Building Organizational Agility into Large-Scale Software-Reliant Environments

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***Abstract*— The tempo at which an enterprise creates new uses for its systems is different from that of its acquisition or systems development processes. The military continues to confront the issue of how fielded systems can support the agility needed by its deployed forces. This problem of diverging tempos applies to a variety of large-scale, software-reliant enterprises—such as those found in healthcare and digital communications. This paper posits four realities underpinning an approach to this problem space: the governance-demand double challenge, edge-driven perspective, stratification, and demand cohesion. It uses a particular case example to show how these concepts support the modeling and analysis of the enterprise as a socio-technical system of systems. The paper argues that analyses based on this approach are necessary for making this problem space tractable.**

Keywords-stratification; governance; organizational agility

I. INTRODUCTION

The Defense Industrial Strategy (DIS), published by the UK Government in 2005, sought to strike a balance between the need for complex, technologically challenging, and expensive systems and the need for agile and flexible forces that can respond effectively to varied challenges [1]. Of major concern was the ability to manage military capability on a through-life basis, centered on support, sustainability, and the incremental enhancement of existing capabilities.

A key driver of the DIS was the divergence of the tempos shown in Fig. 1. On the left is the tempo of acquisition through which systems are modernized, measured in years. On the right is the tempo at which counter-insurgency campaigns are being fought, measured in days. And in the middle is the readiness tempo, measured in months, at which the defense enterprise can generate the forms of operational readiness needed by its campaigns. Readiness is a key driver because of the increasing costs of the workarounds and urgent acquisitions made in support of sustaining an adequate level of operational readiness, in the face of accelerating campaign tempos.

An analogous point is made by U.S. Secretary of Defense Robert Gates, in contrasting the pursuit by conventional modernization of 99% solutions in years and the demand for 75% solutions in months for stability and counterinsurgency missions [2]. The need here is to build innovative thinking and

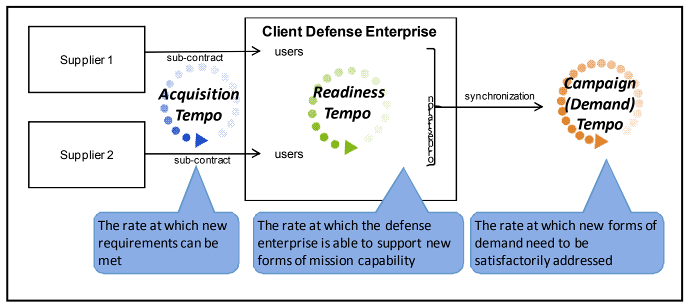

Figure 1. Diverging tempos

flexibility into rigid procurement processes, enabling strategy and risk assessment to drive procurement rather than the other way around.

The defense enterprise can be characterized by the challenges of managing, engineering, and operating in these large-scale, software-reliant environments faced with highly variable demands. Capability gaps have to be defined in terms not only of the *most stressing tasks* facing a particular capability in a specific scenario [3], but also of the *variety of uses* that need to be supported, for example the variety of operational tasks for which an interoperating unmanned aerial vehicle (UAV) can be applied.

The flexibility with which a capability can interoperate within these varieties of use corresponds to the need for multiple forms of collaboration distributed across shared underlying infrastructures, a need that is faced by many large-scale, software-reliant organizations as they seek to respond to changes in their customers' demands [4]. The greater the ability to support distributed forms of collaboration, the more agile the enterprise can be in supporting campaign tempo [5].

How, then, is the defense enterprise to relate the flexibility of individual capabilities to its overall agility, and in particular how is it to attach a value to the impact which that flexibility can have on the overall agility of the enterprise? To be able to define and manage this problem, this paper posits four realities that need to be addressed [6] and uses a case study concerning the use of UAVs to exemplify each reality. The four realities are as follows:

1) Governance-demand double challenge: The problem space in which the defense enterprise finds itself is larger than that defined by the traditional process of acquiring capabilities from suppliers. This space must be described in terms of a double challenge that includes acquisition-readiness collaborations and the changing nature of their relationship to demand.

2) Edge-driven perspective: The changing nature of their relationship to demand requires that the collaborations across the enterprise be driven by those demands—that is, be demand- or edge-driven [7] and distributed. This means that characterizing the larger problem space must include an edge-driven perspective.

3) Stratifying the relation to demand: This edge-driven perspective leads to making a fundamental distinction between hierarchical (traditional chain-of-command authority structures) and stratified (edge-driven, agile readiness, including the authority to reconfigure rapidly) ways of organizing. As a result, there are implications for the types of engineering approaches needed to support the latter.

4) Demand cohesion: In order to give an analytical account of stratification, the larger problem space must be modeled as a socio-technical system. This modeling must give an account of the socio-technical system's ability to generate demand cohesion (i.e. effective alignment of multiple demands within the enterprise's capabilities), as well as of the more familiar concepts describing the quality attributes of its supporting infrastructures.

II. GOVERNANCE-DEMAND DOUBLE CHALLENGE

Current acquisition effort in the U.S. Department of Defense focuses on producing a definable product for which the Program Management Office is accountable as a supplier to the client defense enterprise. When fielded, this product will form part of a solution to some problem that the defense enterprise has (or had).

Looked at from the perspective of the defense enterprise, however, there are two dimensions to consider, defining a double challenge: (i) the form of governance framework within which accountability is created for performance across one or more enterprises for what is supplied (i.e., the role of the Program Management Office) and (ii) the ways these forms of governance framework are organized in relation to the demands being placed on the defense enterprise [8]. This double challenge is represented by the bottom versus the top halves of the double 'V' in Fig. 2.

Applying this thinking to the UAV case, the background was a requirement for modernization that had been formulated against cold war expectations and against a timescale of decades over which this requirement would be fulfilled. In these terms, value for the defense enterprise was to be created by the bottom half of the double 'V' in Fig. 2—the familiar engineering 'V' of the supplier [9]. The top 'Λ' represented the way individual capabilities were then orchestrated and synchronized by command to generate effects at campaign tempo, with the downward part of the top 'Λ' representing the processes by which capability gaps were identified in relation to both the 'most stressing' use and the 'variety of uses'.

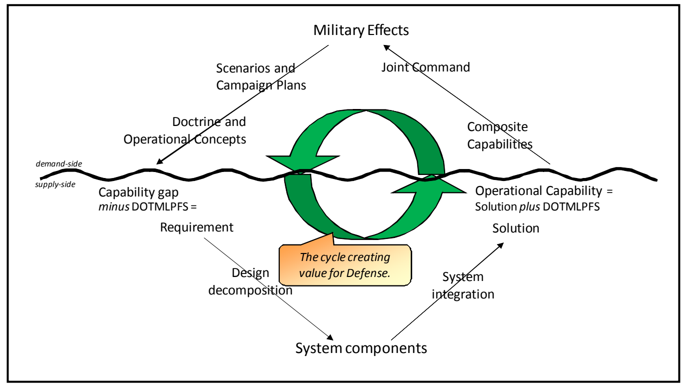

Figure 2. The double challenge as a double 'V'

Looked at from the point of view of the demands being faced in current theatres of operation, the needed UAV solution was changing in ways not reflected in the requirement. Significant elements of these demands could have been met by introducing more flexibility into the original requirements, within the context of managing the double 'V' in terms of through-life management of the capability. But this flexibility was excluded for reasons of adhering to budgets set on the basis of separating the two halves of the 'V'. The double challenge was therefore met by the defense enterprise in the top half of the 'Λ' through workarounds and urgent acquisitions, the effect of which was greatly to increase the cost of the capability.

The readiness tempo of which the enterprise is capable reflects the way it addresses the double challenge in aligning its available capabilities to demands. The increase in cost reflected the absence of a way of valuing supplied flexibility in the bottom half of the 'V' in relation to the potential variety of demands in the top half of the 'Λ'. To make the double challenge more tractable, there therefore had to be a means of making a more direct link between its two halves, starting from an explicit relationship to demand.

III. EDGE-DRIVEN PERSPECTIVE

The capabilities supplied from the bottom half of the 'V' in Fig. 2 become operational capabilities through being added to the *whole product* requirements associated with the capability. The U.S. Army calls these related aspects DOTMLPF [1] constructs. The seven DOTMLPF constructs are applied from the perspective of a single-client enterprise, but adding the relation to demand, represented by the double challenge, means adding in the implications of being edge-driven for the orchestration and synchronization of capabilities [10]. The edge-driven perspective is added in an eighth construct—*situational understanding* [11]—and by changing the emphasis of three of the constructs (organization, training, and personnel) so that they are explicitly edge-driven. Thus, a static organization becomes an active *edge organization*, training becomes *collective training* of the edge organization, and

[1] DOTMLPF is a term used in the U.S. Department of Defense. It stands for doctrine, organization, training, materiel, leadership and education, personnel, and facilities. The equivalent term in the UK is DLOD – Defense Lines of Development.

personnel becomes the *personnel culture* of the edge organization.

The resultant eight DOTMLPFS constructs are divided to reflect the double challenge, so that four constructs (doctrine, facilities, leadership and materiel) are driven from the traditional command hierarchy (the "center"), and the other four (edge organization, collective training, situational understanding, and personnel culture) are those that the center delegates to be shaped by the particular customer situations at the edges of the enterprise. The extent to which all eight constructs can be held in relation to one another through appropriate collaborative processes determines the nature of the cohesion in behaviors at the edges of the enterprise. The challenge is to give appropriate levels of attention to all eight, with the edge-driven constructs becoming increasingly important as the environment demands increasing levels of agility.

In the UAV case, close attention had to be given to the way the UAVs were being used operationally, interoperating with other assets to generate composite capabilities that could deliver mission effectiveness. The UAV itself contributed directly to situational understanding. But viewed through the DOTMLPFS constructs, not only did it become a part of a UAV system of systems [12], but also that system of systems had to be considered as explicitly socio-technical—an organization of both people and technology [13].[2]

IV. STRATIFIED RELATION TO DEMAND

The organization of people and technology is traditionally thought of hierarchically in terms of supervisor-subordinate relationships. The ability of digital networks to reduce commercial transaction costs and increase the external availability of modularized business capabilities has created a peer-to-peer alternative in the form of networked services [14]. Stratification provides a way of describing how this alternative form of organization aligns supplied equipment, people, and materiel to the ultimate desired effects on demand through intermediating layers of organization. These stratified service relationships are not of the hierarchical type "is-a-part-of", but rather of the type "is-used-by" [15], relating underlying technologies to ultimate customers' contexts-of-use. The use of this networked approach, with its supporting system-of-system infrastructures, is a fundamental enabler of the movement by defense enterprises towards a more net-centric, capabilities-based approach [16].

Such stratification provides an analytical framework within which to determine the kinds of engineering, governance, and processes needed to generate alignment in ways that are appropriately dynamic and agile. Six layers can usefully be distinguished, aligning the bottom layer of technological capabilities with the top layer of environments in which demands must be satisfied. These layers are shown in Fig. 3, with the bottom three being the supply-side layers corresponding to the lower 'V' in Fig. 2 and dominated by the acquisition tempo. The top three demand-side layers, corresponding to the upper 'Λ', are dominated by the other two tempos.

The content of these layers is shown for the UAV case in Fig. 3. This view placed the UAV equipment in layer 1 and the fielded equipment in layer 2, which, with the addition of the other DOTMLPF constructs, became an operational capability. On the demand-side, this operational capability became a part of an agile force structure in layer 4, which could be orchestrated and synchronized by mission command in layer 5 to generate decisive points in their campaign in layer 6. The value of this analysis of stratification lay in establishing the ways in which the lower strata needed to be aligned to the variety of uses they were to support in the upper strata, providing a basis on which to define corresponding forms of governance relationship [17]. The analysis underlying the stratification made it possible to identify the risks to being able to support the needed forms of alignment in the upper strata [18]. In turn, identifying risks provided a basis for changing the modularity engineered into the lower layers, which determined the flexibility with which the UAV capability could be used [19].

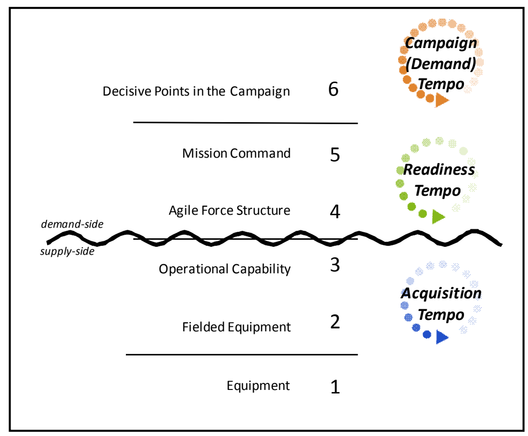

Figure 3. A stratification of the relation to demand for UAVs

V. DEMAND COHESION

In order to generate a stratification, the problem space was modeled and analyzed using a modeling approach that could represent all eight DOTMLPFS constructs in terms of how the supply-side and demand-side were aligned [20]. Any analysis of such a model would conventionally start from a perspective which uses two underlying concepts. One concept is to define the quality attributes expected of the underlying systems, rooted in the accountability and responsibility defined by the governance of the enterprise [21]. The other concept is rooted in how socio-technical functionality is itself defined and coupled with other functionality (i.e., the interoperability of functionality) [22].

Models based on these two concepts alone are not sufficient for defining a supply-side/demand-side stratification from an edge-driven perspective, however. A third concept must be used to describe the way supply-side behaviors in the lower strata are made to cohere around particular demands. It considers cohesion to be a property of the enterprise as a socio-

[2] To make this concept more generally accessible to non-DOD audiences, the constructs and analysis related to this perspective are being generalized within the SEI's SoS Practices Initiative.

technical system, analyzing the particular ways in which supply-side and demand-side layers are aligned to particular forms of demand within their actual contexts-of-use.

The agility of a force structure can be expressed in terms of the variety of forms of alignment between the supply- and demand-sides it can sustain for a given level of resourcing. One way of assessing the value of additional interoperability in individual capabilities is therefore to examine its impact on the economics of alignment. These economics can be analyzed in terms of the costs of demand cohesion: the costs of aligning the whole socio-technical infrastructure of the defense enterprise to a particular form of demand.

In the case of the UAVs, this analysis of cohesion was done for a particular decisive point in six different operational scenarios and used as a basis for analyzing the costs of cohesion. The changes in these cohesion costs, arising from changes in the flexibility-in-use of the UAV, were then used to assess the value of those changes in terms of their impact on the variability of campaign costs for the defense enterprise as a whole. The extent of any reduction in this variability across the variety of scenarios would be a consequence of the increase in force agility. Relating this reduction to changes in the interoperability of the UAV therefore provided the supplier with a means of attaching a value to that increase in flexibility, in this case a value that was as significant as the cost of the individual capability itself.

VI. CONCLUSION

To give an account of the way demands at the edge of the enterprise are satisfied, the problem space has to be modeled and analyzed to take account of the impact of three tempos: the way socio-technical functionality is defined relative to the enterprise, the forms of governance through which the enterprise is held accountable, and the way the behaviors of the enterprise cohere around particular forms of demand.

The resultant stratification presents an engineering challenge on two axes: first, the engineering of the underlying functionality and second, the engineering of the means of aligning that functionality to varying contexts-of-use under conditions of diverging supply-side and demand-side tempos. The paper has put forward four realities that must be addressed in making tractable the challenges of diverging tempos. Based on these realities, it has outlined an approach to modeling and analysis that takes into consideration the socio-technical nature of these enterprises.

The paper has outlined the use of these methods in a particular case. A major benefit of the analysis in this case was the abilty to attach a value to the impact of flexibility-in-use of the particular capability on the agility of the force structure as a whole.

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