The Anatomy of Command and Control: a Generic Functional Model

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Abstract

This paper addresses the challenge that alternative command and control (C2) approaches are required to maintain operation effectiveness in the increasingly complex operating environment, but that current doctrinal definitions of C2 are likely to be incompatible with the needs and characteristics of future C2 systems. The fundamental nature of C2 was explored through an examination of 'Purpose' from which the following definition was derived: a system of relationships and activities that ensure the purposefulness, coherence and effectiveness of collective action within an operating enterprise through the design, maintenance and regulation of operations. This was used as the basis for modelling the functions required to enact C2 and the dependencies between them. The result was a Generic Functional Model that codifies C2 in the widest possible terms such that the same framework can be used to describe any instantiation of C2 now or in the future. To facilitate this aim, an 'interpretive' approach was taken: the model does not rely on rigidly defined terms but rather expresses functional concepts that can be interpreted by the user to suit their application and context. It is anticipated that this will have utility for envisaging, developing and assessing novel C2 approaches.

1 INTRODUCTION

This paper describes work in which the fundamental nature of Command and Control (C2) was examined in order to provide a more appropriate foundation from which to explore alternative approaches that are better suited to the demands of the Future Operating Environment. It will offer a novel definition of C2 derived from a statement of purpose, and a 'Generic Functional Model' that aims to support the design and assessment of future C2 systems.

In an accompanying paper in this symposium, my co-author and I presented evidence based on Cybernetic Control Theory to support the hypothesis that a different C2 paradigm is required to address the increasing complexity of the operating environment [1]. This highlighted that 'variety reducing' [2] factors inherent in the force and the conventional approach to C2 are incompatible with the requirements for generating agency in complex circumstances. Examples of such factors include highly fixed and structured organisations, directive hierarchical relationships, deterministic planning, centralized decision making, and linear chains of command. In contrast, complex operations require the exploitation of a greater diversity of points and means of influence, with actors operating with greater freedoms to innovate and to adapt to local dynamic conditions. We proposed that this required a shift from *directive control* of a highly structured force towards *maintaining the purposefulness* of more independent and diverse networks of actions and actors.

Although our study provided a novel analysis, and highlighted variety as a parameter through which to visualize C2 requirements, it is not new to suggest that different C2 approaches are required to address operating complexity. Aktinson and Moffat previously invoked Cybernetics to argue for a 'transition from centralized, emergent management (the Industrial Age model) to decentralized, emergent management (the Information Age Model)' [3]. Alberts and others also came to similar conclusions in developing approaches such as 'Network Centric Warfare' [4] and the 'C2 Approach Space' [5]. More recently, complexity was cited as a major driver for change in the UK MOD publication, 'The Future of Command and Control' [6].

Despite what are effectively variety amplifying approaches being commonly discussed and the subject of active research, a recent survey by Grant demonstrated that alternative approaches have had comparatively little impact on the development of C2 doctrine. It stated that '…C2 doctrine has only weakly evolved over the past 25 years, adopting few of the concepts developed in the ICCRTS series.' [7]

One issue is that the *implementation* of alternative C2 approaches is far from trivial. They may be counter-intuitive to many because the co-evolution of the force

and the C2 system over centuries means that variety reduction is strongly embedded in military institutions. The required changes to C2 thus have profound implications for many other aspects of how the military organize and operate, including culture [1].

However, there is one aspect of this challenge that is fundamental to instigating change but which can be addressed in the short term. That is, how C2 is defined and envisaged. The term 'Command and Control' enshrines a concept that is appropriate for circumstances where a definitive end-state can be stated and there are relatively few and clear relationships of cause and effect to consider. This, however, is the antithesis of the ethos required for addressing complexity [7, 8]. This is further highlighted by the following NATO definitions where *authority* is the defining concept at the heart of Command and Control [9]:

***Command**: the authority vested in a member of the armed forces for the direction, coordination, and control of military forces.*

***Control**: the authority exercised by a commander over part of the activities of subordinate organizations, or other organizations not normally under his command, that encompasses the responsibility for implementing orders or directives.*

This is problematic as it does not allow for other forms of relationship that may prove to be beneficial. Furthermore, it largely excludes relationships with non-military actors from a genuinely integrated operating enterprise. If there is an ambition for better integration between military and non-military organisations and between different domains [6] then an understanding of C2 should embrace a greater diversity of actors and relationships.

It is often the case in writing about and discussing C2 that an assumption is made that everyone has a common understanding of what the term means. We are therefore in a situation where the concept has vague boundaries and also rapidly declining utility, particularly for a research community that is seeking alternative a pproaches.

Alberts and Hayes highlighted this issue in 2006 [5], and noted that earlier work to address alternative C2 approaches had 'occurred in close proximity to the status quo'. Rather than generating an absolute C2 definition, they offered a range of attributes of C2 as 'trail markers' for a more open consideration of what it could involve. Importantly, the value of a *generic model* that could encompass many different ways of instantiating C2 was established. This gave rise to the 'C2 Approach Space' that captured different C2 modes based on dimensions of decision rights allocation, patterns of interaction, and information distribution.

The problem of C2 definitions was more recently acknowledged by the UK MOD Development, Concepts & Doctrine Centre, which proposed an alternative [6]:

A dynamic and adaptive socio-technical system configured to design and execute joint action.

I would argue that this is also unsatisfactory as it includes the *execution* of action which makes it closer to a definition of an operation. If using such a definition to assess C2 system effectiveness, one would necessarily include the performance of force elements in delivering effects. The connection of this with *C2 effectiveness* is uncertain in any given situation.

The work described in the current paper arose from an exploration of the fundamental nature of C2. Although numerous models of C2 already exist, it was in part an exercise to investigate if C2 could be articulated in a way that actively encouraged and supported practitioners in consideration of alternative approaches. This acknowledges that it can be difficult to envisage change when a particular world view is thoroughly ingrained in an institution. It thus sought to move the debate away from doctrinal definitions or how C2 is currently enacted.

A second aspect of this work is that we have developed theory and methodology based on Cybernetics that aims to support understanding of complex situations and the design of appropriate responses - The Variety Calculus [11, 12]. The methodology is intended to help people think differently and to envisage their situations and options in more constructive ways. Some aspects of this approach was applied here to exploring C2.

The outcome of this study was a novel statement of the purpose of C2, more rigorously defined boundaries around the concept of C2, and a Generic Functional Model that captures the essential activities and relationships between them. This provides a framework that describes what C2 *could be*, including ideas that have yet to be formulated. It is not therefore a model of doctrinal C2 *per se*, but of some other concept that could in the future fulfil the current role of C2 and which includes conventional C2 in its set of possibilities. Regardless of this, we will continue to label this concept 'C2' for the sake of consistency while acknowledging that the name may not be appropriate.

It is hoped that this work may contribute to the future development of C2 in two main ways. Firstly, it will provide a framework that helps people to envisage C2 activities and relationships in ways other than through

conventional practice. Secondly, it may be used to support the assessment of a diverse range of C2 systems, including novel proposals.

This paper firstly describes how the nature of C2 was examined by exploring its purpose, before using this as a basis for establishing a C2 definition and boundaries for the C2 system. These enabled the core functions of C2 to be identified and a model architecture developed that is capable of capturing any potential C2 system regardless of how C2 is implemented. The nature of the model and key information to aid the user to understand and implement it are discussed before covering the generic C2 functions in greater detail.

2 THE APPROACH

An exploration of the C2 concept was initiated in a workshop that was attended by representatives of three of the UK stakeholders in the development of future C2 – the Development, Concepts and Doctrine Centre, Strategic Command Joint Warfare Directorate, and the Defence Science & Technology Laboratory. The 'Variety Calculus Purpose Method' [12] provided a structured approach to constructing a robust and concise purpose statement for C2 through a facilitated debate and challenge process. This considered *why* C2 exists rather than *what* it is, *how* it is done, or *who* does it. It therefore provided a novel foundation for capturing the fundamental nature of C2.

The purpose statement was then used as a basis for identifying the activities that are required to enact that purpose through an 'activity modelling' approach [10]. This starts at a high level of abstraction and works towards greater detail, using each activity as a purpose in its own right for the identification of further subordinate levels of activity. The dependencies between activities were identified and the model was constructed by mapping the activities and dependencies.

The original output provided a first level mapping that was subsequently developed outside the workshop. The initial model was subject to review by various subject matter experts and revised accordingly. It was also tested in association with observing an operational level headquarters exercise. The version reported here is the most recent at the time of writing (Version 7), but it will continue to be adapted as experience with its use provides further insights. Users are encouraged to adapt it for their own requirements and the author is happy to receive comments and suggestions for future amendments.

3 WHAT IS C2?

The purpose statement that was derived from the original workshop study is provided below. C2 can thus be defined as a system of activities and relationships to deliver this purpose.

The purpose of C2 is to ensure the purposefulness, coherence and effectiveness of collective action within an operating enterprise through the design, maintenance and regulation of operations.

It should be noted that C2 is considered here to be *a system*. This implies that it is a coherent entity that is distinguishable from its environment and has its own characteristics and behaviours. It should therefore be possible to draw clear boundaries between the C2 system and other systems and activities associated with headquarters and operations. The relationships between the system components are what determines its coherence and gives rise to its specific characteristics in a given instantiation.

This statement also places C2 in the context of 'operations' and can thus be taken as distinct from management activities in other contexts, such as capability development. An operation is here intended to mean a formally declared and coherent set of activities designed to fulfill a defined and bounded purpose.

The 'operating enterprise' describes the entire collection of entities that are engaged in collective action regardless of their affiliation and the nature of the relationships between them. It is not therefore limited to military organisations or the military 'chain of command'. This was intended to be inclusive of modes of operating that integrate military and non-military actors. It is assumed that all entities included in the enterprise are working towards the same higher-level purpose, although their individual or local aims may vary within this wider context. 'Purpose' thus became a key concept for defining and cohering an operation, the operating enterprise, and the relationships between actors.

'Design' is a decision process in which a operation solution or response is identified. It is intended to convey not only activity planning *but also the design of organisational structures, processes and relationships*. Design may also refer to the design of the C2 system itself.

To ensure clear boundaries between the C2 system and other operational or headquarters activity, it was decided that *the C2 system does not engage directly with the operating environment but operates solely through other entities that do so*. The analogy is with the human central

nervous system. This is the main regulator of human action but its interaction with the environment is mediated by eyes and ears for providing information and arms and legs for action. Information is thus supplied to the C2 system by 'sensors' and actions are delivered by 'effectors', neither of which form part of the C2 system but are essential to its function. This provides a simple and pragmatic approach to differentiate the C2 component within the wider context of C4ISTAR and other headquarters activity. It also emphasizes that not all activities conducted by commanders or headquarters staff are necessarily components of C2.

4 C2 Model architectures

The predominant architecture employed by the military is a hierarchical power structure that operates in a directive manner from superiors to subordinates. However, it is necessary that a generic description of C2 is capable of representing other possible architectures, such as looser networks of relationships. C2 systems are here envisaged as a collection of 'nodes' that carry out C2 functions, and the relationships between nodes. The character of any particular approach to C2 is determined by:

- The structural arrangement of nodes,
- The nature of the relationships between nodes,
- The manner in which the functions are instantiated within nodes.

The majority of C2 relationships are between C2 nodes, although each may have direct inputs from sensors. There must ultimately be an interface with effectors that take action in the environment, but this boundary may be vague in practice. In the context of conventional operations, a Divisional Headquarters will communicate with a Brigade Headquarters. Both of these entities are C2 nodes while the fighting personnel and platforms associated with the formations are effectors. However, the commander of a tank may also be considered a C2 node.

Note that the designation of nodes, sensors and effectors refers to a *role* within the operating enterprise and is not a fixed characteristic of a given actor or organisation. For example, a commander who meets with local civilian leaders in order to influence them is acting as an effector. If they are also gathering intelligence to support situational awareness then they are acting as a sensor. Neither act is part of the C2 system according to this definition, regardless of who does it.

5 Node functions

It is necessary to distinguish between headquarters activities that are part of C2 and those that are not. The first iteration high-level functions derived from the modelling process are illustrated in Figure 1.

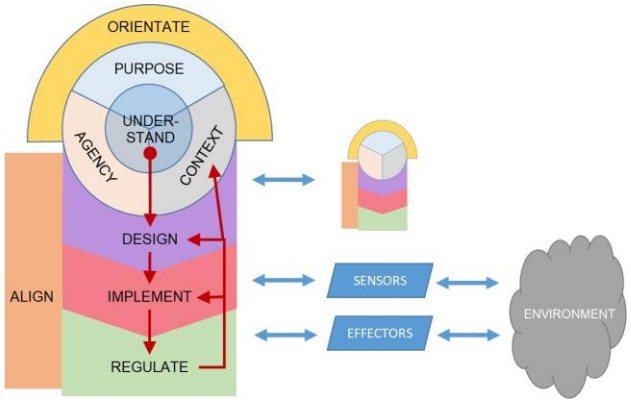

Figure 1: A high-level representation of the functions that constitute a 'C2 node'. The red arrows illustrate the feedback loops through which operation design can adapt to changing circumstances and that contextual understanding, operation design, and design implementation can be modified through experience and learning.

The decision was made to use non-conventional language to describe C2 functions in order to mitigate the risk that conventional terms could lead to an assumption of what the function means and how it should be conducted. *The function descriptions provided are intended to be illustrative of the general concept that they represent and must be interpreted for the specific context in which the model is used.* The language in which they are expressed here is not intended to be restrictive or definitive. The limitation of words and their interpretation is acknowledged and so the debate engendered by precise definitions is avoided by a more interpretative modelling approach. This makes the model more flexible in application, opens the way to considering a range of approaches to delivering each requirement, and enhances the exploration and interrogation of existing C2 systems.

The high-level functions are described as follows.

Orientate. This is the function through which a C2 node is incorporated into the operating enterprise or otherwise establishes a 'licence to operate'. It includes acquiring an understanding of their role and position within the enterprise, the structure of the enterprise, and the higher level purpose of the operation and the purpose of other associated actors. It is *enterprise awareness* rather than situational awareness.

Understand. Generating an understanding that provides a basis for designing a response to the situation. This is a

consolidated understanding that reconciles three different elements. **Purpose** - although all nodes will conform to a higher level purpose of the operation as a whole, each will require a more specific and localised purpose that is relevant to its own role, activities and situation. **Context** - understanding the operating situation in the context of the operation purpose. **Agency** - understanding and acquiring the means that are available or are required to deliver the node's purpose. 'Agency' could include capability, influence, authority and resources. The node can only deliver effect through relationships with effectors and acquires such relationships through this function.

Design. A decision process that determines the node's response to its situation. This involves reconciling Purpose, Context and Agency and devising a feasible response to the operating situation in terms of actions and organisation design.

Implement. Putting the design into practice through relationships with other entities within the operating enterprise, and ultimately with effectors that can take action within the operating environment. Implement can also include node activities that are part of the designed response, such as targeting, synchronising and resource allocation.

Regulate. Ensuring the continued effectiveness of the design and its implementation through a process of assessment, learning, and modification.

Align. Conducting relationships with other nodes where this is required to ensure enterprise coherence. This may involve various activities depending on the relevant relationships, including sharing information, coordination, or co-creation.

Node functions incorporate various regulatory feedback loops that ensure the maintenance of operation effectiveness and viability. The main operating loop is represented by an on-going process of understanding context, converting this into design decisions, and the implementation of these decisions. The system thus adapts to changes in the situation, whether caused by operational action or by other factors. The Regulation function enables learning from experience by assessing the effectiveness of the operation. It can influence how the design is implemented or identify the need for more substantial changes through questioning the validity of the design or the understanding that informed it.

Activities outside of these, such as logistics, human resources functions, and force generation are not here included in C2, even although they may be carried out by a headquarters and are necessary functions of operations.

6 MODEL CHARACTERISTICS

The information presented so far lays out a proposition for what C2 is and the boundaries placed around it. Before describing the node functions in more detail, there are a number of aspects of the model that must be understood to inform its effective application.

Since this is a functional model it describes functions and the relationships between them. It does not say how functions are carried out or by whom. It should not be interpreted as a process-flow model or an organisation design.

It is emphasised that the model is not intended to be regarded as a fixed, rigorously defined 'formula' but must be interpreted appropriately for the circumstances in which it is used. It is reiterated that the text describing the functions, both in the previous high-level model and later in more detail, are not definitions in a strict sense but are provided as an indicator of a concept. Their interpretation should not be overly constrained by the limitations of the language used. Conventional military terms have been deliberately avoided as these tend to be pre-loaded with a particular meaning and interpretation of how they are done and by whom.

Arrows are used in the model to indicate relationships between functions. This tends to mean exchange of information, and it is emphasised that such communications are *all potentially dialogues rather than one-way flow*. This could range from the acknowledgment of an order to a lengthy discourse that results in joint decision making. A single arrow indicates where the influence, dependency, or primary route of information exploitation tends to be stronger in one direction than the other. Where a double arrow is used this shows potential for strong interdependency or mutual influence. However, these should not be regarded as definitive and the model user is free to determine what type of relationship is most appropriate in each case.

The model uses the same collection of functions to describe the activities of all C2 nodes within the operating enterprise regardless of their task or level of command. *It therefore makes no distinction between strategic, operational and tactical functions.* The model holds that the functions are actually the same in each case but may be implemented in different ways. For example, the same collection of functions may be carried out by a range of boards and bureaus at a high organisational level, but may all occur within the head of an individual decision maker

at the point of effect delivery.

The activities described also *define a C2 node* and this is agnostic of organisational boundaries. It is therefore conceivable that the collection of node functions are distributed between different organisations, in which case it is the group of organisations, or the relevant parts thereof, that constitute a node. For example, if information analysis is 'contracted out' or if design decisions must be authorized by a different organisation, then these separated functions are still part of a single node. Similarly, node functions in a given organisation may be physically distributed but still regarded as a single node.

7 C2 NODE FUNCTIONS

The functional model of a C2 node is shown in greater detail in Figure 2. This was derived from the activity modelling process, but supplemented using the idea of 'complementarity'. If the same set of functions are to be applicable to all nodes then it is necessary that each function that generates an external output is complemented by a function that can receive the relevant input.

The yellow arrows in Figure 2 indicate *potential* external interfaces with sensors, effectors or other nodes. In some cases these may be satisfied by an internal decision rather than requiring interaction with an external entity. For example, a role could be acquired (Function #O3) through orders from a higher authority or by an internal decision.

Note that there are no specific functions designated under the higher-level 'Align' function. Alignment can pertain to any of the functions described where there is external information sharing, consultation, collaboration or co-creation.

The individual functions are described below and their relationships are shown in Figure 2. It is emphasised again that these descriptions are intended to be illustrative of a general concept and must be interpreted for the specific context in which the model is used. The language used is not intended to be restrictive or definitive.

#O1 Acquire Licence to Act
This is the function through which the node is incorporated into the operating enterprise and its activities are legitimised as part of an operation. It may range from a formal commissioning process that has legal or contractual implications, to an internal decision to act made by the node operators.

#O2 Acquire Enterprise Purpose
Gaining an understanding of the higher level purpose of the operation of which the node is a part.

#O3 Acquire Role
Gaining an understanding of the specific role of the node within the wider operation context.

#O4 Acquire Relationships Information
Understanding the structure of the operating enterprise and position of the node within it, including the relationships that it requires with other actors.

#O5 Acquire Policy and Constraints
Policies and constraints here refers to those limitations on design, decision making or actions that are imposed from outside the node. This may include ethical or legal constraints, 'rules of engagement' and directives from higher authorities.

#P1 Decide Node Purpose
Creates the driver for analysis and decision making by establishing how the node envisages its role in the context of the wider operation and its local task and situation.

#A1 Acquire Effector Agency
Agency is about having the means to act purposefully and includes capability, resources, authority and influence. Since a node does not engage directly with the operating environment then it requires relationships with effectors to do so. This function establishes these relationships, as well as access to other necessary resources or capabilities.

#A2 Identify Agency Requirements
Enables a node to understand the agency that it requires to implement a particular operation design. Design can therefore be an interplay between the agency that is desired and that which is available.

#A3 Understand Available Agency
Enables an understanding of the capability, authority, influence, and resources available to the node to be factored into the design possibilities or consideration of the additional agency that is required.

#U1 Identify Context Information Requirements
Enables the node to identify the information that it requires to understand the operating context.

#U2 Acquire Context Information
The node does not directly observe the environment but is dependent on 'sensors' to do so. This function enables the node to request and receive contextual information from sensors with which to generate contextual understanding.

#U3 Process Context Information
Enables information to be exploited to generate understanding. Processes may include storage, retrieval, analysis, visualization, etc.

#U4 Understand Context
Generates understanding of the situation or environment in which the node must deliver its purpose.

#U5 Provide Context Information
The node can receive requests for and provide information to other nodes through this function so that they can use it to inform their contextual understanding.

#D1 Consolidated Understanding
The ability to design the node's response to its task and situation is dependent on a consolidated understanding of Purpose, Agency and Context. This function is where these different aspects of understanding are brought together.

#D2 Explore Design
Uses a consolidated understanding of Purpose, Context and

Agency, combined with an understanding of relevant constraints, to identify plausible design solutions for the delivery of the node's required contribution to the operation. It determines the 'art of the possible'.

#D3 Identify Solution Criteria

Incorporates into design decisions influencing factors that originate from within the node. This could include, for example, risk appetite, ethics, or experience and preferences derived from past events. The double arrow with the Explore Design function (#D2) indicates that such factors may be shaped through consideration of design options and the exploration process rather than being independent of it.

#D4 Decide Design

The formal decision making process where the design of the node's contribution to the operation is decided.

#D5 Decide to End Operation

Enables one of the plausible design options derived from continuous re-assessment of the situation to be that the node's contribution to the operation is terminated.

#I1 Provide Licence to Act

This embodies any activity required by the node to incorporate another actor involved in the implementation of the design into the operating enterprise, thus legitimising its activities as part of the operation.

#I2 Provide Enterprise Purpose

Communicates to another actor an understanding of the overall operation purpose to provide further context to its specific role within it.

#I3 Provide Task

Provides to another actor a specific role or task within the operating enterprise.

#I4 Provide Relationships Information

Situates another actor within the operation enterprise structure such that they can understand the relationships they have or need with other actors.

#I5 Provide Policy & Constraints

Enables the node to communicate to other actors the limits and constraints within which they may act to deliver their tasks and roles. It is thus a means of ensuring coherence within the enterprise.

#I6 Enable Effector Agency

Enables one node to provide another node or effector with access to the agency that it requires to fulfill its purpose within the operation. This would include, for example, assigning resources or delegating authority over them.

#I7 End Operation Activities

Implements a decision to terminate operational activity by taking the action necessary with regard to the relevant nodes or effectors.

#I8 Coordinate & Manage

Enables the node to take a continuing role in how the design is implemented by, for example, coordinating or synchronising the activities of multiple nodes or effectors.

#I9 Resource Balancing

Decides allocation of shared resources between multiple nodes or effectors.

#I10 Receive Coordination Input

Enables a node to receive continuing input from another node to influence the conduct of its operational activity. This may include the synchronisation, coordination, or prioritisation of activities.

#R1 Identify Assessment Requirements

Enables specific information requirements to be identified to enable the assessment of the implementation of the operation design.

#R2 Acquire Assessment Information

The process through which the node requests and acquires information to support assessment of the real-world implementation of the design. This could include specific requests for information or routine transmission of metrics, for example.

#R3 Process Assessment Information

The function whereby information is rendered usable for the assessment of design implementation. Includes storage, retrieval, analysis, visualization, etc.

#R4 Assess Performance

Assesses if the activity conducted is delivering what was expected of it and, if not, why.

#R5 Decide Interventions

Determines the actions that are believed necessary to optimise or improve the implementation of the operation design based on performance assessment. Actions to change the design itself are implemented through the Challenge Function (#R7).

#R6 Implement Interventions

Puts in place the interventions that are required to optimise or improve the implementation of the operation design by intervening with the relevant effectors or nodes.

#R7 Challenge Function

Enables conclusions derived from the assessment function (#R4) to be used to challenge the on-going validity of the operation design, or the prevailing understanding on which the design was based. It effectively enables the node to learn from the execution of operational activities.

#R8 Provide Assessment Information

Enables the node to provide information to another regulator to inform its assessment of its operation design implementation.

#R9 Receive Regulatory Input

Enables the node to receive interventions from another node that modify its implementation of operation activities. This would be relevant where another node has a regulatory role with respect to the actions of the subject node.

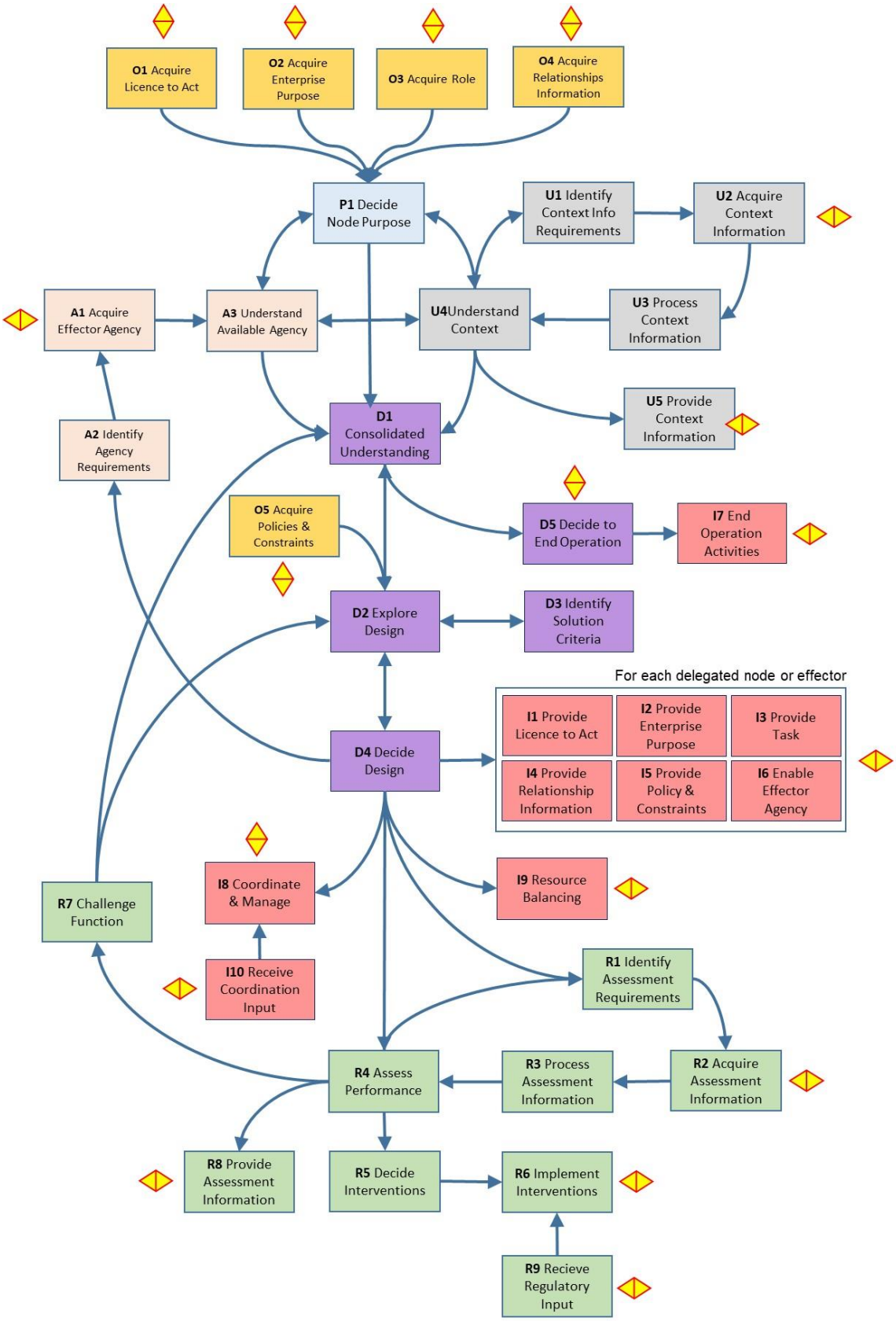

Figure 2: The functions that constitute a C2 node. Blue arrows represent internal relationships between functions while yellow arrows indicated potential interfaces between the C2 node and external nodes, sensors or effectors. Functions are colour coded and given a prefix letter in line with the higher-level functions in Figure 1, but this is for ease of navigation only and is not intended to be indicative of organisation design.

8 DISCUSSION

This work is intended codify C2 in the widest possible terms such that the same framework can be used to describe any instantiation of C2 now or in the future. It is therefore agnostic of the means used to enact C2, including methodology, organisational boundaries and the nature of relationships. This enables the model to be applied widely to support the design of new approaches or the assessment of existing ones.

This model has been subject to review by various subject matter experts, both civilian and military. This has included personnel from Dstl, independent consultants, various branches of the UK Ministry of Defence, and international partners. It was also explored in the context of an operational level headquarters exercise and revised in the light of that experience.

Not all of those who have reviewed this model were content with the 'interpretative approach' in which functional concepts can be freely interpreted by users in context. This was seen by some who sought more robust and absolute definitions as lacking rigour and precision. I disagree and believe that debates over exact functional definitions can be distracting and counterproductive when the onus should be on facilitating creativity and innovation. A model is merely a representation of the world and any judgement of its validity depends on its purpose and the context of its use. Here, it is intended to constrain in the sense that it allows a more precise understanding of what C2 is for, but liberating in the sense that it allows the greatest possible freedom to envisage how the purpose of C2 may be achieved. I have therefore sought to make a clear distinction between the C2 system and the operation delivery system and other aspects of operations, although they are of course intimately linked in reality.

This model emphasises that the relationships between things - actors and functions - are an important element of the C2 system, in addition to the functions it carries out. Key points of input and output are identified in Figure 2 and these represent the channels through which communications are mediated between a node and other actors. Not all channels will necessarily be active in every relationship, depending on the respective roles of the parties involved and the architecture of the C2 system.

Another approach to testing the model, which is still on-going, is its comparison with other published models to identify potential gaps it its provision. This initially focused on the 'Viable Systems Model' (VSM) [14], a Cybernetics-based management model that also claims universality and should therefore be applicable to military C2. The approach to its development was different from that described here in that it was based on biological regulation and it therefore offers a strong contrast. Both models are 'interpretative' in that it is necessary to define the functions in context during use.

Although they take very different forms and use different vocabulary, it was found that VSM and the model described here could be interpreted in the context of each other without significant omissions. An interesting observation was that in one model an important element may be instantiated as a function (i.e. a 'box' in the model illustration) while in the other the same element took the form of a line that joined the functions. This emphasises that relationships between things are as important as the 'things' themselves, regardless of how they are expressed.

An important distinction between the two models is that VSM is resolutely hierarchical and does not overtly reflect external collaborative relationships. This possibly reflects its creator's background in manufacturing industry, although these aspects align well with conventional military C2.

This model was also examined relative to the 'Essence of C2' model [15], which also sought to distil a view of the fundamental generic elements of C2. This was constructed using the RIVA method which bases the modelling activity on an organisational perspective and the activities and processes thus identified as being required to enact C2. A key contrast with the model described in this paper was that this work was derived from an analysis of contemporary conventional HQ activities.

In general, many of the core elements of each model were recognisable in the other, but I would highlight two main differences. There was no equivalent in the Essence of C2 to the concept of 'agency'. Nor was there the capacity to consider relationship types other than the authority of a superior over a subordinate and the exercise of directive command. It can be speculated that there was not the same driver to consider these elements as both the allocation of resources and types of relationships are often 'built in' to the nature of C2 in conventional operations. In this case, the model reflected the conventional practice and organisational activities on which it was based.

This perhaps demonstrates the particular value of the approach described here to provide a novel perspective that may provide added value when thinking about future C2 and alternative approaches. The increasing complexity of military operations challenges conventional C2 practice, which suggests that different thinking is needed

in this area to enable future operating advantage [6]. The Generic Functional Model described here should therefore be viewed in that light rather than as a representation of current C2 structures and practices.

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