Complex Systems of Systems: The Double Challenge

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Briefing Objectives and Agenda

Instigate an alternative way of viewing systems of systems

- Begin equipping participants to ask different questions about the challenges and the opportunities

Agenda

- Describe a project approach
- Explore implications of a changing world
- Describe an alternative reasoning framework

Many Organizations Have These Problems

The DoD

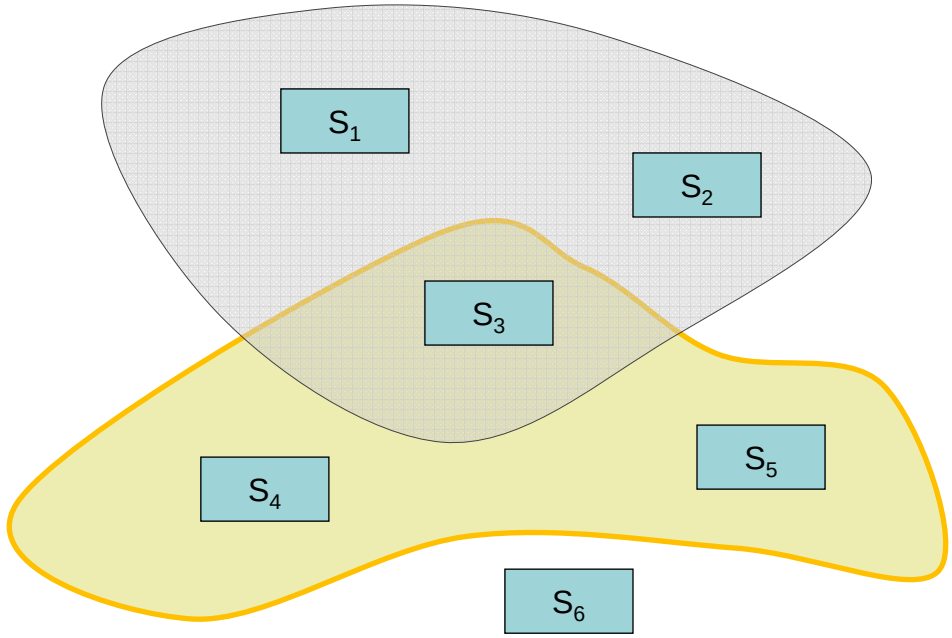
Other federal agencies

Large and small industrial organizations across the globe

Recent studies by the SEI and international consortia show that large, systems of systems (SoS) are endemic

- SoS challenge the capabilities of high-performing, high-capability organizations accustomed to large systems.
- These challenges surface throughout development, acquisition, deployment, and evolution.
- These challenges derive from working across multiple enterprises in response to rapidly changing and unanticipated forms of operational demand.

Creating, Using, and Evolving Composites of Systems



Why isn’t This Straightforward?

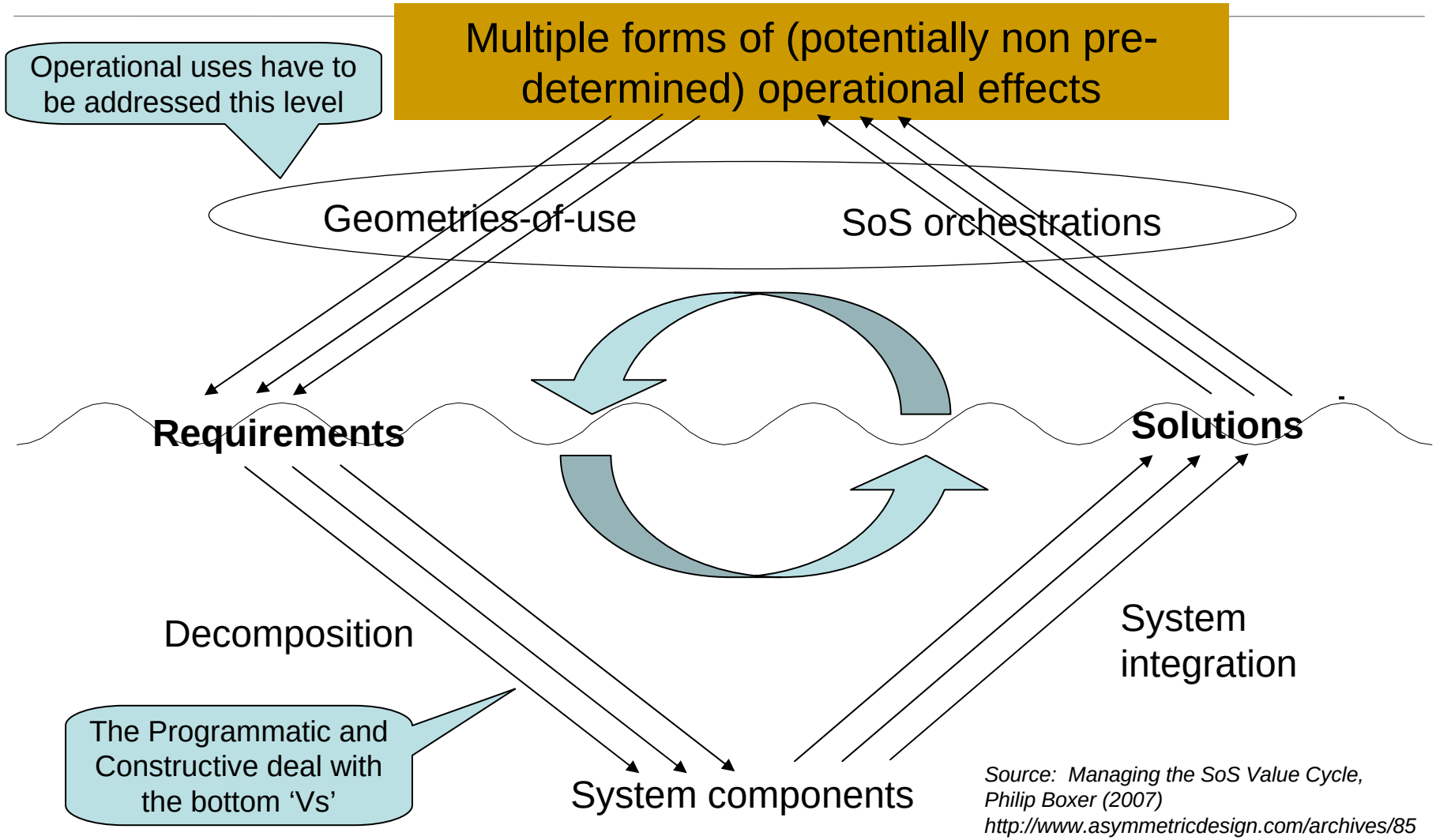
A typical approach

- Look at the software aspects of individual systems
- Determine which ones are “good” for the composite system of systems
- Determine how to put the good ones together—quickly

“Click and Clack” example

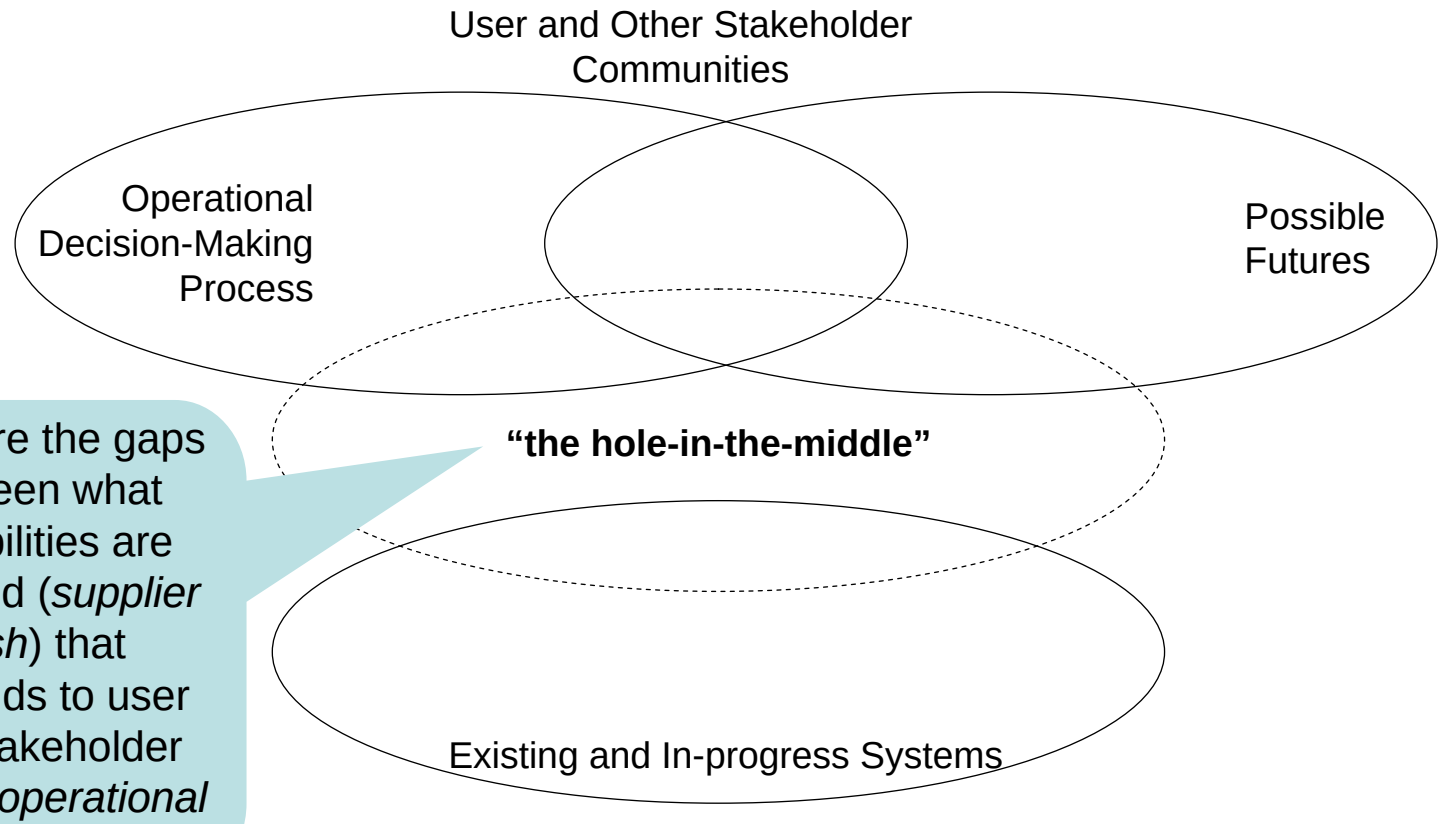
National Public Radio’s *Car Talk*

What is Needed: A Concept of "Operational" that Takes a Broader View



Source: Managing the SoS Value Cycle, Philip Boxer (2007) http://www.asymmetricdesign.com/archives/85

Looking at the Situation from a System-of-Systems Perspective



Key Challenge: How Entities Work Together and Resolve Conflicts

- Number, type, and roles of participants are increasingly diverse, reflecting differing vested interests
- Scarce resources and the need for concurrent uses make a single decision authority increasingly unlikely

Single Task System

A single program directs composition; little potential for conflict

Single Enterprise System

A real or virtual entity directs how multiple entities collaborate to compose multiple programs; and resolves potential conflicts by imposing constraints

Multi-Enterprise System

Multiple real or virtual directing entities making competing demands on SoS; and conflict resolution requires negotiating mutual constraints

Category names from "Architecting Principles for Systems of Systems", by Mark W. Maier. http://www.infoed.com/open/papers/systems.htm

Key Challenge: Increasingly Turbulent Operational Contexts

- Customers and users want specialized solutions in ever shorter time frames continuously adapted to their changing and evolving situations
- Suppliers and systems have to become more agile to respond

Product-based

Users want products or services that can be provided in a way that is unaffected by how they are used

Solution-based

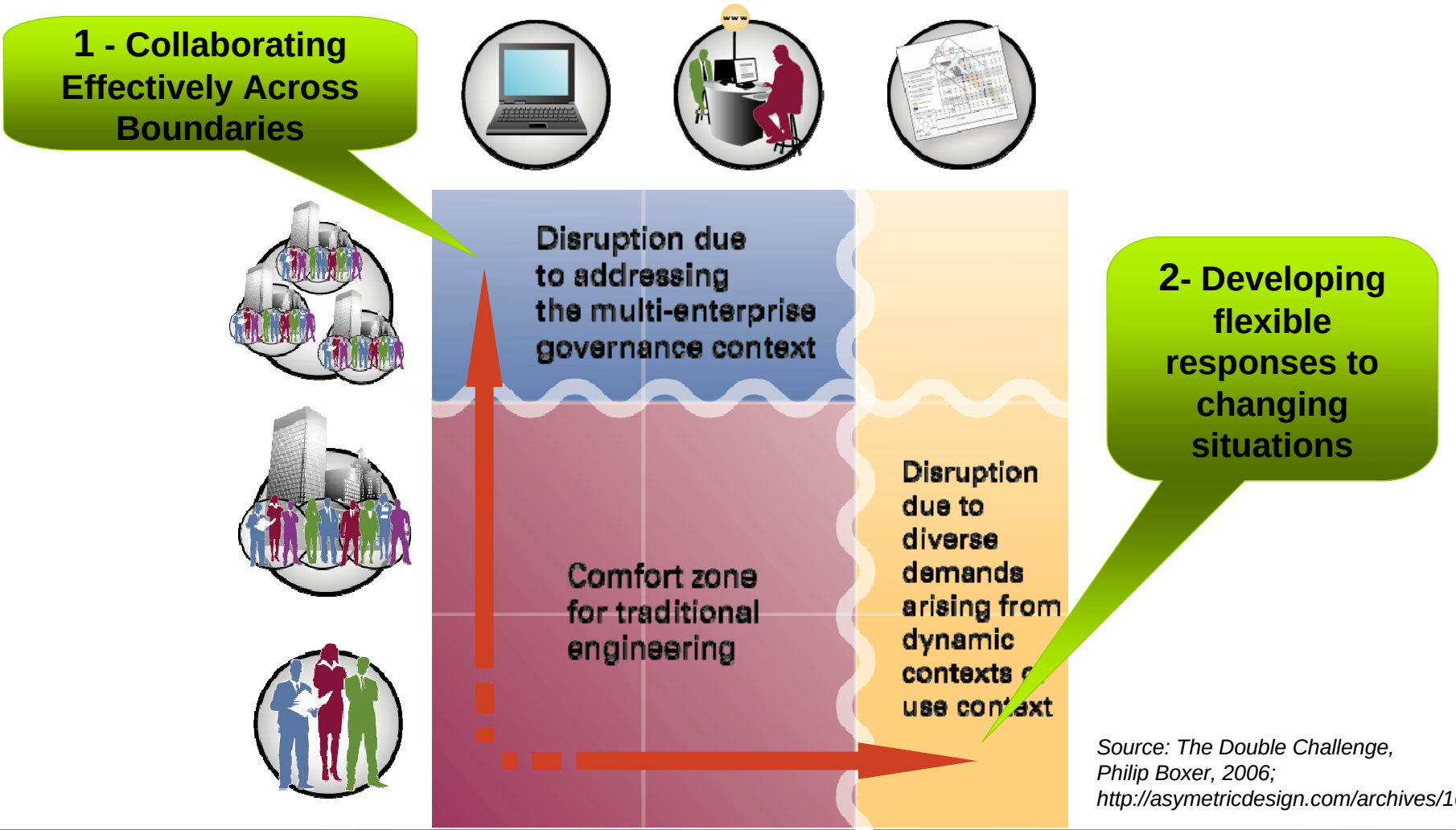
Users want integrated solutions that are customized to their context, but in a way that can be specified beforehand

Customer Experience-based

Users want integrated solutions that are customized in ways that change and evolve throughout the life of the mission that they support

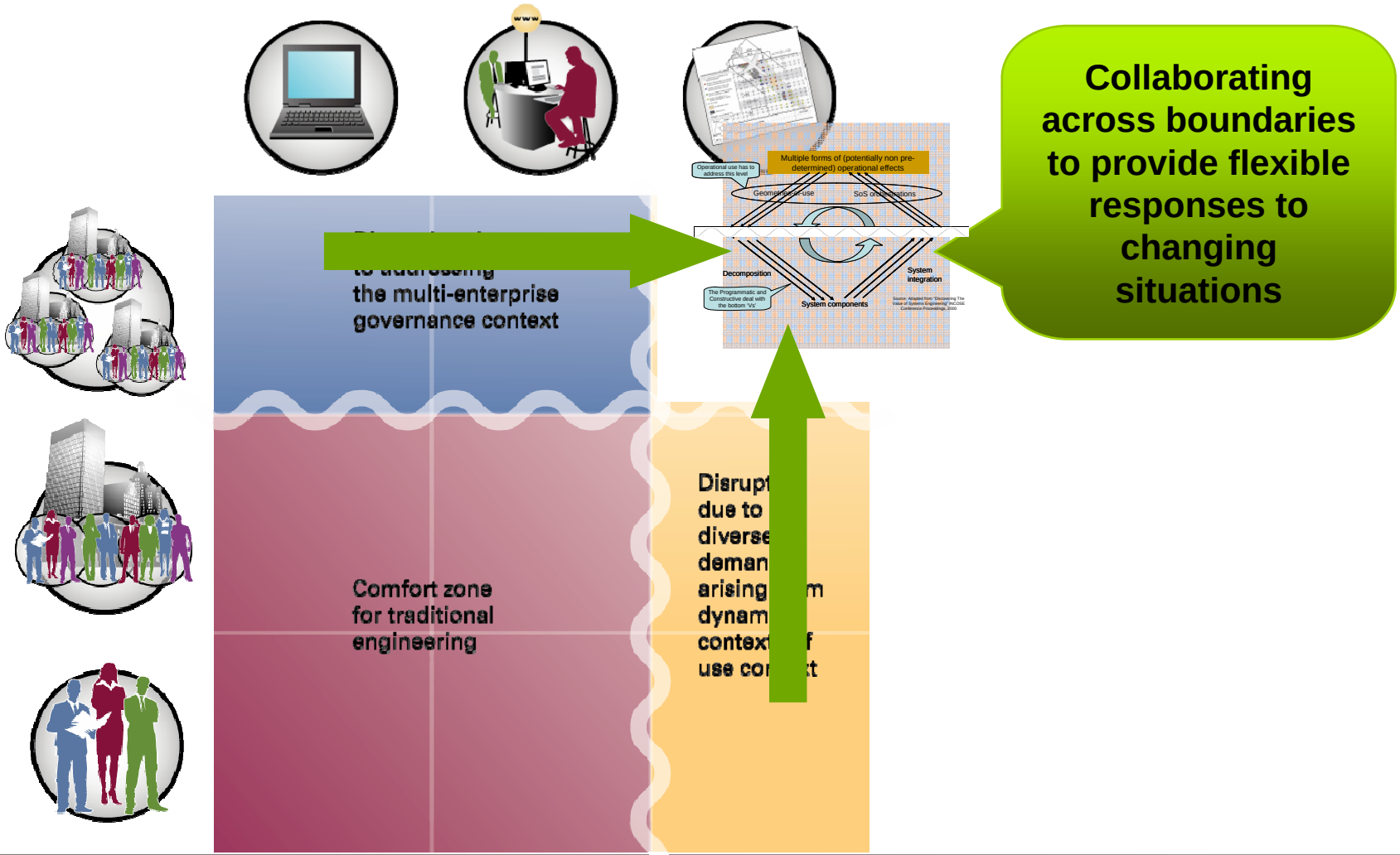
'Turbulence' as per "The Causal Texture of Organizational Environments", Emery F E and Trist E, Human Relations 1965, 18, pp 21-32.
Categories adapted from "The New Frontier of Experience Innovation", Prahalad and Ramaswamy, MIT Summer 2003

A Double Challenge: Diversity of Participants with Turbulent Usage Contexts and Needs

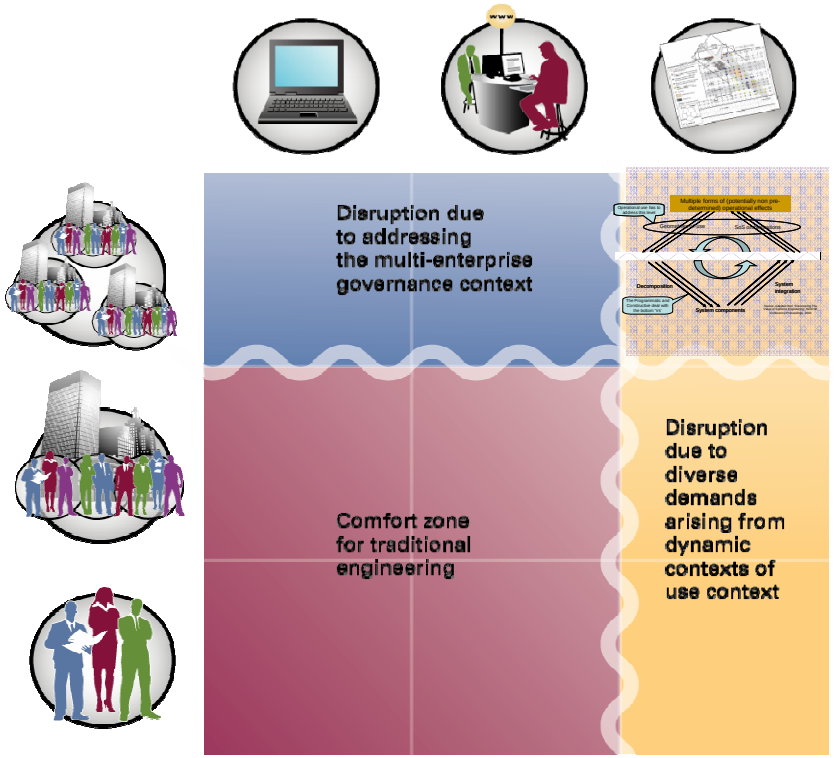


Source: The Double Challenge, Philip Boxer, 2006; http://asymetricdesign.com/archives/16

The Need: Leveraging the Double Challenges



An Example



Where were they?

Where did they need to be?

What were the gaps?

The Situation

Multi-national stakeholders in an acquisition program updating a system of systems within an operational capability

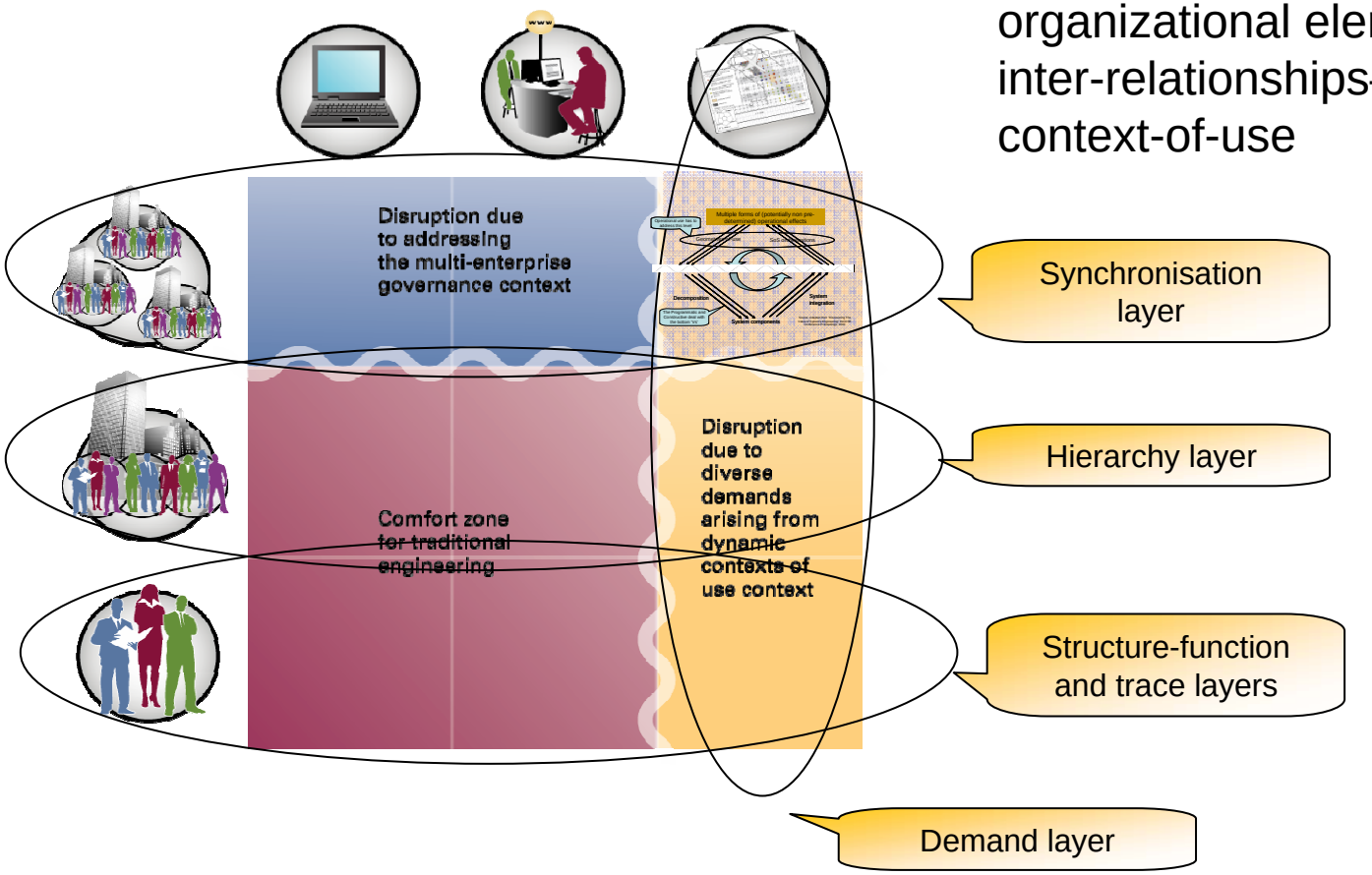
- Operational capability itself occupies a key role interoperating with other capabilities within a single unified command undertaking joint missions.
- Issue was the sustainment of the operational capability through its life given anticipated changes in its role and the complex nature of its systems.

This involved three challenges:

1. managing the process of upgrading within the context of sustaining the operational capability
2. improving the way these processes are managed through the life of the capability, given their systems-of-systems nature
3. improving the role of acquisition in support of this kind of sustainment

Modeling the Whole Space

Objective: understand and analyze technical, cognitive, process, and organizational elements and their inter-relationships—within their context-of-use



5 Layers of Analysis

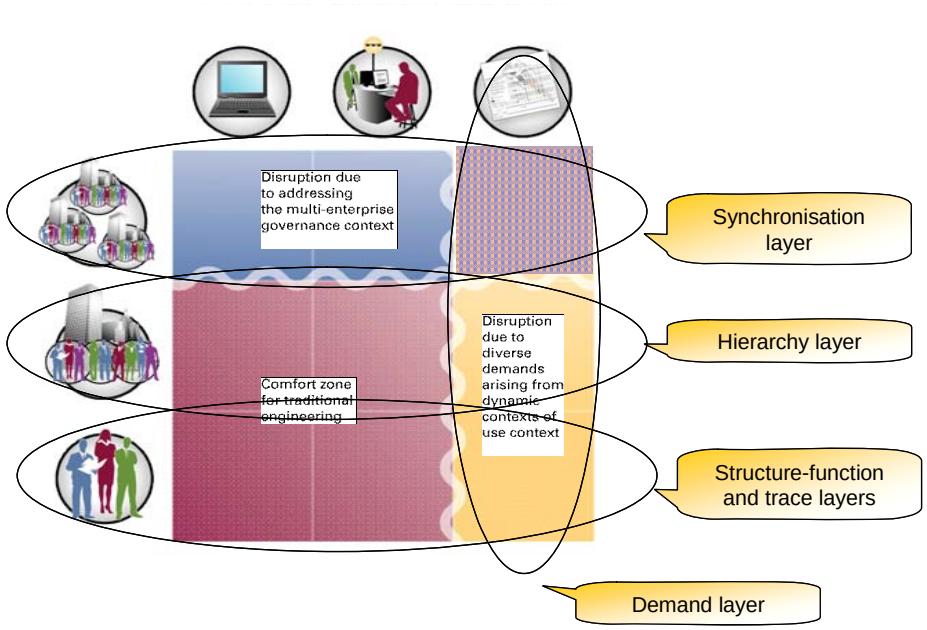
Structure/Function: The physical structure and functioning of resources and capabilities

Trace: The digital processes and systems that interact with the physical processes

Hierarchy: The formal hierarchies under which the uses made of both the physical and the digital are held accountable

Synchronization: The lateral relations of synchronization and orchestration within and between the organizations providing services “on the ground”

Demand: The nature of the contexts-of-use giving rise to demands on the way the operations are organized to deliver effective and timely services



The Outputs

Stratification analyses different levels of interoperability* from the point of view of the demands placed on the system of systems by the environment

- Synchronization (Can the configurations needed interoperate in practice?)
- Orchestration (What are the dynamic load characteristics generated?)
- Customization (Will baseline functionality be met?)

*** Stratification**

6. Effects environment
5. Mission environment
4. Deployed Force

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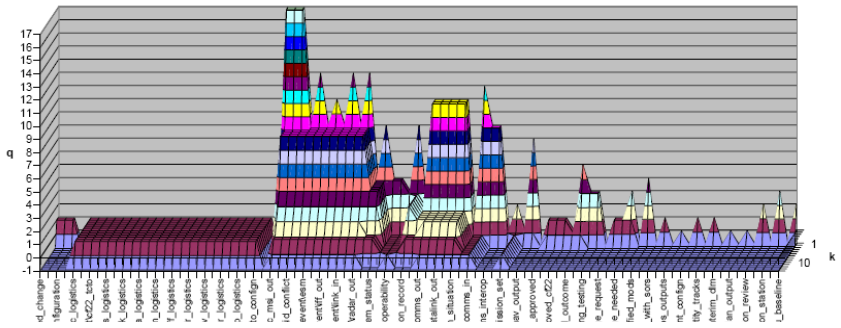
3. Operationally ready capabilities
2. Field-able capabilities
1. Equipment and bought-in capabilities

Landscapes represent topological characteristics of the system of systems

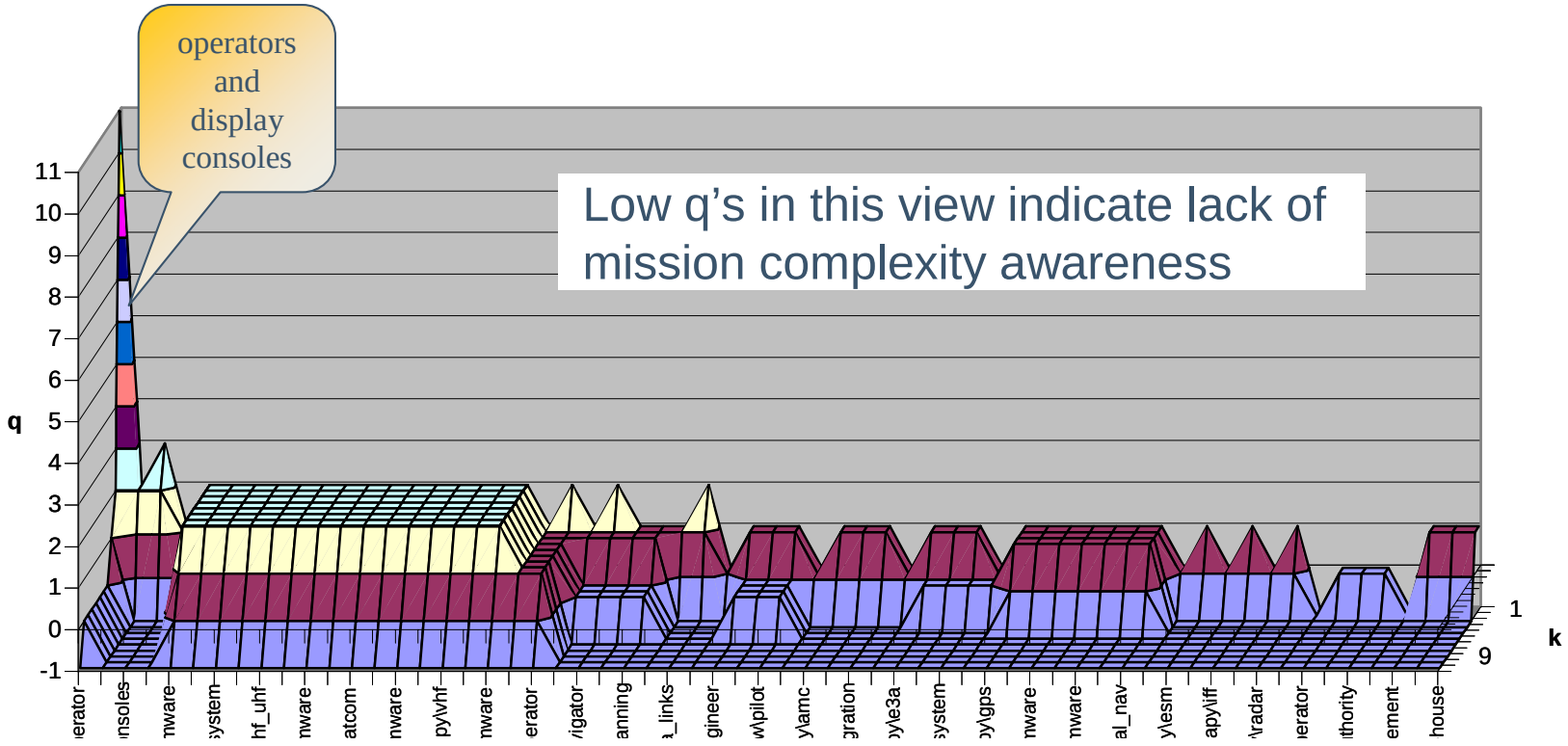
- Interoperability ‘hotspots’ (peaks)
- Risks (gaps between peaks)

Landscape



Analysis for Synchronization

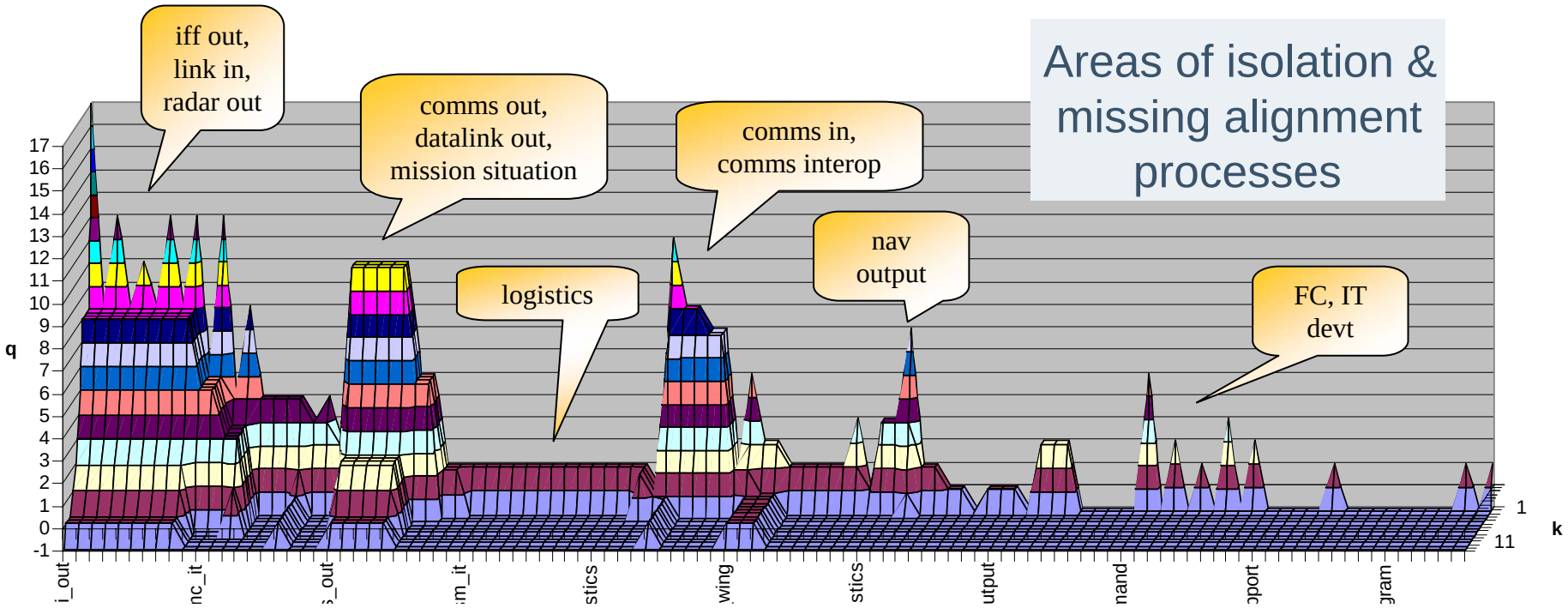
Shows that the predominant mission awareness integration point is the system operator and the operator's display console



Source: An Examination of a Structural Modeling Risk Probe Technique, Anderson, Boxer & Brownsword (2006), http://www.sei.cmu.edu/publications/documents/06.reports/06sr017.html

Analysis for Orchestration

Reveals areas of isolation, islands of high connectivity, and broad regions of separation



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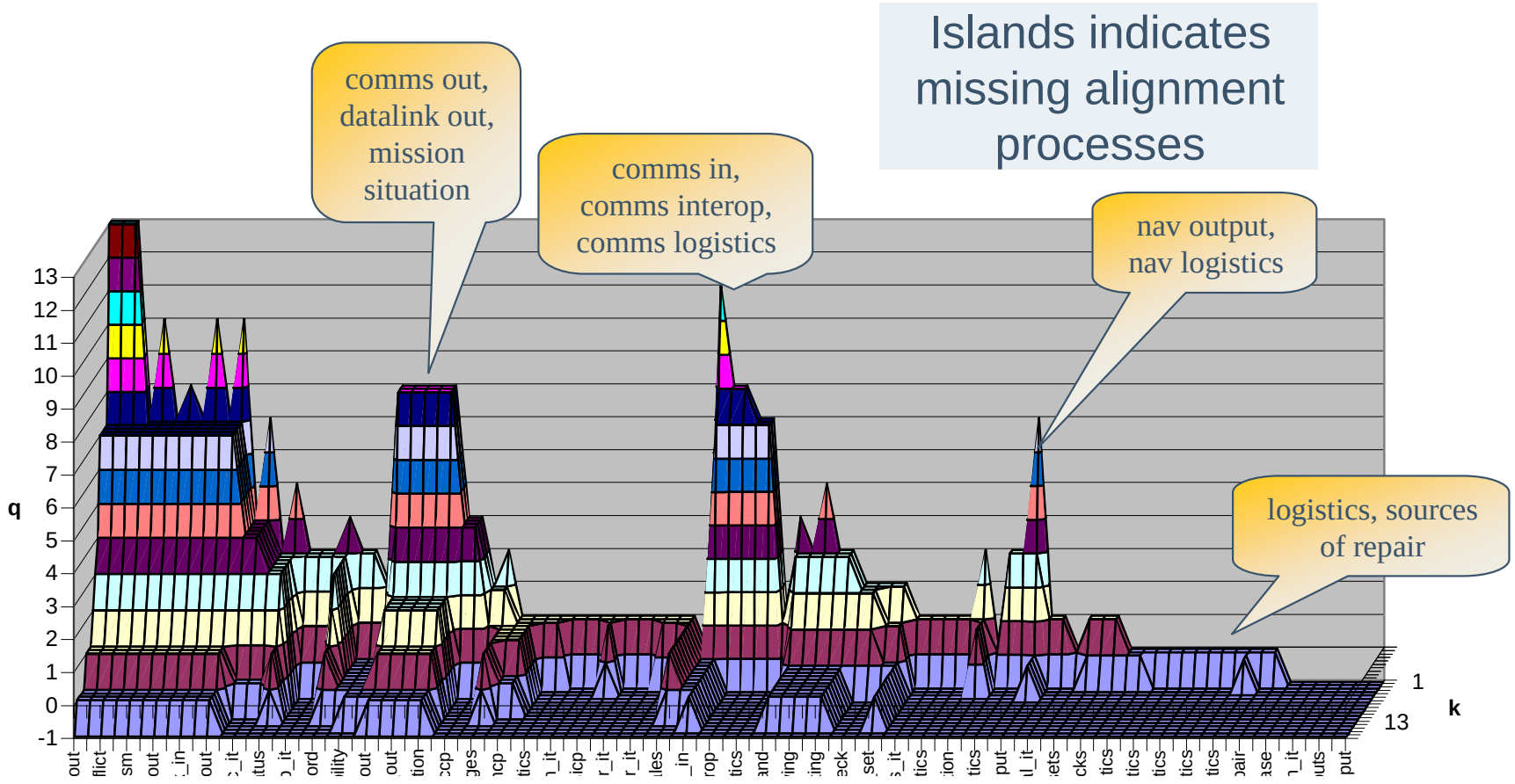
Analysis for Customization



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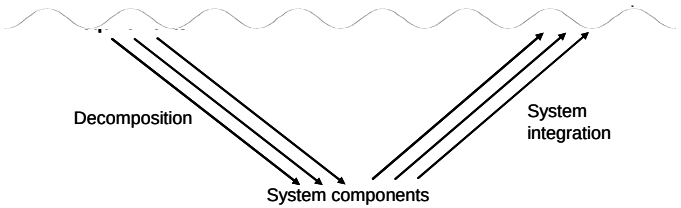
Putting It Together

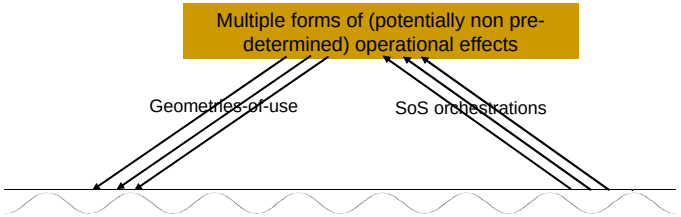
Where were they?

- The organization was driven by an acquisition focus for systems with a pre-defined range of performance requirements.



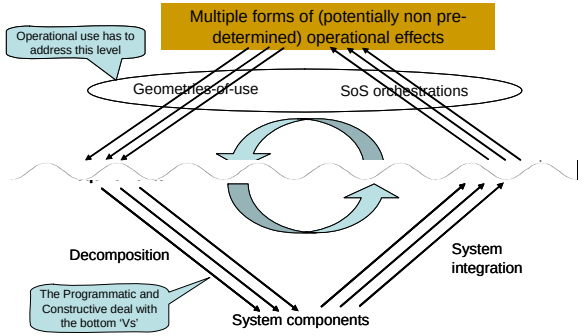
Where did they need to be?

- They needed to relate the current state of operational mission capability to its evolving role through its life.



What were the gaps?

- They had no effective way of managing this cycle as a whole.



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Summary

Systems of systems offer new opportunities and challenges

- Potential for greater range of composite mission capabilities orchestrated across systems of systems.
- Need for the ability to continuously extend and adapt an operational capability through its life as a part of a system of systems

This presents a double challenge—both the institutional alignment and the alignment to new and emerging forms of demand.

We can evaluate and characterize the gaps and risks by examining the forms of interoperability possible within a context.

Providing methods to “work” the double V as an integrated cycle can provide the means of mitigating risks arising from this dynamic (re-) alignment through the life of the military operational capability.

For More Information

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