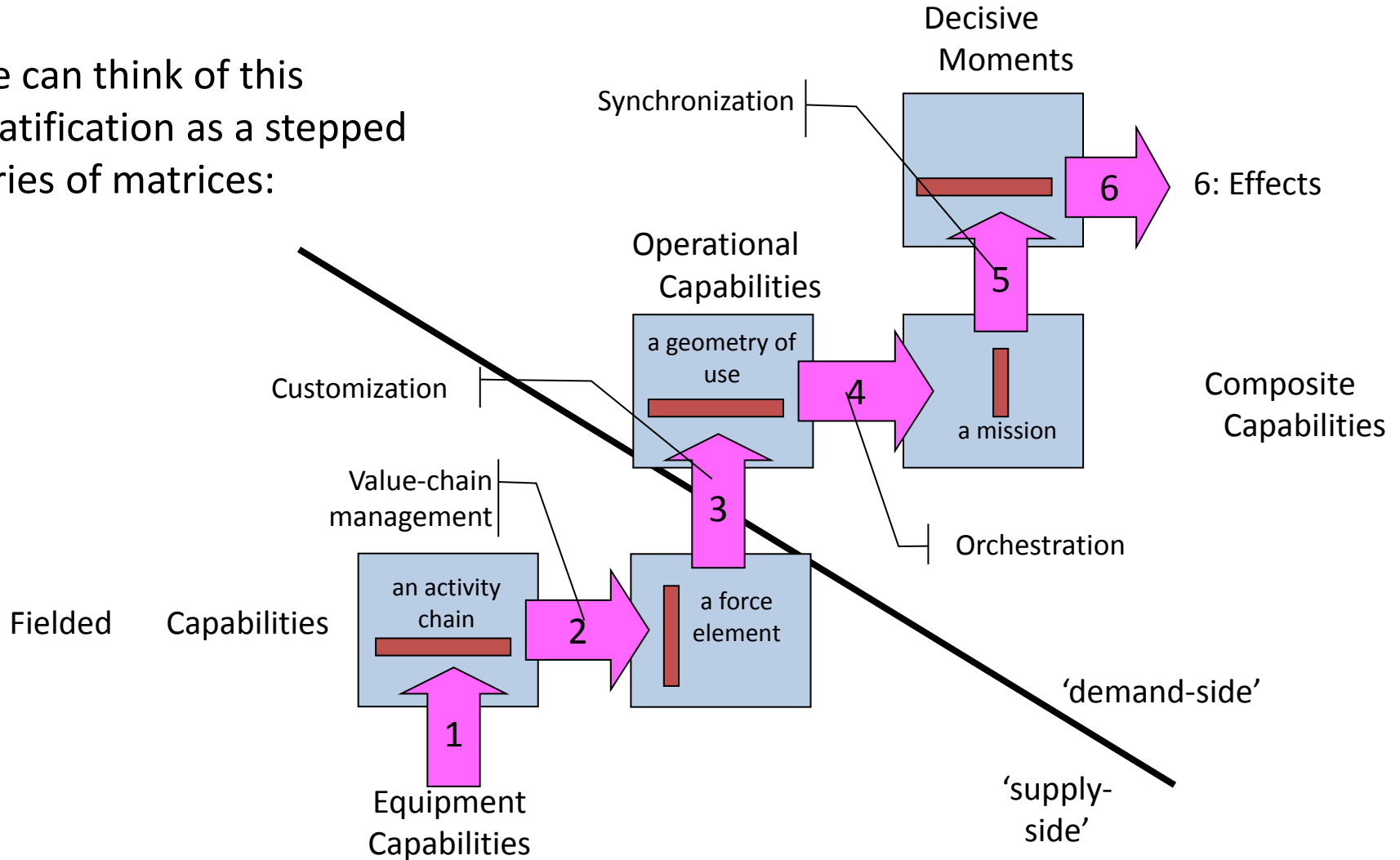
- ① **Visual PAN[†] Models**—a layered, graphically represented, relational model whose schema is identified by the study team and which is populated by subject matter experts in a workshop setting
- ② **Stratification Matrices**—a stratified collection of Boolean matrices, derived from the Visual PAN Models by relational operators defined by the study team, that relate the supply side and demand side structures of the client's enterprise
- ③ **Interoperability Landscapes**—3-D histograms, derived by the study team from the PAN Matrices considered as simplicial complexes, which are the primary representation for reasoning back to the stakeholder community



[†] PAN (Projective ANALYSIS) is used with permission of BRL.

Composition to Achieve Effects

We can think of this stratification as a stepped series of matrices:

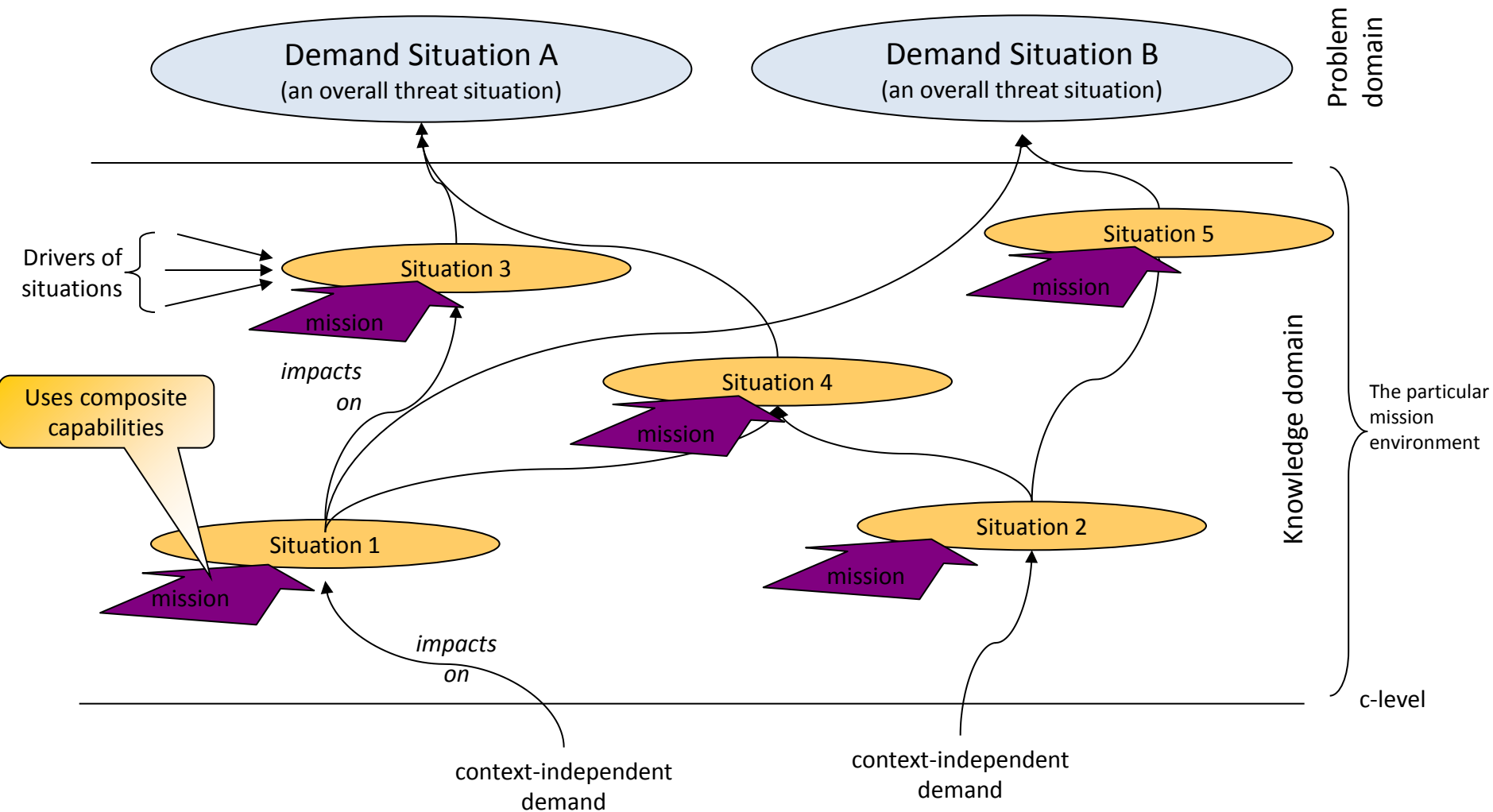


So how do we look more closely at the demand-side from which the 'pull' is coming?

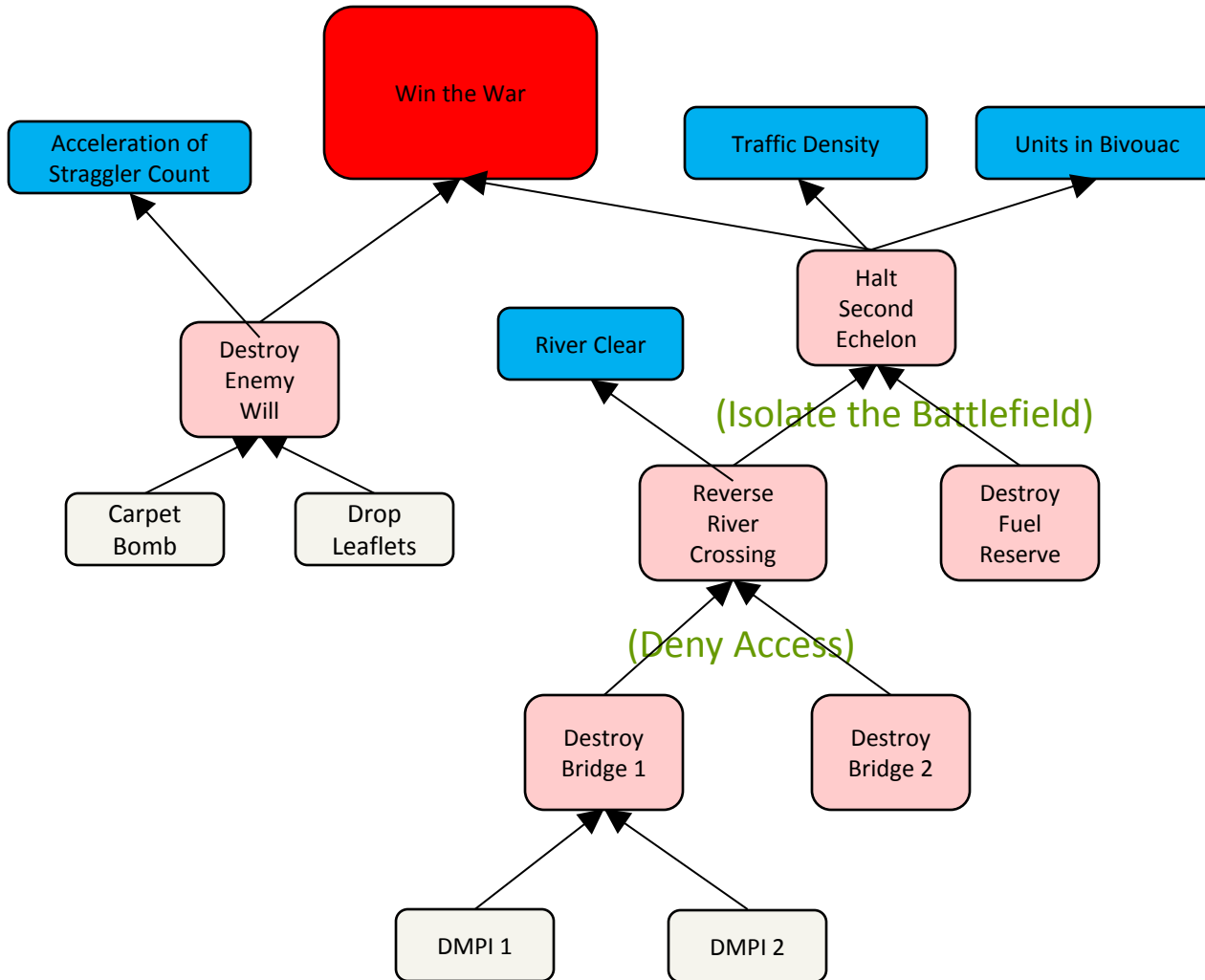
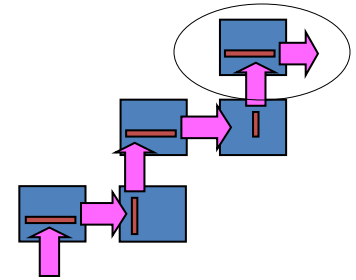
Analysing 'geometries of use'

THE PRAGMATICS OF DEMAND

Demand – what are the effects being supported?



Matrix 6: An effects ladder



Effects Based Operations Terms

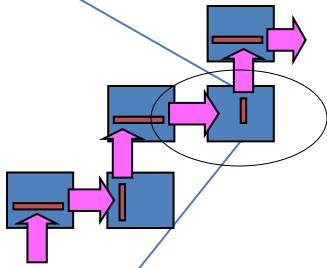
- Objective
- Effect Desired
 - direct effect
 - indirect effect
 - complex effect
 - cumulative effect
- Indicator
- Task/Activity
- (Mechanism)

Source: M. McCrabb, "Effects-based Operations: An Overview" Available: <http://www.au.af.mil/au/awc/awcgate/af/ebo.ppt>.

Reverse
River
Crossing

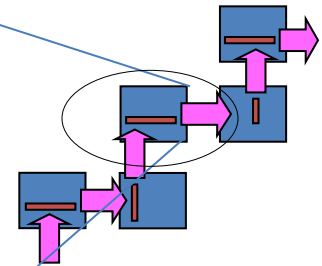
Synchronisation Matrix 5

Decisive Moments									
Enemy crosses boarder									
Enemy reaches river	X	X							
Enemy crosses river	X	X	X	X	X	X	X		
Recce approaches enemy			X	X	X	X			
Recce comes into contact with enemy				X	X	X	X		
Enemy reaches meeting engagement location					X	X	X	X	
Meeting engagement						X	X	X	
Enemy defeated									
Enemy follow-on forces advance									
Composite Capabilities									
	X	X	X	X	X	X	X		
	X	X							
			X	X	X	X			
	X	X	X						
		X	X	X	X	X			
				X	X	X	X		
			X	X	X	X			
X	X	X							
	X	X	X	X					
X	X	X	X	X	X	X	X	X	X

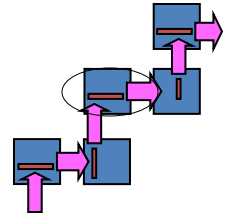


Geometries-of-use Matrix 4

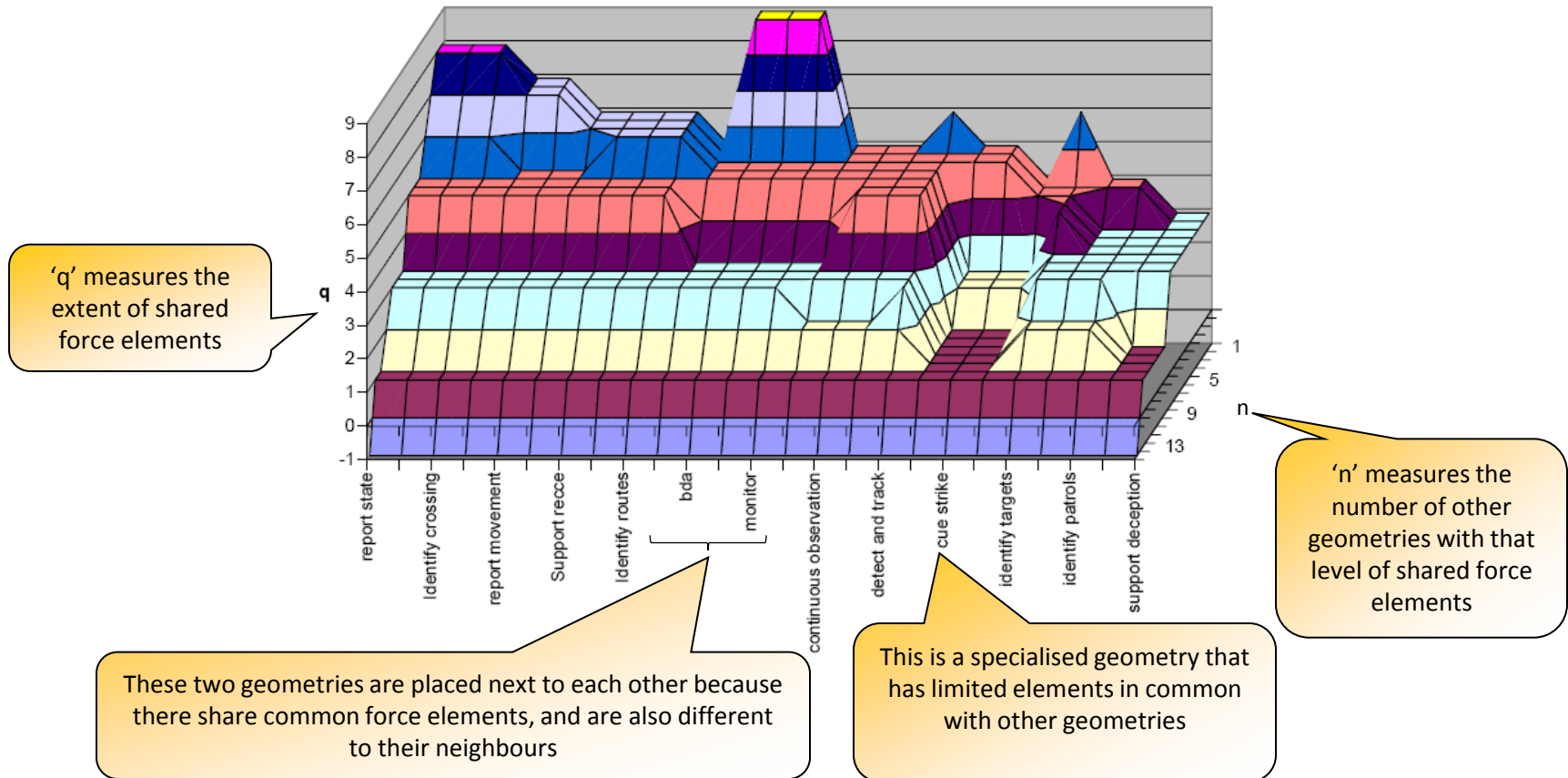
Operational Capability														Composite Capabilities	
Force element 1	Force element 2	Force element 3	Force element 4	Force element 5	Force element 6	Force element 7	Force element 8	Force element 9	Force element 10	Force element 11	Force element 12	Force element 13	Force element 14		
x	x	x			x			x					x	Support Recce	
x	x	x	x		x	x		x					x	Identify enemy routes	
x	x		x	x		x	x	x						Report state	
x	x	x	x	x	x	x	x	x						Identify crossing	
x	x	x	x		x	x								Continuous observation	
x	x	x	x		x	x							x	Detect and Track	
x	x								x	x	x	x		Cue strike	
x	x		x	x		x	x		x	x	x	x		Bda	
x	x		x	x		x	x		x	x	x	x		Monitor	
x	x			x		x		x					x	x	Identify tragets
x	x					x		x					x		Identify patrols
x	x		x			x									Support deception
x	x			x		x	x	x					x	x	Report movement



Geometry-of-use Landscape

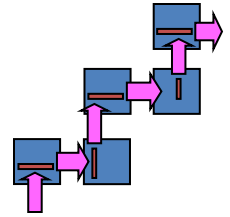


The more jagged the landscape, the greater the variety of geometries



TO CONCLUDE

To Conclude



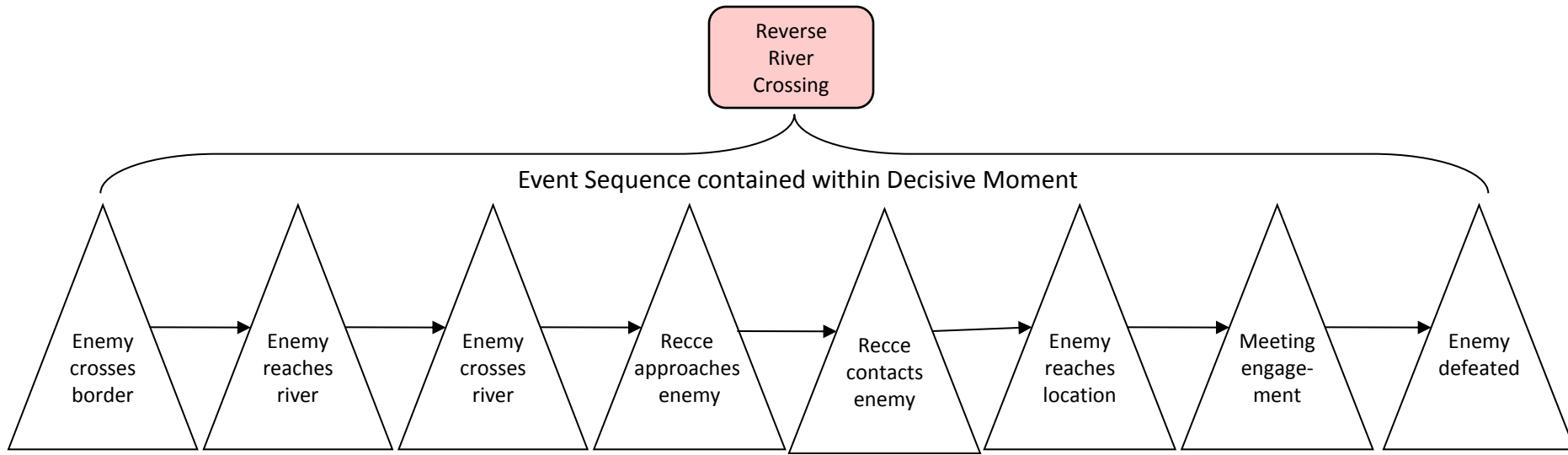
An effects ladder can be analysed in terms of the geometries needed to support the sequences of events generating its decisive moments.

The variety of geometries across an appropriate number of effects ladders defines the degree of agility required of the supporting systems of systems.

This requisite variety can then be used to define the granularity of the functionality that the supporting systems need to provide.

END

The Sequence of Events contained in the Decisive Moment

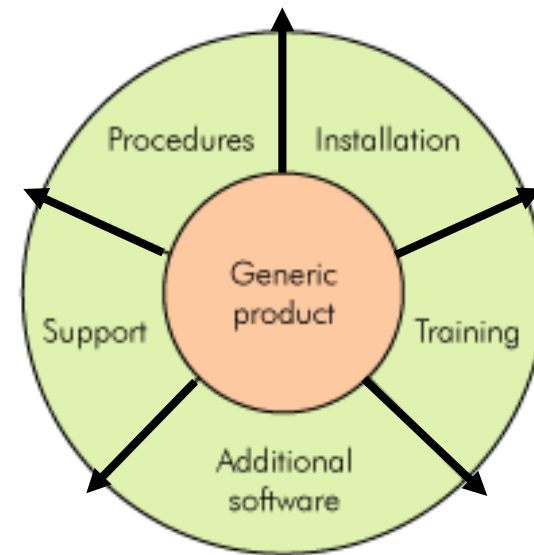


The limitations of 'Whole Product' Thinking

The supplier cannot anticipate all the ways in which their product will be used.

“In marketing, a whole product is a generic product augmented by everything that is needed for the customer to have a compelling reason to buy. The generic product is what is usually shipped to the customer. The whole product typically augments the generic product with training and support, manuals, cables, additional software or hardware, installation instructions, professional services, etc.”

http://en.wikipedia.org/wiki/Whole_product

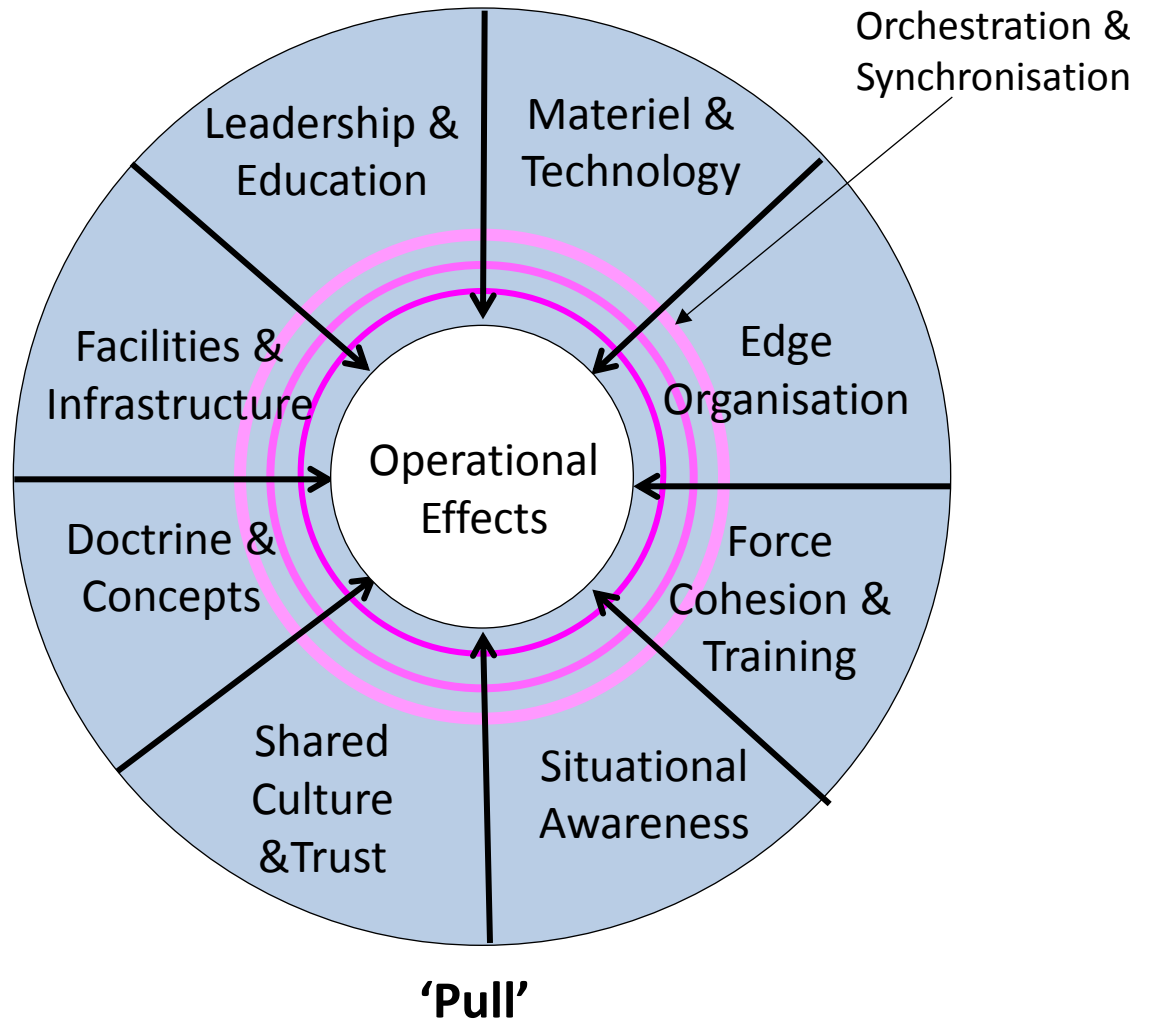


'Push'

The shift from 'push' to 'pull' logics

A (socio-technical) system of systems must support a wide variety of operational effects

- Healthcare
- Edge-driven responses to threats



How do we move from a 'push' to a 'pull' perspective?

We need a way of thinking through how the 'push' perspective can be aligned to the other 'pull' perspective.

