Software Engineering Institute

Valuing Multi-Sided Systems

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Executive Summary

If the most significant discovery of the last century was truly the individual, then what marks the early part of the current one is the integration of disparate systems and services to meet the particular needs of the individual in his/her particular context. This is the chief challenge facing enterprises as disparate as Defence and Healthcare as the cost of covering all eventualities from the perspective of the systems themselves becomes unaffordable and the costs of workarounds demanded by operational experience escalate to unacceptable levels.

The emergence of the individual compels enterprises such as Defence to look into their activities much more from the perspective of the markets they serve than from the perspective of the systems and platforms they procure and field. In the past, Defence could be conceived of in terms of (1) the equipment procured and the complementary lines of development that deliver capability and (2) the sustainment of the services to perform some range of missions against a portfolio of operational types, and (3) a budget for those areas. However, the increasing tempo of changes in operational assumptions and the inexorable rise in expenditure from contingency budgets has demonstrated that a conception of the Defence Enterprise from the perspective of the operational context is more appropriate for assessing both its cost and the value it delivers. This has led to the need for an approach to the through-life management of operational capabilities that depends not on the through-life management of particular systems or equipment, but on the through-life management of the ways systems and equipment may be combined to form operational capabilities.

The linking of the two concepts of cost and value forms the basis of all commercial transactions. Whilst the absolute value of Defence is difficult to assess in purely monetary terms, the cost is much clearer in human and fiscal terms. However, reductions in the cost of providing the same effects may be linked to the costs of securing such reductions, and thus a commercial transaction may be conceived. This is the premise of this report, which evaluates trades in a variety of missions to arrive at a means of ascribing value to collaborations of equipment—the goal for Network-Enabled Capability (NEC)—and thus to ascertain the maximum price that should be paid for flexibility in the collaborating systems. The result is an economic basis for the through-life management of operational capabilities.

Whilst the report has drawn on rough orders of magnitude (RoMs) for costs—no access was available to endorsed government figures—it nonetheless presents both a method based on real option pricing and illustrates this with such RoMs to show how the concepts of value for Defence, agility, and flexibility in design may be evaluated.

Abstract

The report examines the challenges surrounding Through-Life Capability Management where operational capability is not dependent on any one type of platform or equipment, but rather constitutes a composite capability generated through collaborating system of systems. It presents a multi-sided market framework for describing the relationship between composite capabilities generated in this way and the supporting role of its suppliers. This framework defines costs of alignment as the costs incurred by a user in bringing the collaborating systems together operationally to meet particular demands. These costs of alignment are demand-side costs, and the report describes the use of real option valuation methods to establish the value of changes in these demand-side costs of alignment arising as a consequence of introducing new supply-side flexibilities.

1 Introduction

The previous report on *What Price Agility?* identified the nature of the competitive advantages open to Industry in taking up a relationship with the UK Ministry of Defence (MoD), based on Through-Life Capability Management (TLCM) (Boxer, What Price Agility? 2009, 1-8). This relationship was relevant to acquisition situations in which there was a need for a continuing provision of military capability, of which the report argued there were two kinds:

- **TLCM**, being those situations where the military capability could be identified with particular platforms or equipment and, therefore, could be managed in terms of the life cycles of those platforms or equipment (for example Tactical or Strategic Lift); and
- **TLCM+,** being those situations where no such identification was possible (for example Dabinett, a system of systems intended to enable persistent collection, processing and dissemination of near real time ISTAR[1] data in the deep battlespace).

A system of systems (SoS) may be termed as such when its component systems fulfill valid purposes in their own right and continue to operate to fulfill those purposes if disassembled from the overall system, and the component systems are managed (at least in part) for their own purposes rather than the purposes of the whole (Maier 1999). From an acquisition perspective, the difference between TLCM and TLCM+ has remained unresolved because while it was clear how to acquire a major system from a Tier 1 supplier on a TLCM basis, it was not clear how an SoS might be acquired, other than by treating it as another major system (for example treating an aircraft carrier as a single autonomous system). Thus it became unclear what was being acquired when the viably independent component systems participating in an SoS were separated from the interoperability and alignment issues associated with their composite uses. This has left unresolved the post-acquisition challenges peculiar to sustaining the dynamic alignment of an evolving SoS to *operational demands*, which themselves are subject to change.

When looked at from this post-acquisition perspective of the ongoing planning of military operations, this TLCM acquisition focus on a Tier 1 basis placed constraints on the ways component systems could be composed to meet changing campaign demands. This occurs because demands were not identified in the original requirement, or the variety of supportable compositions was traded out in the early stages of the system design. Given the accelerating tempo at which these new types of demand were emerging, the resultant costs of aligning existing operational capabilities to them could be very high. (For example the costs of meeting urgent operational requirements that could have been met by Uninhabited Airborne Vehicle (UAV) capability were of the same order of magnitude as the cost of planned UAV capability itself over its whole life).

The need for TLCM introduced by the Defence Industrial Strategy (DIS) in December 2005 (Defence White Paper 2005) ushered in a second epoch (Epoch II) in the MoD's relationship to Industry, the first epoch (Epoch I) having been defined by the earlier introduction of Smart Acquisition in 1998, which addressed equipment. The report argued that a practical approach needed to be formulated to TLCM+. And until there was a practical approach, a third epoch (Epoch III)

1 ISTAR is Intelligence, Surveillance, Target Acquisition, and Reconnaissance.

could not begin, in which distinct practices could emerge that were particular to the acquisition of systems of systems in their own right (Boxer, What Price Agility? 2009, 20-33).

The aim of this report is therefore to propose a practical approach to TLCM+, drawing on three innovations within the framework provided by multi-sided markets (Evans, Hagiu and Schmalensee 2006):

1. Defining composite mission capabilities as collaborations between multiple operational capabilities across systems of systems. The particular configurations of relationships between individual operational capabilities needed to support these collaborations are defined as *geometries-of-use*, so that the agility of a force deployed to theatre can be defined in terms of the variety of these geometries that it can support at the campaign tempo (Boxer, Morris and Anderson 2008).
2. Introducing a distinction between Activity-based Costing (ABC) used for supplied products or services (Kaplan and Anderson 2004) and *Cohesion-based Costing* (CBC) that includes the demand-side costs of alignment associated with these geometries-of-use (Whittall and Boxer February 2009). The use of CBC involves costing of the way particular geometries support cohesive collaborations, in addition to the ABC-defined costs of their independent parts.
3. The use of *real option valuation* to value the impact on the costs of alignment of new flexibilities in individual operational capabilities, the impact being on the costs of alignment of a deployed force across its expected variety of mission environments.

2 The Multi-Sided Market Framework

The *multi-sided market* is one in which the supplier is providing a multi-sided service to market participants that is more valuable than the market participants could capture on their own (Evans, Hagiu and Schmalensee 2006, 54). This value for market participants takes two possible forms, shown in the triangular relationship in Figure 1.

- There is value in the interactions between the supplier and each type of market participant.
- There is value in the interactions between market participants supported by the supplier.

One example of this triangular relationship would be between a credit card supplier, vendors, and credit card holders. Another would be between a mobile phone supplier, applications providers, and phone users (further examples extend to *inter alia*, hospitals, airports and sports clubs). In each case, value is created by the support given by the supplier to the relationships between different types of market participants as well as by the supplier's direct relationships with each participant. In each case, this value is greater than the participants could capture on their own.

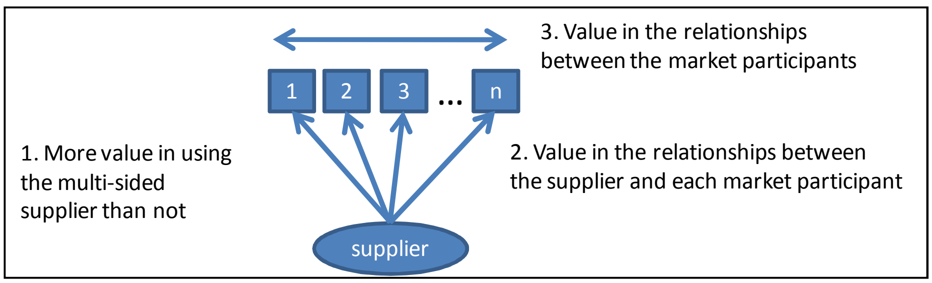

Figure 1: Defining Value provided by the Supplier in Multi-Sided Markets

These multi-sided markets are distinguished from one-sided markets where no value is attached to the relationships between different types of market participants. For example, in the report on *What Price Agility?*, the supplier was providing UAV systems. The first two generations in the use of UAVs were one-sided markets for the supplier, meaning that the supplier only had one customer—the artillery unit alone in the first generation and the artillery unit supplying Divisional command in the second. In both cases, the way the UAV could be used was "hard-wired" into its design as a means of providing forward observation to its customer. Only with the third generation in the use of UAVs did the market supported by the UAV system become multi-sided, the market's participants becoming the various different forms of collaboration between soldiers on the ground, airborne strike, HQ command, UAV platforms, and sensor and communications providers that could be supported by the UAV system. What made the third-generation use of the UAV market multi-sided was the value of the support the UAV system could give to the variety of these collaborations, this becoming as important as the original functionality of the UAV itself as a flying "eye-in-the-sky." Thus, through buying a service defined as hours of flying airborne sensors, the value of the information increased as it became available to more users outside the artillery unit entrusted with operating it.

2.1 Users and Complementors

A collaboration within a multi-sided market enables the demands of some particular situation to be met. For the credit card supplier, this is the convenience and minimal risk associated with its way of enabling a purchase; for the mobile phone supplier, this is the ease with which communications are managed under all circumstances. Amongst the participants in such multi-sided markets, it is useful to distinguish two kinds of role that any given type of market participant takes up: *end-users* (for example purchasers, or the senders and receivers of text messages) and *complementors* providing services to the end-users enabled by the supplier (for example application vendors, or the message services, like flight change alerts). The multi-sidedness of the market comes therefore from the following:

- **A demand situation**, giving rise to the need for collaboration between end-users and complementors.
- **End-users**, needing to collaborate with each other in order to meet the demands of the situation.
- **Complementors**, providing services that add value to end-users' collaborations
- **A supplier's multi-sided platform**, both providing services to end-users and complementors, and enabling and supporting collaborations

These different aspects of a multi-sided market are summarized in Figure 2, the particular collaboration and its relationship to the demand situation being shown in red:

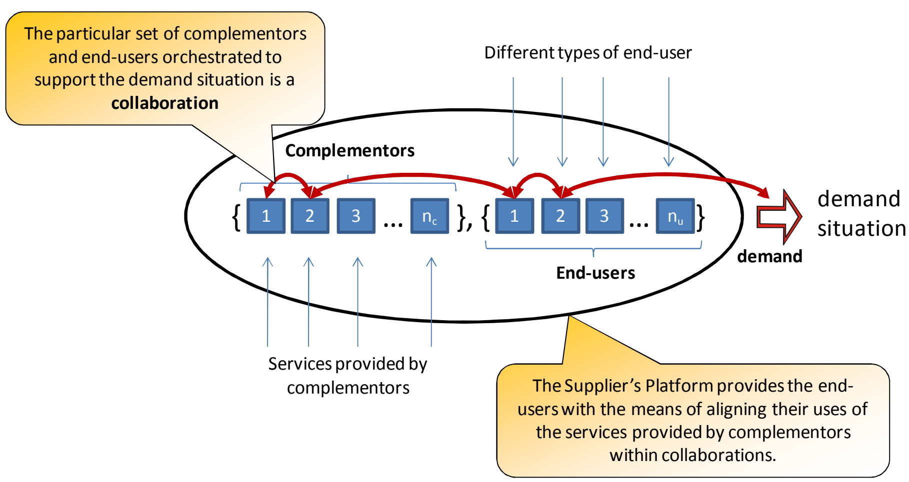

Figure 2: Defining a Multi-Sided Market

The comparison between the three generations of use of UAV systems (Boxer, What Price Agility? 2009, 36-39), and in particular the difference between the 'single-sided' first two generations and the 'multi-sided' third generation of use, can be summarized in these terms (see Table 1). In the case of UAV I, what was acquired was equipment to a specification—forward observation for artillery. In the case of UAV II, this became a solution to Divisional Command's need for intelligence. In both of these cases, there is a single end-user to whom the product or solution is being delivered. What made the difference in the third generation of use was the support for the UAV's multiple roles through the way the UAV systems support its interoperation with other assets and end-users. It is important to recognize, however, that this third generation use did not arise through intentional planning, but emerged in response to an urgent operational requirement.

Table 1: Summary of Market Characteristics of Three Generations of UAV System

	Single-sided		**Multi-sided**
	UAV I	**UAV II**	**UAV III**
Demand situations	Over-the-horizon targeting	Divisional Command's information requirements	Situations dependent on presence of persistent surveillance (e.g., interdicting fleeting targets)
End user(s)	Artillery Battery	Divisional Command	Soldiers on ground, airborne strike, synchronization command
Complementors	*No complementors because the only service provided is directly to a defined end user*		Strike assets, ground, airborne and space sensors, communications interfaces
Multi-sided platform	*Not multi-sided because only one end-user is supported*		UAV platform + systems supporting collaborations

Thus in the case of the third generation use of the UAV, while each variety of collaboration required its corresponding set of end-users and complementors, in practice the costs of aligning the geometries of some of these collaborations was very high. This was because of the *ad hoc* methods that had to be used to compensate for gaps in the ability of the existing UAV system to support them (one example was using reconnaissance aircraft to fill gaps in communications capabilities, another using substitute UAVs to bring different sensors into theatre). These costs of filling gaps in current operational capabilities and aligning particular geometries so that they could be used operationally were defined as *cohesion costs.* The cohesion cost of each particular geometry-of-use was the cost of the particular composite operational capability it provided, including any one-off costs incurred in compensating for gaps in existing capabilities. From the multi-sided market perspective, these cohesion costs therefore represented the current expenditure on the multi-sided market.

2.2 Assessing the Impact of New Flexibilities on the Value of a Multi-Sided Market

A major reason for the very high cohesion costs with the third-generation use of the UAV was the limited range of geometries that the UAV system could support due to inflexibilities built into the second generation requirement of the UAV, resulting from a one-sided view of the market. This is a systemic issue where the military equipment acquisition program is driven by the needs of the particular unit within an existing service (i.e., the Army, Navy, etc.) and by the concerns of the front-line commands and delivered through stove-piped Integrated Project Teams (IPTs).[2] Thus, the UAV is delivered to the artillery unit as the user community when, in fact, the user of the information product is a variety of commanders, units and even individual soldiers/airmen. At the time of its acquisition, although known about, this wider *variety of uses* had been left for funding on a contingency basis. The question therefore arose as to what value additional flexibilities the UAV might have had, had a multi-sided view of the market been taken. This is a key question for

2 Indeed, the different perspectives of (emerging) doctrine, legacy organizations, service imperatives, extant R&T, industrial capacity and competence, competition regulations and acquisition by IPTs against watertight contracts all conspire to narrow the definition of what is procured within a largely frozen requirement against which systems engineering processes are designed to drive out value as the contractor delivers the maximum return to shareholders through meeting the letter of the contract.

the military procurement organization which takes a single user view of the market. That is, it supplies to existing services and units according to their traditional remit. Thus, in the UK, 32 Royal Artillery Regiment mans Watchkeeper as the replacement for Phoenix, even though the system's capability as an ISTAR asset far transcends anything the Phoenix system could have delivered.

One way of evaluating the potential value of multiple alternative uses of a given capability is through Real Option Theory. Real option valuation considers the future spread of potential revenues for a given project, and the value of delaying an investment until there is greater certainty over whether there is sufficient positive 'upside' market revenue. For example, the factory is only extended when the test marketing has been positive (Mun 2006). This approach is used not only for investment projects (Luehrman 1998), but also for valuing options built into the way a system is designed, for example, the addition of new interfaces is only made when it is clear that there is going to be substantial demand for them (Sullivan, et al. 1999); (Ozkaya, Kazman and Klein 2007). To these alternatives, the report on 'What Price Agility?' (Boxer, What Price Agility? 2009, 34-39) added a third approach, in which a value could be attached to a reduction in the spread of future expenditures as a result of an investment. This provides a way of valuing the impact on the economics of different collaborations as well as valuing the impact of the trade itself (i.e., a way of valuing both forms of value in a multi-sided market).

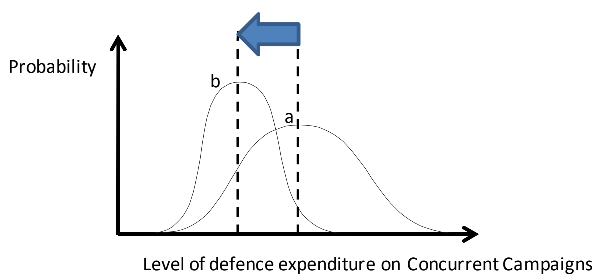

Figure 3: Real Option Valuation

In this third approach, the addition of new flexibilities, for example to the UAV system, would increase the variety of geometries that could be supported by it at the tempo required by the campaign, thereby making it more agile. The result would be to reduce the spread in expenditures generated by the variety of collaborations that had to be supported by the composite force. Thus instead of having to re-purpose other assets to meet the particular operational need, the need could be met by flexing the existing UAV system. The *difference* between the two curves in Figure 3 therefore represented a real option that (a) reduced the average defence expenditure through the reduced cost of using the UAV system instead of a more expensive asset (a 'trade'); and (b) reduced the future potential spread in defence expenditure as a result of the ability to support a wider variety of collaborations. These two values, the second of which is established by real option valuation, corresponded to the two kinds of value generated in a multi-sided market: the value from the relationship with the supplier and the value from the supplier's support of the collaborations between the participants.

2.3 TLCM+ Involves Creating Multi-Sided Markets

From the point of view of defence expenditure, the multi-sided market is a particular variety of collaborations with their supporting geometries-of-use corresponding to some number of composite capabilities not identified with particular platforms or equipment. The expenditures are associated with aligning operational capabilities to particular kinds of mission capability. The term *TLCM+* does not really capture the extent of this fully network-enabled management of composite capabilities, defined by the geometries-of-use that support the multi-sided market. The three epochs represent the acquisition focus moving from equipment through capability to agility, with agility being the ability to match particular geometries to campaign demands. From the point of view of a supplier, however, these collaborations are multi-sided markets in which new supplied flexibilities can reduce defence expenditures by increasing agility. The next section describes a worked example based on a mission capability of “interdicting fleeting targets.”

3 Valuing the Introduction of New Flexibilities in Multi-Sided Markets

The multi-sided market to be supported by the UAV system was defined by all the collaborations appropriate to "the interdiction of a fleeting target." Within this market, a number of different situations were isolated to identify its main characteristics, each demanding a different form of collaboration that could be defined in terms of the following:

- The decisive issue
- The concept of operations (intent, scheme of manoeuvre, main effort, end-state)
- The force components required
- Supporting and supported relationships between the force components
- The controlling time and space issues
- The necessary command and control arrangements

Defining this initial set of situations, with their corresponding sets of force components, was the first step in the analysis. The situations chosen are listed in Table 2.

Table 2: The Situations Chosen to Represent the Multi-Sided Market

Situation		Decisive Issue	Controlling Issue
1	Individual in Afghan-Pakistan border	Disrupts terrorist command	Hard to see, effects easy
2	Individual in Kabul Blue Zone	Disrupts terrorist command	Hard to see, effects difficult
3	Stinger missiles in Baghdad city centre	Neutralization of manoeuvrist threat	Hard to see, effects difficult
4	Shoot-and-scoot in tribal lands	Neutralization of manoeuvrist threat	Easy to see, effects difficult
5	Terrorist escape by sea	Disrupts terrorist command	Hard to see, effects easy

Given these situations representing the significant varieties of collaboration to be supported within the market, the subsequent steps in the analysis were then:

- Modeling the way these geometries generated effects and the impact on these geometries of changes in the flexibility of the UAV system
- Analyzing the cohesion costs for these different geometries
- Predicting before-and-after defence expenditures on the market
- Valuing the change using real option pricing

3.1 Defining the Geometries-of-Use

Each of the situations was modeled using projective analysis methods to identify the force components involved, the relationships between them, the necessary command and control arrangements, and the proposed changes in each geometry (see Table 3).

Table 3: The Changes in the Geometries-of-Use

Situation		Change in geometry
1	Individual in Afghan-Pakistan border	Reaper replaced by armed tactical UAV
2	Individual in Kabul Blue Zone	Reaper replaced by tactical UAV
3	Stinger missiles in Baghdad city centre	Apache replaced by armed tactical UAV
4	Shoot-and-scoot in tribal lands	Tornado replaced by armed Reaper
5	Terrorist escape by sea	Sea King replaced by tactical UAV

The result was the following set of models, each one describing a different collaboration within the context of the multi-sided market as a whole:

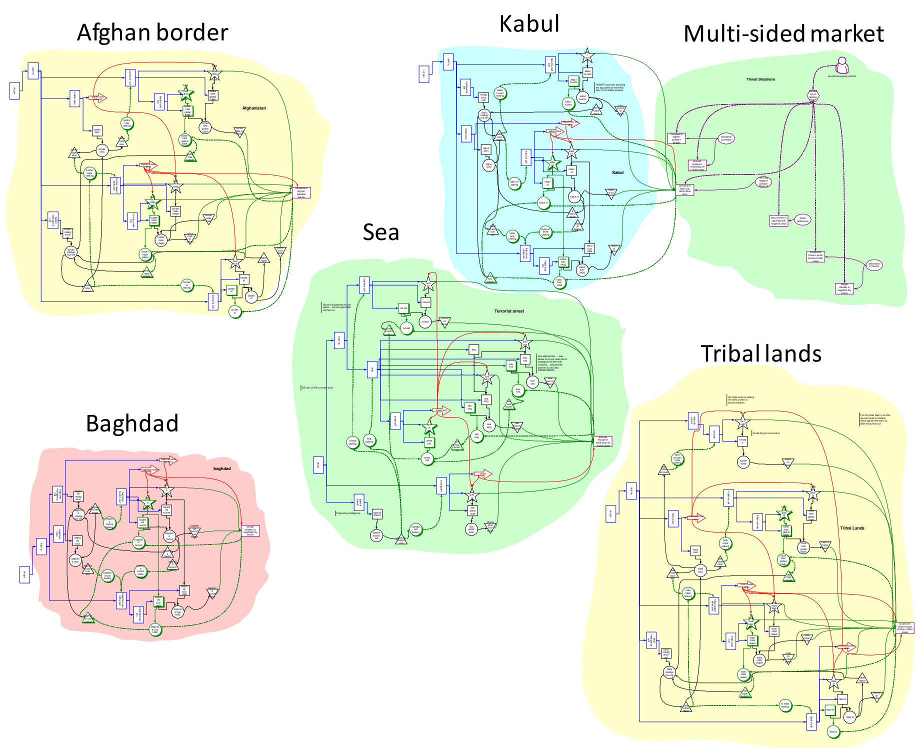

Figure 4: Models of the Different Collaborations

The particular force components used in each case are summarized in Table 4.

Table 4: Force Components used in Each Scenario

Situation		End-users	Complementors	Change
1	Afghan-Pakistan border	Soldiers on ground, Strike synchronization	High Altitude UAV, Medium Altitude UAV	Tactical UAV for Medium Altitude UAV
2	Kabul Blue Zone	Intelligence, Soldiers on ground, strike synchronization	Medium Altitude UAV	Tactical UAV for Medium Altitude UAV
3	Baghdad city centre	Intelligence, strike synchronization	Apache, Tactical UAV	Tactical UAV for Apache
4	Tribal lands	Soldiers on ground, Strike synchronization	High Altitude UAV, Medium Altitude UAV, Tornado	Medium Altitude UAV for Tornado

5	Escape by sea	Ship, Arrest synchronization	Nimrod, Sea King, Fast Patrol Boat	Tactical UAV for Sea King

The underlying relationships in these models formed a knowledge base of relationships defining and supporting the multi-sided market. These were analyzed for patterns in how they aligned the underlying capabilities and processes to the ultimate situations. This alignment was defined in terms of strata as follows:

Table 5: Stratification Layers

Layer	
6	Situations
5	Composite (mission) capabilities
4	Fielded force
3	Operational capabilities
2	Fielded capabilities
1	Equipment and people capabilities
0	The underlying levels of activity

The resultant stratified set of matrices derived from the knowledge base (see Figure 5) described both the content of each of these layers (matrices 1-6), and the relationships between the layers (the remaining matrices).[3] This analysis then formed the basis for the subsequent steps.

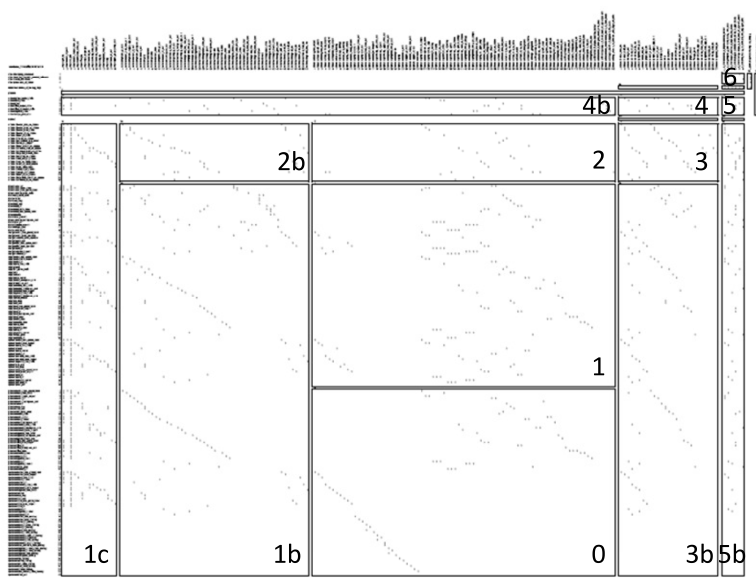

Figure 5: The Stratified Matrices

3 The cell entries in each matrix represent a particular relationship between the row and the column names. The row and column names themselves correspond to different objects and patterns derived from the models by the analysis.

3.2 Cohesion-Based Costing

An analysis of cohesion involves examining how these stratified matrices are aligned to a particular situation. This analysis of cohesion was therefore used as a template for analyzing how underlying costs were aligned to each particular situation, building up an analysis of costs as follows:

Table 6: The Build-up of Cost Analyses Across the Layers

Cost analysis		Output
Costs of alignment		
6	Costs of mission capability + costs of C4ISTAR synchronization (matrix 5b)	Cohesion Costs
5	Costs of operational capability + costs of orchestration (matrix 4b)	Costs of mission capability
4	Costs of Operational use (matrix 3) + costs of command (matrix 3b)	Costs of operational capability
3	ABC costing (matrix 2) + operational costs (matrix 2b)	Costs of operational use
Activity-based costs		
2	matrix 0 x direct costs (matrix 1) and overheads (matrix 2)	Activity-based costing (ABC)
1	Direct costs (matrix 1) + direct overheads (matrix 1b)	Direct costs
0	The levels of activity associated with each capability	Activity cost drivers

The overall cohesion costs are a combination of the activity-based costs captured in layers 0 to 2, and the costs of alignment captured in layers 3 to 6. When the actual scenarios were analyzed in terms of the before and after geometries in Table 7, this resulted in the following:

Table 7: Comparing Activity-Based and Alignment Costs

Situation		Activity-based cost		Alignment cost	
		'before'	**'after' as % of 'before'**	**'before' as % of ABC 'before'**	**'after' as % of 'before'**
1	Afghan-Pakistan border	100	-41	1.1	-12
2	Kabul Blue Zone	100	-90	2.0	-39
3	Baghdad city centre	100	-30	13.1	0
4	Tribal lands	100	-20	1.2	-26
5	Escape by sea	100	-2	0.1	0

The changes in 'escape by sea' and 'baghdad city centre' (lines 5 and 3 in Table 7) did not affect the costs of alignment (0 in the last column), and the base costs of alignment in 'escape by sea' were very low (0.1% of the 'before' activity-based cost) because they were organic to the operational command in the ships included as part of the ship's activity-based costs. In the other situations, even the highest of the alignment costs (in 'kabul' – 2.0%) were very low in relation to the ABC costs, even though the impact of the changes in geometry was substantial.[4]

4 Part of the explanation for this was because of the way the costs of alignment are built into the way the underlying capabilities and their costs are defined. A more detailed analysis of the different forms of collaboration would increase the proportion of alignment costs. For the purposes of this analysis, however, the aim was to establish how to value the processes of alignment between the participants in each collaboration.

3.3 Real Option Valuation

3.3.1 Predicting the variability of defence expenditure on the multi-sided market

The different kinds of situation associated with interdicting fleeting targets appeared with different frequency within different kinds of campaign. The relative frequency of these different kinds of campaign was estimated, and within each of these campaign types, the relative frequency of occurrence of the different kinds of situation was estimated. This data, combined with an estimate of the variability of these relative frequencies (summarized in Figure 6), was used to drive two Monte Carlo simulations, the first on the 'before' basis (see Table 3), and the second 'after' making the changes to the geometries supporting the situations. Each of these simulations themselves simulated the variation in campaign types and the variation in the mix of situations within each campaign type.

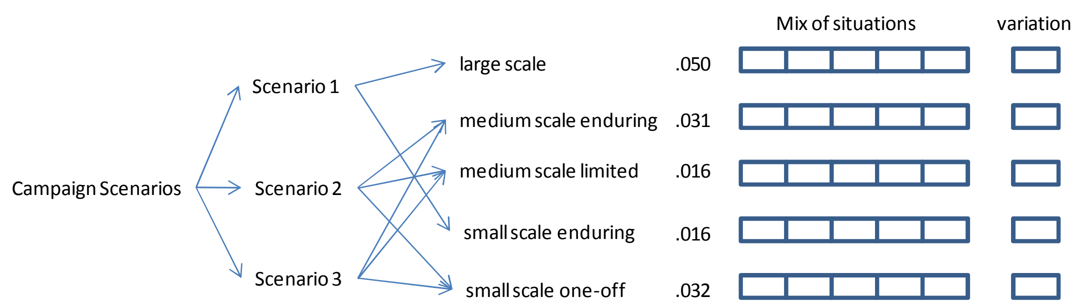

Figure 6: Predicting the Frequency with which Situations Occur Within Campaigns

The results of these simulations, each one based on 1,000 iterations, predicted variation in the occurrence of the different kinds of situation within a predicted variation in the occurrence of campaign types. Multiplying these occurrences by their cohesion costs (summarized in Table 7) provided estimates of annual levels of expenditure on this market. Normalizing their relative frequencies to normalize the areas under the graphs produced the graphs in Figure 7, summarized below in Table 8:

Table 8: Summary of Levels of Defence Expenditure

	'before'	'after'	difference
Average (£m)	385	244	140
Standard Deviation	230	143	88
90th percentile volatility	70%	70%	78%

The bimodal nature of the graphs in Figure 7 reflected the cost impact of differences in the mix of situations. The main characteristic of these graphs was the reduction in both the average and the spread of expenditures as described in Figure 3. The scaled difference graph in Figure 7 shows the levels and spread of potential reductions in expenditure within the market.

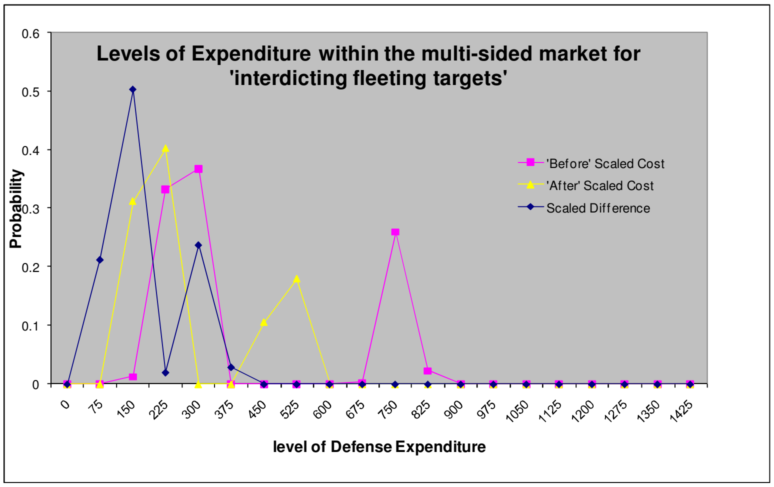

Figure 7: Levels of Expenditure within the Multi-Sided Market for 'Interdicting Fleeting Targets'

Part of the spread in these expenditures is generated by the reduced activity-based costs shown in Table 7 as a result of trading capabilities. The ability to use these cheaper capabilities is part of the benefit of the UAV platform. To establish as clear a view as possible of the value of reduced alignment costs in the overall cohesion costs, however, the alignment costs alone were also analyzed. Table 9 and Figure 8 show the corresponding figures and graphs:

Table 9: Summary of Levels of Defence Expenditure Relating to Alignment Costs Alone

	'before'	'after'	difference
Average (£m)	4.9	3.6	1.3
Standard Deviation	2.9	2.1	0.8
90th percentile volatility	74%	72%	83%

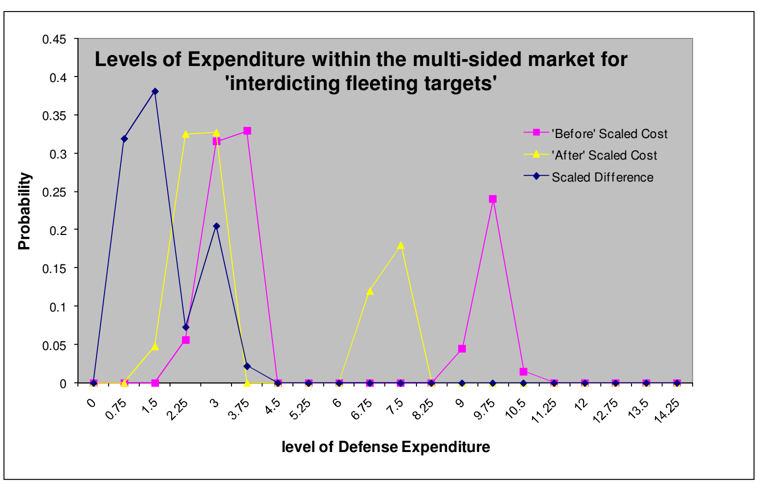

Figure 8: Levels of Defence Expenditure Relating to Alignment Costs Alone

These figures now provide the basis for valuing the multi-sided market.

3.3.2 Valuing the through-life savings

The valuation starts from a baseline defence expenditure on the through-life costs of the multi-sided market (the 'revenue' in Figure 9 of £3850m representing the through-life net present value (NPV) of the full 'before' operational costs of the mix of situations across the range of concurrent scenarios[5]).

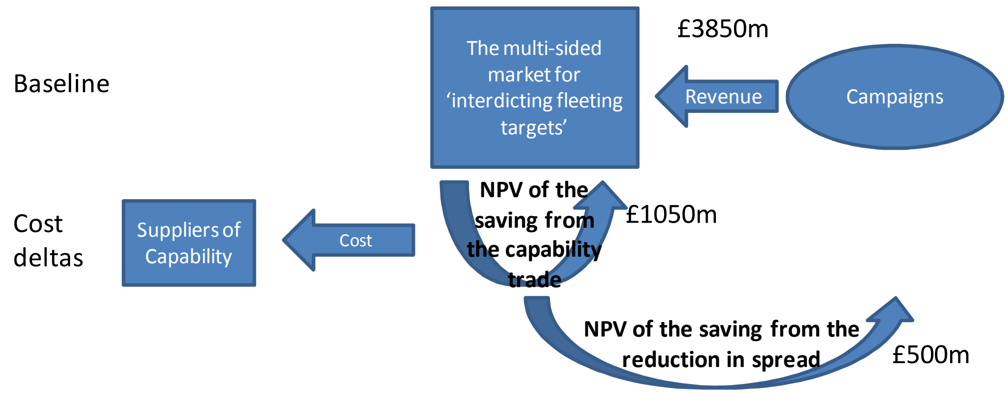

Figure 9: Real Option Valuation based on Through-Life Costs

The cost of moving to the 'after' geometries is then set to the through-life net present value (NPV) of the savings (£1050m), defining the ceiling on the price the supplier can charge for this value, and representing a potential maximum saving in costs to the multi-sided market6. The value of the reduction of spread is then shown as the through-life NPV of the reduction in spending on campaign costs relating to these situations (£500m).7 These figures are summarized in Table 10, together with the figures for the alignment costs alone:

Table 10: Summary of Savings

	Full cohesion costs	Alignment costs alone
Annual Costs (£m)	385	4.9
NPV of Through-Life Costs (£m)	3850	76
Annual Savings (£m)	140	1.3
NPV of Through-Life Savings (£m)	1050	10
NPV of Through-Life Savings in spread (£m)	500	5
Savings in spread/Total Savings	32%	30%

Thus the potential present value to HM Treasury of exercising this option in year 3 is a reduction in average expenditures of £1050m and an additional reduction arising from the reduction in the variability in expenditures of £500m on a baseline expenditure of £3850m—a total value to de-

5 This is the £385m annual costs in perpetuity at an annual discount rate of 10%.

6 This is the present value of savings of £140m annual costs in perpetuity from year 4 onwards.

7 The method of real option valuation chosen was the Black-Scholes method, this being considered adequate to establish approximate values. The time of expiration of the option to make these savings was set at 3 years, the discount rate set at 10% and the risk free rate set at 5%. The time horizon was set at 6 years, with costs and savings being set for 100 years. The stock price was set to the NPV of the savings, and the exercise price was set to NPV of these savings at the risk-free rate.

fence of £1550m. The monetary value that the supplier can capture by offering this option is therefore something less than this £1550m.

Looking at acquisitions in this way adds another kind of value for defence to the one currently used in evaluating substitutions in the tradespace. Establishing this additional kind of value associated with the multi-sided nature of the market then opens the door for acquisitions whose major impact is on the variability, and not on the substitutions—the characteristic of acquisitions enabling the greater interoperability of systems of systems.

The proportion of alignment costs identified in the analysis is about 1% of the full cohesion costs. Current methods of accounting mean that these alignment costs are understated since they are normally taken as activity overheads8. Whether considering the full cohesion costs, however, or simply the alignment costs, the reduction in the spread arising from the change in geometry facilitated by the UAV platform generates about one third of the total savings. With greater precision in the analysis of alignment costs, greater precision becomes possible in valuing the impact on them of new acquisitions.

3.3.3 The economics of TLCM+

TLCM+ involves systems of systems, the capabilities of which are not identified with any particular platform or equipment. The UAV system stands on the edges of TLCM+ as its role shifts increasingly from its airborne sensor function to its ability to support the alignment of multiple sensors and platforms in pursuit of a tactical objective. The mission capability of interdicting fleeting targets provides an example of this role, which can be described in terms of a multi-sided market framework as in Figure 10.

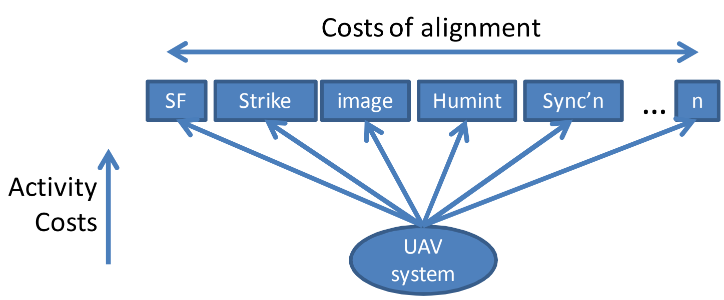

Figure 10: The UAV System as Supporting a Multi-Sided Market

Figure 10 shows the two kinds of cost that together define the cohesion costs for any particular collaboration. In the situations analyzed, the baseline annual expenditure in this market is £385m, the through-life NPV of which is £3850m. Introducing new flexibilities into the UAV system generates annual savings of £140m through the ability to substitute different component capabilities within the overall capability, the through-life NPV of which is £1050m. Of these average annual savings, only about £5m of the baseline annual expenditure of £385m relates directly to the costs of alignment (through-life NPV £76m). The annual savings on these are £1.3m, the through-life NPV of which is £10m. Thus the average savings arising from the UAV system are estimated at

8 The Sea King Integrated Operational Support (SKIOS) contract in another context may show the extent to which the costs of alignment implicit in the way a current system is organized may be very high.

about 27%, the proportion of which is allocated to alignment costs increasing significantly with better cost data.

In addition to these average savings, the through-life NPV of the reduction in the spread of expenditures as a result of the changes in cohesion costs is about 50% of the through-life NPV based on average savings, bringing the total saving up to about 40% of the baseline cost. The ratio of average savings to the savings from the reduction in spread is about the same for both the total cohesion costs and for the costs of alignment.

4 Conclusions and Recommendations

The analysis within a multi-sided market framework has shown how the costs of alignment can be identified independently from the activity costs. The combination of both of these forms of cost analysis in cohesion-based costing makes it possible to unify the analyses of acquisition and operational costs. The analysis has also shown how the introduction of a multi-sided UAV system reduces the variability in defence expenditure on these situations, adding value through the ability of the multi-sided approach to increase the agility of the force as a whole. The use of a 'real option' approach to this analysis shows how capital expenditures secure savings in both the absolute levels of operational expenditure and in the variability in operational expenditures.

The report has not sought access to endorsed actual costs, but has rather worked with rough orders of magnitude to test the hypothesis that real option pricing offers a means by which to ascribe a monetary number to value for Defence, assess the costs that may be incurred in delivering this value, and thereby construct the means for value for money transactions.

The isolation of activity-based costs and the introduction of cohesion-based costs together point towards evaluating the "NEC dividend" that arises from increased collaboration delivered by improved interoperability. If the NEC journey is constrained by the railway lines of legacy equipment, but driven by technological advance that enables collaboration, then the methods outlined in this paper and those that precede it offer a means to evaluate what should be spent on design flexibility to deliver what value for Defence.

This work offers a means for Defence departments to enumerate the value they deliver in terms set within the operational contexts of use and, thus, to better assess the true costs of delivering this value. Further progress in this will require the collaboration of such departments.

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Glossary

CBC – Cohesion-Based Costing 2

cohesion costs - the cohesion cost of a particular geometry-of-use is the cost of the particular composite operational capability provided, including any one-off costs incurred in compensating for gaps in existing capabilities. 5

complementors – the providers of services to the end-users enabled by the supplier (for example application vendors, or the message services, like flight change alerts) 4

demand situation – a situation giving rise to the need for a collaboration between end-users and complementors ...., 4

DIS – Defence Industrial Strategy 1

end-users – end-users of services in a multi-sided market (for example purchasers, or the senders and receivers of text messages)..., 4

geometry-of-use – the particular configurations of relationships between individual operational capabilities needed to support a composite mission capabilities constituted as a collaborations between multiple operational capabilities across systems of systems..., 2

MoD – Ministry of Defence.. 1

multi-sided market – a market in which the supplier is providing a multi-sided service to market participants that is more valuable than the market participants could capture on their own.......... 3

multi-sided platform – the means by which a supplier provides a multi-sided service to a multi-sided market. 4

NEC – Network-Enabled Capability ix

real option valuation – a means of valuing the impact on the demand-side costs of alignment of new flexibilities in individual operational capabilities, the impact being on the costs of alignment of a deployed force across its expected variety of mission environments.................................... 2

RoM – Rough order of Magnitude. ix

SoS – system of systems in which the component systems fulfill valid purposes in their own right and continue to operate to fulfill those purposes if disassembled from the overall system, and the component systems are managed (at least in part) for their own purposes rather than the purposes of the whole (Maier 1999).. 1

TLCM – Through-Life Capability Management in situations where the military capability can be identified with particular platforms or equipment, and therefore could be managed in terms of the life-cycles of those platforms or equipment (for example Tactical or Strategic Lift). 1

TLCM+ - Through-Life Capability Management in situations where it is not possible to identify the military capability with particular platforms or equipment (for example Dabinett, a system of systems intended to enable persistent collection, processing and dissemination of near real time ISTAR data in the deep battlespace) 1

tradespace - a multi-variant space for analyzing the complex tradeoffs in resource, costs and provisioning involved in large projects with multiple stakeholders and multiple objectives....... 15

UAV – Uninhabited Airborne Vehicle.. 1

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13. **ABSTRACT (MAXIMUM 200 WORDS)**

The report examines the challenges surrounding Through-Life Capability Management where operational capability is not dependent on any one type of platform or equipment, but rather constitutes a composite capability generated through collaborating system of systems. It presents a multi-sided market framework for describing the relationship between composite capabilities generated in this way and the supporting role of its suppliers. This framework defines costs of alignment as the costs incurred by a user in bringing the collaborating systems together operationally to meet particular demands. These costs of alignment are demand-side costs, and the report describes the use of real option valuation methods to establish the value of changes in these demand-side costs of alignment arising as a consequence of introducing new supply-side flexibilities.

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