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"Operationalizing C2 Agility: Approaches to Measuring Agility in Command and Control Contexts"

Topic: C2 Metrics and Assessment

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Abstract

Modern military operations are characterized by highly dynamic environments, complex strategic, operational, and tactical situations, a rich and evolving mix of allies and adversaries, inherent and sometimes massive uncertainty, and high risk. This combination of factors requires that military forces must continually transform and adjust to remain highly effective in extremely fluid environments. This capability, known as agility, is emerging as a key attribute of the forces and organizations that will enable them to respond to the nature of modern operations.

In an everyday language sense, agility as a concept is well understood. However, operational definitions of agility, needed to enable unambiguous recognition and measurement of the different aspects of agility have been lacking. This paper lays the groundwork for a unifying approach for measuring and experimenting with agility and its enabling factors by suggesting definitions of agility and its associated attributes that are amenable to measurement, and describing potential approaches to agility measurement and description.

Keywords: Agility, responsiveness, resilience, robustness, flexibility, innovativeness, adaptiveness, measures, measurement, metrics, command and control, C2 maturity.

Introduction

Modern military operations are characterized by highly dynamic environments, complex strategic, operational, and tactical situations, a rich and evolving mix of allies and adversaries, inherent and sometimes massive uncertainty, and high risk. This combination of factors requires that military forces must continually transform and adjust to remain highly effective in extremely fluid environments. The U.S. Department of Defense and others around the world who have recognized the nature of the emerging security environment are developing concepts and capabilities aimed at enhancing their ability to succeed in the face of change and uncertainty, both in their military forces and in the endeavors that they support. This ability, known as agility, is emerging as a key attribute of the forces and organizations that will enable them to respond to the nature of modern operations.

In an everyday language sense, agility as a concept is well understood. The Merriam-Webster Dictionary defines agility as “the ready ability to move with quick easy grace.”[1] In this sense, the physical agility of a dancer or athlete can easily be recognized and appreciated. However, when the agility of military forces is considered, there is a need to go beyond physical agility (in terms of speed or operational tempo), though such physical abilities can contribute to agility. Rather, what is sought is, more broadly, a capability to change across the physical, information, cognitive, and social domains, and to achieve

[1] Merriam-Webster Online Dictionary, http://www.merriam-webster.com. Accessed July 2007.

success in the face of the myriad changes that may occur at various time scales in the problem space within which a military force is operating or may be called upon to operate. Thus, more than simple physical attributes need to be considered when defining agility. Further, this agility must be achieved not only within the context of activities that span across agency, sector, and international lines.

In addition, if the capability for agility is to be planned and designed for in military forces and systems, there is a need for objective recognition criteria, metrics, and measurement approaches. There must be a means of assessing how agile forces are, and for comparing "as is" forces with "to be" forces and recognizing which has more agility. Even the relatively simple concept of physical agility remains in the eye of the beholder until the concept can be measured using agreed upon criteria. The existence of these measurement mechanisms will allow for more rigorous research and experimentation on agility and its enablers, and will sharpen discussion in the concept development, research, acquisition and operational communities on how agility is to be achieved and exploited in military operations. Sir William Thomson (Lord Kelvin) emphasized the importance of measurement in a lecture at the Institution of Civil Engineers in London in 1883:

> ...[W]hen you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the state of s*cience*, whatever the matter may be.[2]

Most views of agility recognize it as a multi-dimensional concept, each face of which corresponds to a different class of responses or a different class of stimuli in the problem space to which response is needed. In several publications, the Command and Control Research Program (CCRP) has defined agility as being comprised of six synergistic attributes; these attributes are listed and defined in Table 1.

Other communities work with similar—though not identical—concepts and terms, but specific taxonomies vary and are often not sufficiently precise for measurement. The CCRP's goal in this activity is to lay the groundwork for a unifying approach for measuring and experimenting with agility and its enabling factors. This groundwork is an essential first step toward building a conceptual model of agility that can be applied in C2 contexts, enabling community discussion of different approaches to defining agility, facilitating community convergence on agility metrics, and ensuring effective experimentation and testing of C2 agility concepts.

The process of defining a term in a way that makes it unambiguously measurable is known as operationalizing the definition. In this context, when the term "operationalize" is used, it means something quite specific. Commonly, operational concepts refer to descriptions of how a force will operate, or how an operational function will be carried out. In this paper, the concepts associated with agility will be operationalized in the sense that measurement of the degree to which the concepts are present or absent in an entity of interest is enabled.

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[2] Sir William Thomson, *Popular Lectures and Addresses*, Volume 1, London: Macmillan and Company, 1891.

Table 1. Agility attributes and associated definitions from *Power to the Edge*. [3]

Attribute	Definition
Robustness	The ability to maintain effectiveness across a range of tasks, situations, and conditions
Resilience	The ability to recover from or adjust to misfortune, damage, or a destabilizing perturbation in the environment
Responsiveness	The ability to react to a change in the environment in a timely manner
Flexibility	The ability to employ multiple ways to succeed and the capacity to move seamlessly between them
Innovation	The ability to do new things and the ability to do old things in new ways
Adaptation	The ability to change work processes and the ability to change the organization

In "Fundamentals of Operations Research," Ackoff and Sasieni described what is meant by an operational definition. To convert the definition into an operational form, it is necessary to specify explicitly a number of factors:[4]

- The object or class of objects to be observed
- The conditions (environment) under which the observations should be made
- The operations, if any, that should be performed in that environment
- The instruments, if any, and the metric standards that are required to perform the specified operations
- The observation(s) that should be made

Adapting this approach to generate operational definitions of agility, the work discussed in this paper focused on several distinct aspects of measuring agility and its constituent attributes: concise definitions of the object of the assessment, a description of the environment and conditions under which the assessment will occur, metrics to express the results of the assessment, and what operations or activities the assessment involves.

Since a key theme of agility is the ability to maintain effectiveness in the face of change and uncertainty, how the environment for measurement is treated is particularly important. It is in fact at the interface between the environment and the object operating in that environment that many aspects of agility are manifested (this will be discussed further in Section 3.3.1 of this report).

One final note of context for this report: This work was conducted for the Command and Control Research Program of the U.S. Department of Defense. The CCRP is interested in the study of command and control: the behavior of people, organizations, and the processes and systems that people create. In thinking about measuring agility, this work examined agility in that context—consciousness, intent, and purposefulness are all part of what scopes the kind of agility discussed in this report. This kind of definition is meant to

[3] David S. Alberts and Richard E. Hayes, *Power to the Edge: Command and Control in the Information Age*, Command and Control Research Program Publication Series, 2003.

[4] Russell L. Ackoff and Maurice W. Sasieni, *Fundamentals of Operations Research*, New York: John Wiley & Sons, Inc, 1968.

differentiate this focus for agility from, for example, the agility of evolutionary biological systems, which often rely on the ability of random mutations to sometimes lead to improvements in survivability, which in turn improves the ability of that mutation to survive as the environment changes. Randomness may in fact be a part of exploiting agility to achieve factors like surprise and unpredictability; in this case it is still of interest because there was a *choice* to randomly select from available actions.

This report is organized as follows: The next section is a brief review of the survey of selected literature conducted for this effort. The following section presents the definitions and measurement approaches for agility and its constituent attributes. The final section discusses observations and suggests follow-on research that could be conducted to further refine these ideas.

Perspectives on Agility

A wide range of CCRP publications has included discussions of the importance and nature of agility in Industrial Age activities. Selected extracted quotations (with emphasis added) are shown to illustrate some of the key themes and ideas:

- Language defining the nature of agility
  - The capacity to react more effectively in a rapidly *changing operating environment*[5]
  - Adjusting to *changes in the operational situation* in a timely manner[6]
  - An ability of the forces *to adapt, to learn, and to change* to meet the threats that they face[7]
- Other key observations on agility
  - Presumes effective actions and implies a degree of self-synchronization[8]
  - A key characteristic of an Information Age organization; a characteristic to be sought even at the sacrifice of seeking to perfect capabilities associated with specific missions or tasks[9]

On the nature of agility, a recurring theme is the concept that agility enables effective responses to change, and implies an ability on the part of the force or endeavor to instantiate various types of change in ways appropriate to the stimulus for the change.

The fourth quote (from *Understanding Command and Control*) highlights the fact that effectiveness is assumed when agility is observed. The ability to do many different things

[5] David S. Alberts, John J. Gartska, Richard E. Hayes, and David T. Signori, *Understanding Information Age Warfare*, Command and Control Research Program Publication Series, 2001. 197.

[6] Ibid., 217.

[7] Simon Reay Atkinson and James Moffat, *The Agile Organization*, Command and Control Research Program Publication Series, 2005. 164.

[8] David S. Alberts and Richard E. Hayes, *Understanding Command and Control*, Command and Control Research Program Publication Series, 2006. 201.

[9] David S. Alberts, *Information Age Transformation*, Command and Control Research Program Publication Series, 2002. 82.

and change rapidly and on the fly does not make for an agile system unless those things are done effectively within the context of the environment within which the system is operating.

In the last quote, *Information Age Transformation* makes explicit the fact that there are likely to be tradeoffs between optimization of the force or organization for a particular set of operations and environments and seeking the agility to be able to be effective across a range of operations and environments that are not enumerable or foreseeable. Furthermore, it implies that this satisficing[10] approach is unavoidable—and is in fact desirable. This is a challenge, as it runs counter to traditional approaches to force planning and organizational design, but it is entirely consistent with what is needed in current and emerging strategic and operational environments.

These ideas, including some of the definitions and detailed treatment of agility concepts, have been adopted by others. The NATO Command and Control Conceptual Reference Model,[11] developed by the NATO Study Group SAS-050, and the NATO Network Enabled Capability Command and Control Maturity Model, currently under development by the NATO Study Group SAS-065, both draw on concepts of agility and its enablers discussed in earlier CCRP work.[12]

The need for agility is making its way into the doctrine and planning of other defense organizations as well, including the Joint Staff, the U.S. Military Services, and the Office of the Secretary of Defense in the United States, the Ministry of Defense in the United Kingdom, and the Defense Science and Technology Organisation in Australia. Emphasis and terminology vary, but there exists a common recognition of the importance of the concept. A broad cross-section of the international security community appreciates the relevance, utility, and importance of agility in thinking about current and future forces. However, there is a need to move beyond differences in language to the underlying ideas.

As a part of this effort, selected documentation from a variety of sources from around the world was reviewed to get a feel for how agility is defined and treated in various communities—from the defense sector to private industry. This review was certainly not comprehensive (one goal of this work is to initiate a discussion of other ideas and

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[10] Satisficing is an alternative to optimization for cases where there are multiple and competitive objectives in which one gives up the idea of obtaining a “best” solution. In this approach, one sets lower bounds for the various objectives that, if attained, will be “good enough” and then seeks a solution that will exceed those bounds. The satisficer’s philosophy is that in real-world problems there are too many uncertainties and conflicts in values for there to be any hope of obtaining a true optimization and that it is far more sensible to set out to do “well enough” (but better than has been done previously). From W. Findeisen, A. Iastrebov, R. Lande, J. Lindsay, M. Pearson, E.S. Quade (eds.), *A Sample Glossary of Systems Analysis*, prepared for the *Preliminary Version of the Handbook of Applied Systems Analysis*. IIASA, 1978, cited in *Web Dictionary of Cybernetics and Systems,* http://pespmc1.vub.ac.be/ASC/indexASC.html, accessed August 2007.

[11] NATO Study Group SAS-050, *Exploring New Command and Control Concepts and Capabilities*, 2006. Available at http://www.dodccrp.org/files/SAS-050 Final Report.pdf .

[12] These NATO working groups have involved representatives from Australia, Belgium, Canada, Denmark, France, Germany, Italy, the Netherlands, Norway, Portugal, Slovakia, Sweden, Switzerland, the United Kingdom, and the United States.

concepts that may facilitate useful approaches to working with agility), but it was useful in gaining broad insight into how agility and related concepts are being dealt with in other nations and organizational settings.

Sources reviewed

CCRP has published extensively on agility as a desired result of network-centric transformation. From 1999, when *Network Centric Warfare*[13] discussed the rising importance of and ability of Information Age concepts to enable responsiveness and revolutionary speed of command, to today, when recent publications such as *Understanding Command and Control* and *Planning: Complex Endeavors*[14] provide detailed descriptions of the nature of agile command and control and how it may be achieved, members of the international C2 research community associated with CCRP have contributed to a growing body of literature on this subject.

U.S. strategic and conceptual documents also discuss the importance of the agility of the future force from Joint and Service perspectives. The *National Defense Strategy of the United States of America* has extensive language describing the changing strategic environment and about the need to be able to "continually adapt how [the U.S. Department of Defense] approach[es] and confront[s] challenges, conduct[s] business, and work[s] with others." [15] The *National Military Strategy of the United States of America* identifies agility as one of three strategic principles guiding the development of joint operational concepts and joint force capabilities, enabling the force to "contend with the principal characteristic of the security environment – uncertainty."[16] These strategic statements are expanded upon in the *Net Centric Environment Joint Functional Concept,* which identifies agility and related attributes as desired properties of the future U.S. Joint Force, and is a key element of the foundation for the capability-based planning and development processes used by the U.S. military today.[17] The U.S. Services have also begun to include agility in their own planning and concept documents; examples reviewed in this work were the U.S. Army White Paper, *Concepts for the Objective Force*,[18] and the U.S. Air Force's *USAF Transformation Flight Plan*.[19]

[13] David S. Alberts, John J. Garstka, and Frederick P. Stein, *Network Centric Warfare*, Command and Control Research Program Publication Series, 1999.

[14] David S. Alberts and Richard E. Hayes, *Planning: Complex Endeavors*, Command and Control Research Program Publication Series, 2007.

[15] Office of the U.S. Secretary of Defense, *National Defense Strategy of the United States of America*, 2005.

[16] U.S. Joint Chiefs of Staff, *National Military Strategy of the United States of America*, 2004.

[17] U.S. Joint Staff, *Net Centric Environment Joint Functional Concept*, 2005.

[18] U.S. Army, *Concepts for the Objective Force*, U.S. Army White Paper, 2001.

[19] U.S. Air Force, *USAF Transformation Flight Plan*, 2003.

Many international partners have doctrine that incorporates agility ideas as well, including the United Kingdom's *Agile Command Capability*[20] and *Joint High Level Operational Concept*.[21] Further, the UK's emergency/disaster response high level policies are based on the idea of resilience to disaster.[22] Additionally, UK defense research organizations, such as QinetiQ, have studied agility in military operations and published on these and related concepts. Two 2006 publications by QinetiQ researchers containing thinking on the definition of agility and associated terms are Beautement's "Agile and Adaptive Operations – Leveraging the Power of Complex Environments" and a QinetiQ research report by Dodd, Richardson, Alston and Beautement: *Investigation into the C2 Arrangements for Edge Organisations*.[23]

Australian researchers have also been active in the study of agility. In addition to treatments of agility from organizational and operational points of view (for example, see Kingston et al[24] and Dekker[25]), several researchers from the Australian Defence Science and Technology Organisation (DSTO) have examined the subject of agility (referred to in DSTO literature as *adaptivity*) from the perspective of complex adaptive systems, applying thinking from complexity science and evolutionary biology to develop general models of adaptation that are applicable to individuals and organizations, as well as the organisms and ecologies from which they were derived.[26]

Outside of security contexts, many non-defense communities have also dealt with agility concepts. These include the engineering, evolutionary biology, complexity sciences,[27]

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[20] United Kingdom Ministry of Defence, *Agile Command Capability: Future Command in the Joint Battlespace and its Implications for Capability Development*. Unclassified paper: DG INFO/11/5/6/2/1(CBM), 7 January 2003.

[21] UK Ministry of Defence, *The UK Joint High Level Operational Concept: An Analysis of the Components of the UK Defence Capability Framework*, 2005.

[22] UK Cabinet Office, *Dealing with Disaster*, 3rd Edition, 2003.

[23] Patrick Beautement, "Agile and Adaptive Operations – Leveraging the Power of Complex Environments." *Proceedings of the 11th International Command and Control Research and Technology Symposium*, 2006; Dodd, Lorraine et al, *Investigation into the C2 Arrangements for Edge Organisations* QinetiQ, 2006.

[24] Gina Kingston, Suzanne Fewell, and Warren Richer, "An Organizational Interoperability Agility Model," *Proceedings of the 10th International Command and Control Research and Technology Symposium*, 2005.

[25] Anthony Dekker, "Agility in Networked Military Systems: A Simulation Experiment," *Proceedings of the 11th International Command and Control Research and Technology Symposium*, 2006; and Anthony Dekker, "Measuring the Agility of Networked Military Forces." *Journal of Battlefield Technology*, Volume 9, Number 1, March 2006.

[26] See A.M. Grisogono, "What Do Natural Complex Adaptive Systems Teach Us About Creating a Robustly Adaptive Force?" *Proceedings of the 9th International Command and Control Research and Technology Symposium*. Command and Control Research Program. 2004; and A. M. Grisogono. "Co-Adaptation." *Invited paper 6039-1, Complex Systems Conference, SPIE International Symposium on Microelectronics MEMS and Nanotechnology, Conference 6039: Complex Systems*. Brisbane. 2005.

[27] For example, see J. M. Carlson and John Doyle, "Complexity and Robustness," *Proceedings of the National Academy of Sciences*, Volume 99, Supplement 1, 2538-2545, 2002; and Gunter P. Wagner and Lee Altenberg, "Complex Adaptations and the Evolution of Evolvability." *Evolution*, Volume 50, Number 3, 967-976, 1996.

and the commercial sector, which has dealt with such subjects as agile manufacturing and supply chain management.[28] In addition, the terms associated with agility each have common-language definitions, which were also reviewed in this survey.[29]

Observations

The documents surveyed addressed agility concepts at a variety of levels and from a number of different perspectives. Many of the Service-level documents focused on physical aspects of agility, such as speed and multi-functionality, while others were explicit about the information, cognitive, and social aspects of agility. Despite these differences, the common theme and core sense of agility, as being concerned with an effective response to uncertain and dynamic environments, were displayed across the literature reviewed.

The primary purposes of this brief survey were twofold: (1) to get a sense for the core meaning of agility and related terms as used by the community; and (2) to identify aspects of agility that are fundamental, but not captured in the six attributes that have emerged from the CCRP literature. Some of the reviewed discussion highlighted aspects of the six agility components that suggested a different way of looking at or measuring a component. Others used different nomenclature, but made reference to common ideas.

While most of the agility terms defined and used in the documents surveyed could be mapped into the six agility attributes listed earlier, there were some areas of emphasis and differentiation that were not reflected in the current definitions in the CCRP literature. In particular, QinetiQ researchers defined an end state-related concept of agility (operational agility: the achievement of end states by an organization), as well as two distinct types of agility that combined to yield operational agility: organizational agility (the means that an organization has to achieve operational agility, in particular the capacity and structural flexibility of the means) and command agility (the affordance in ways of using the organizational agility, reflecting the willingness and ability to use the available means to achieve desired ends) as two distinct capabilities.[30] This approach makes explicit the differentiation between possessing the means to be agile and having ways (and the willingness) to exploit those means to actually manifest agility in terms of end states. Further, this approach separates the concepts of organizational change (flexibility in the means) and process change (flexibility in how the means are employed). These ideas will affect the task of measuring agility in particular systems of interest approached, and will be discussed later in this report.

The UK *Joint High Level Operational Concept* also introduces another key idea to the agility lexicon: the concept of self-reflection, defined as the ability to self-reflect on aims,

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[28] Examples of discussions of agility in the commercial sector (which has been cited by some in the defense community) are Wong and Whitman, "Attaining Agility at the Enterprise Level," *4th International Conference on Industrial Engineering Theory, Applications and Practice*, San Antonio, TX, 1999; and Richard Dove, Sue Hartman, and Steve Benson, *An Agile Enterprise Reference Model with a Case Study of Remmele Engineering*. The Agility Forum, Report AR96-04. 1996.

[29] Merriam-Webster Dictionary (online), http://www.merriam-webster.com, last accessed July 2007.

[30] Dodd et al. 2006.

methods, and command style.[31] This concept places emphasis on the importance of sensemaking and decision making capabilities, not just from the point of view of understanding the changing and uncertain environment, but also understanding the command and control approach being used and recognizing when it needs to change. This cognitive aspect of agility will need to be accounted for in thinking about how to recognize and measure agility.

The aforementioned documents added new perspectives to consider when defining and measuring agility. Other documents used new terms or detailed concepts, but were not considered to contribute to the core meaning of agility terms. Some of the pieces reviewed were considered to be out of scope, dealing with aspects of agility other than those with which this work is concerned (purposeful command and control). Still others referred not to new aspects of agility, but rather to *enablers* of currently-represented aspects of agility. For the purposes of defining core agility concepts in pure ways, it is important to avoid, as much as possible, definition or measurement approaches that specify how particular aspects of agility are achieved.[32] For example, the following terms from the *Net Centric Environment Joint Functional Concept* were determined to be enablers or ways to achieve various aspects of agility, but were not core agility concepts themselves:

- Scalable: The ability to seamlessly adjust size and scope to meet a given mission requirement
- Diverse: Not dependent on a single element, media, or method
- Distributed: Dispersed throughout the geographical area being served
- Survivable: The ability to continue to function during and after a natural or man-made disturbance, for example, a nuclear burst[33]

Beautement's paper, "Agile and Adaptive Operations," introduces a term from the board game *Othello*™, mobility, which is defined as the number of moves player A has available, compared with the number that B has available.[34] While this highlights one of the potential values of being able to measure agility (enabling agility comparisons between entities), the concept of the *number of moves available*, if augmented by consideration of how available moves potentially lead to winning the game, is related to the concept of flexibility (the ability to employ multiple ways to succeed) in the set of agility terms described earlier.

Finally, from the field of evolutionary biology, a paper by Wagner and Altenberg addresses the concept of evolvability, which is in fact not addressed in the definitions provided earlier in this report. Evolvability is defined as "the ability of random changes

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[31] UK Ministry of Defence. 2005.

[32] Assessment approaches based on concepts of how an attribute is achieved are subject to bias introduced by poor or incomplete models of the enablers. Where possible, it is preferable to define observables that are not reliant on knowledge of the enabling model. Further, it may be the case that there are multiple ways to achieve an attribute; enabler-dependent models may undervalue alternative attribute achievement paths.

[33] U.S. Joint Staff. 2005.

[34] Beautement. 2006.

to sometimes produce improvement."[35] While evolvability is certainly an important concept for forms of natural complex adaptive systems, recall that this work is intended to focus particularly on command and control contexts, in which intentionality and purposefulness are driving considerations.[36] As a result, no attempt is made to define or measure the ability of random change in organizations or command and control socio-technical systems to produce improvement.

Definitions and Measurement Approaches

A Working Definition of Agility

Based on the body of work reviewed, the following definition for agility was crafted, to form that basis of measurement approach development:

> Possessing the potential for robustness, resilience, responsiveness, flexibility, innovation, and adaptation and a capability to synergistically exploit these components to achieve and maintain effectiveness in a dynamic, uncertain, and risky environment.

Note that in this definition, agility is not just the *potential* to succeed in the face of change or uncertainty, but also requires the sensemaking capability to recognize the need for change and the nature of the response required to achieve or maintain effectiveness. As before, this definition makes reference to the now-familiar six components, which the abbreviated literature review described previously showed to be a reasonable starting point, but now includes explicit reference to both effectiveness and cognitive factors, which were suggested by some of the references reviewed, and which is consistent with the earlier discussion of the kinds of systems around which this discussion is centered.

Defining the Object of Assessment

In thinking about measurement, properly defining the object of assessment to align with what you want to learn is important. This can be challenging due to the changing nature of activities and participants that may be involved in an operation or set of related operations. There is an emerging recognition that traditional approaches to organizational theory and static social networks do not appropriately account for some of the fundamental items of interest in the study of agility and agile systems.

In *Planning: Complex Endeavors*, Alberts and Hayes orient their discussions around the social construct of an *endeavor*, which captures the nature of the systems that are often of the most interest. Key attributes of an endeavor are:

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[35] Wagner and Altenberg. 1996.

[36] While it is possible, it is hoped that it is not the case that US, coalition, or allied command and control approaches are so ineffective that random changes will improve them; however, it may well be that a degree of randomness in a command and control approach could provide access to much better regions of the command and control approach space than if changes were limited to incremental gradient climbing. Thus, while randomness may help to generate variation and innovation from which improvement can result, this work assumes that deliberate and purposeful entities make non-random selections from among generated alternatives in their agility processes. Future work may account for the fact that some randomness inevitably remains in the system, due to deliberate choice (e.g., game-theory-based mixed strategies) and due to inability to execute decisions in reality precisely as made.

- Endeavors have a purpose or set of related purposes.
- Endeavors involve a large number of disparate entities whose activities are related to a broad range of effects.
- Actors involved in an endeavor do not have a single “leader” or commander.
- No subset of the endeavor is capable of achieving its relevant goals without the contributions of other members.
- Actors in an endeavor may have a variety of relationships with one another (in an open source community, relationships may range from collaborations, code sharing, code contributions, review, requirements generation, customers, users, etc.).
- Actors in an endeavor may be working toward different goals or purposes.

An example illustrating the concept of a complex endeavor is the evolving response to a national emergency incident. The National Response Plan issued by the Department of Homeland Security[37] classifies entities responding to an incident into Emergency Support Functions. Emergency Support Functions (ESFs) are organized according to the specific type of assistance needed, such as transportation, firefighting, or energy. Each ESF has a pre-designated lead federal agency or agencies and supporting federal agencies, through which all necessary behaviors should occur. However, when an incident first occurs, the response rests with the local first responders. In situations where multiple jurisdictions must come together to manage an incident, hastily formed networks develop. The Unified Command Structure has to function as an agile entity as the incident evolves and the specific emergency responders enter and leave the incident. Figure 1 shows some of the entities and relationships involved in such a response.[38]

Augmenting the entities shown in the figure, this disaster response endeavor could also include volunteer organizations and individuals, media outlets, private-sector participants (contractors, materials vendors, etc.), and others—further driving the complexity and diversity of the effort.

In addition to looking at entire endeavors, scale and/or scope can be varied to match the system boundaries of interest. Focus can be scaled down to examine elements of an endeavor (component organizations or groups, lower echelons, or even individuals). Alternately, scope can be expanded to cut across many endeavors, looking at groups or individuals who may participate in (and adapt to) multiple endeavors over time.

This problem of what to measure is a key first step in assessing agility; some definitions of the assessment targets may be more “natural” than others, but, as in systems theory, the definition of the assessment object is entirely man-made. That said, it is critical to

[37] U.S. Department of Homeland Security, *National Response Plan*, updated 25 May 2006. Available at: http://www.dhs.gov/xlibrary/assets/NRP_FullText.pdf.

[38] Evidence Based Research, Inc., *Emergency Management Conceptual Model*, 2007. The Emergency Management Conceptual Model (EMCM) was developed by Evidence Based Research, Inc. for Joint Forces Command (JFCOM) as part of a larger effort with a Virginia Modeling, Analysis, and Simulation Center (VMASC) Consortium, with a second iteration done for the Emergency Management Training, Analysis, and Simulation Center (EMTASC) and funded by the Virginia Economic Development Partnership (VEDP). Figure 1 is a screenshot from the final product for the Phase I EMTASC/VEDP effort.

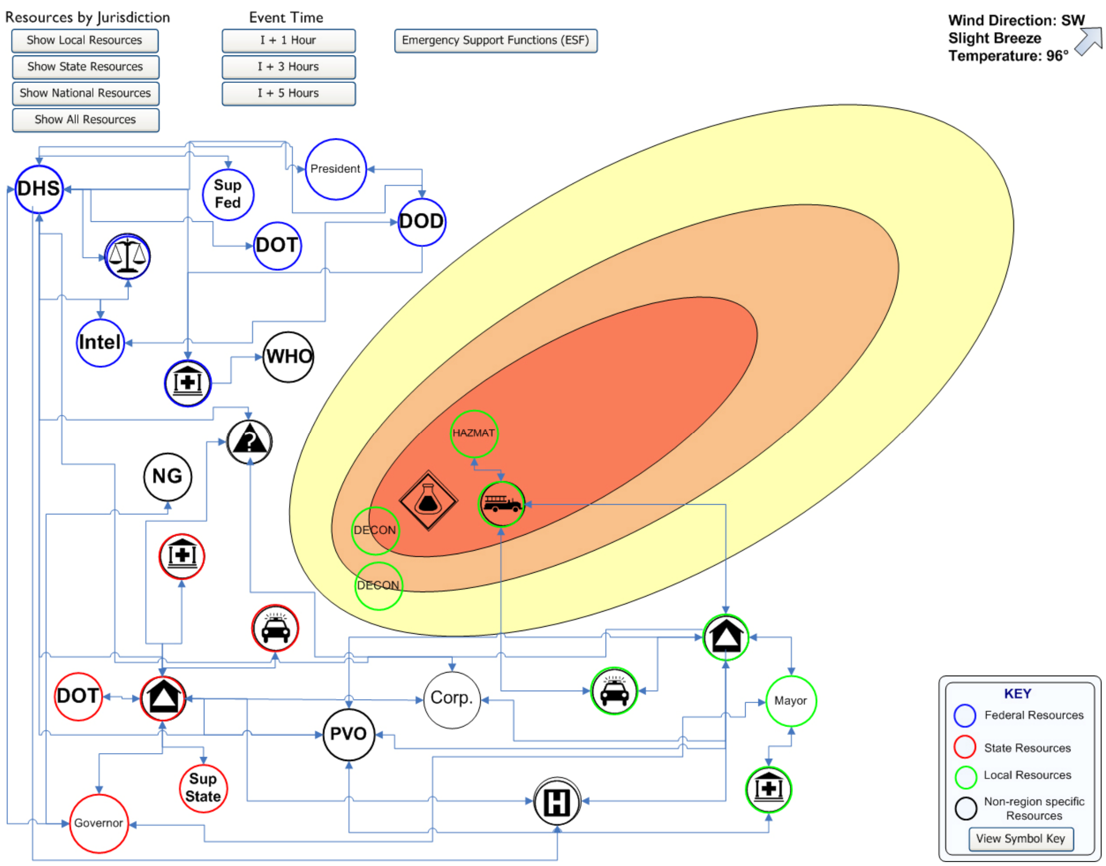

Figure 1. Entities and organizations involved in the planned response to a notional chemical event scenario. Source: *Emergency Management Conceptual Model*, Noell (2007).

ensure that the measurement approaches that will follow are consistently applied to the assessment object as it is defined. For example, it may be misleading to attempt to draw conclusions regarding the agility of a Joint Task Force (JTF) by assessing the agility of the Joint Task Force headquarters; an assessment at the level of the JTF would be needed. Though the agility of the JTF as a whole and that of the JTF may be correlated, the objects of assessment of the two measurements are quite different.

Manifesting Agility at the Interface

As asserted earlier, the treatment of the operating environment is key to measuring agility. In many cases, it is changes in or properties of the environment that result in aspects of agility becoming observable or that stimulate the object of assessment to manifest some component of agility. Different agility attributes are associated with different types of changes in the environment or different types of responses to the environment. Indeed, Australian work, by Grisogono and others, on this topic describes classes of adaptivity, each of which characterizes the robustness of the system in question to different types of change.[39] It follows that many of these changes can be used as "environmental probes" to elicit information from the assessment object about its agility.

[39] Grisogono, Anne-Marie, "The Implications of Complex Adaptive Systems Theory for C2", *Proceedings of the 2006 Command and Control Research and Technology Symposium*, 2006.

These probes likewise illustrate situations in the operating environment that require some aspect of agility on the part of the command and control capability of the object of assessment.

Figure 2 shows how the attributes of agility are related to types of changes in or aspects of the environment. All of the elements of an endeavor's capability, including its people, their knowledge (derived from training, experience and education), the C2 approaches that can be used, and the materiel providing physical, information, and networking capabilities, contribute to the endeavor's quality of intent (shared purpose), planning, decision making, and execution capabilities. The central place of command and control in the figure is indicative of the key role that C2 plays in responding to these kinds of environmental factors. The environmental demands must be detected, recognized for what they are, and responded to from among pre-planned or newly generated options. This must be done in ways that are consistent with intent and can be synchronized and executed across the endeavor.

Note that as the discussion turns to how to recognize or probe for agility components, it sometimes resembles descriptions of how to enable effective responses to change. This is part of the difficulty inherent in trying to assess a concept like agility, which is about the potential for response and capacity to respond, from what is observable. *A system under observation only displays the agility that is called for by its environment.* Whether or not the observed system could have responded to even more change, or change that manifested itself in a slightly different form, is a question that is difficult, if not fundamentally impossible, to answer. Experimentation, in which stimuli can be varied systematically, may be the only real way to explore these issues.

In the following sections, approaches for measuring each of the six attributes of agility will be described. Many of these approaches are based on identifying a problem space that systematically describes the important changes of a certain type that could take place in the environment, and that are of consequence to the object of assessment. Other approaches, for those attributes related to the nature of the object's ability to respond, include a general concept of how an agility attribute is enabled. In some cases, heuristics postulated to be associated with that attribute are suggested. Ideally, it would be preferable to have scenario-free and heuristic-free assessment approaches. These approaches would be less subject to bias introduced by not choosing and defining scenarios properly, or by poor or incomplete models of the enablers.

This problem is not unique to C2 agility measurement. Many concepts in science are not directly observable, requiring the construction and testing of models for measurement. For example, the gravitational potential energy of a massive object cannot be observed directly; however, it is straightforward to measure the height of the center of mass of the object above some referent elevation, and since the model for gravitational potential energy is known (and is valid, credible, and reliable under certain established conditions), an observer is able to make statements about the object's gravitational potential energy. As research and experiments are conducted to refine and mature the concept of agility in military command and control contests, it is hoped that models will emerge that will more directly tie observable parameters with the agility attributes they are used to assess.

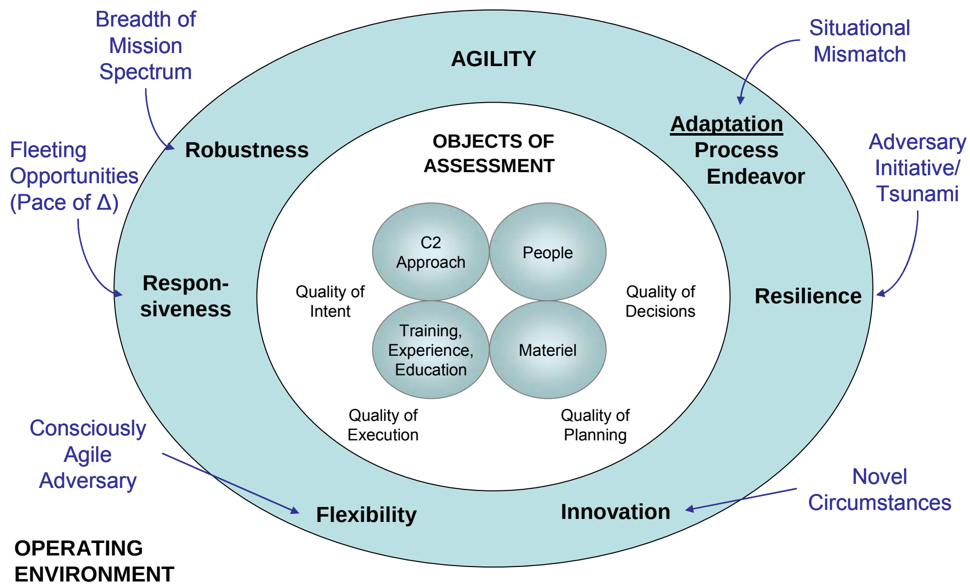

Figure 2. Illustrative environmental probes for agility attributes.

There is at least one other serious potential pitfall of enabler-based indicant approaches to measuring agility: by associating an agility metric with a particular model of agility, other potential ways to achieve agile C2 may not be recognized as adding value, and force planners may overlook potential investments that might pay large dividends. In thinking about how to use metrics in the planning, design, and acquisition of future force capabilities, decision makers must take care not to "teach to the tests" when there is acknowledged uncertainty about whether the tests being used are the right ones.

Measuring C2 Robustness

Command and control robustness is defined as the ability to maintain effective C2 across a range of tasks, situations, and conditions. This attribute clearly refers to particular types of changes that are taking place over time in the environment; in this case, these changes are related to the nature of the threat, the mission, or the conditions under which mission-related operations are being executed. The approach to measuring C2 robustness is to identify a set of use cases that are considered to sample a problem space that defines the ways in which the mission or mission conditions may change in ways relevant to the object of the assessment, and then to assess the ability of the assessment object to maintain effective command and control in each use case. The suggested metric for C2 robustness is the estimated proportion of the problem space within which effective and appropriate C2 capability can be achieved.[40] In arriving at this estimate, use cases may be "weighted" by criticality, likelihood, or the relative importance of the represented region of the problem space, depending on the goals of the assessment.

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[40] Recall that the focus in these metrics is on the agility of C2, and not the broader concept of the agility of the endeavor. Even though endeavor agility is in many ways enabled by C2 agility, other non-C2 capabilities are required as well.

Needless to say, proper definition of the C2 robustness problem space can be challenging, yet the ability to succeed across a broad range of use cases is at its core what the concept of robustness is about. For example, the use cases associated with measuring the C2 robustness of a counterinsurgency endeavor would describe a representative set of possible futures associated with how the insurgency in question may evolve. When assessing an endeavor assembled to respond to a natural disaster, the use cases would describe ways in which the disaster might play out. In both cases, the use cases will describe not only different ways in which the mission may evolve, but the range of mission conditions that may be encountered as well.

How the object of the assessment is defined affects the selection of use cases. While the above examples suggest how the use cases may be defined for illustrative endeavors, if the object of assessment is an element of an endeavor that has persistence beyond the lifetime of the endeavor, the use cases must also be chosen to represent other endeavors that the element may participate in over time.

Measuring C2 Resilience

C2 resilience is the ability to recover from or adjust to the degradation of C2 capability due to misfortune, damage, or a destabilizing perturbation in the environment. The measurement approach for C2 resilience is similar to that described above for robustness, in terms of identifying representative use cases. In this instance, however, the use cases are chosen to sample the space of how C2 capability may be reduced. For example, use cases may be chosen to address (1) systems or capability elements that may fail or be lost; (2) systems or capability elements that may be degraded, either temporarily or permanently; (3) degraded ability of system elements to work together, whether from technical issues or from cultural/personal issue; and others. Note that use cases may be defined in ways that are environment-oriented (events that could occur in the operating environment that could cause degradation) or endeavor-oriented (ways that the endeavor could be degraded, regardless of the source). Descriptions of the problem space oriented around the endeavor are generally more straightforward to define completely; however, such definitions carry little information about the relative likelihood of the degradation, given the nature of the causal event and potential countermeasures or protections that may be in place. Literature concerned with the resilience of complex networks uses two straightforward measures to characterize the ability of a network to resist degradation: the resistance to attack (effectiveness retained after removal of the node whose removal would cause the most degradation) and resistance to failure (expected degradation in effectiveness due to failure of a random node).[41] Use of these two measures would give a sense of how reliant the C2 capability of the assessment object is on a single point of failure, as well as how generally resilient the network is (how widespread are opportunities for an enemy, or bad luck, to cause cascading failures).

Regardless of how the use cases are defined, the residual effectiveness of the C2 capability is assessed for each, as is the rate at which C2 effectiveness can be restored

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[41] See, for example, Paolo Crucitti, Vito Latora, Massimo Marchiori, and Andrea Rapisarda, "Efficiency of scale-free networks: error and attack tolerance," *Physica A* **320** (2003): 622-642; and Lazaros K. Gallos, Reuven Cohen, Panos Argyrakis, Armin Bunde, and Shlomo Havlin, "Stability and Topology of Scale-Free Networks under Attack and Defense Strategies," *Physical Review Letters* **94** 188701 (2005).

after the degradation event occurs. The metric for C2 resilience is the estimated proportion of problem space in which adequate C2 capability remains after degradation and in which timely and relevant restoration is possible. As with C2 robustness, this estimate is calculated from the use case results, which may be weighted by relative likelihood of failure, successful attack, or affecting perturbation.

Measuring C2 Responsiveness

C2 Responsiveness is the ability to react to a change in the environment in a timely manner. This attribute of agility involves monitoring, decision making, and synchronization aspects of C2 capability, and is typically characterized by the ability to recognize and counter emerging threats or exploit fleeting opportunities. Timeliness is an important aspect of responsiveness.

The measurement approach for C2 responsiveness is once again based on the identification of a relevant set of use cases, ones that sample the space of types of threats (e.g., a new tactic or a new type of improvised explosive device in a counterinsurgency endeavor, or a disease outbreak in a disaster response situation) that may emerge or classes of opportunities (e.g., a window opens to enter ceasefire talks with an insurgency leader, but a delay recognizing the opportunity and approaching him would give hard-liners a chance to change his mind or remove him) that may arise. To facilitate a complete treatment of the threat/opportunity problem space, it is often helpful to identify *classes* of exploitable events that exist, rather than attempting to exhaustively list individual threats and opportunities.

For each use case, the timeliness of the response to the threat or opportunity is assessed. Timeliness is measured relative to what is needed in the circumstance under consideration, and assumes that the response made is appropriate and effective (if the response is inappropriate or ineffective, responsiveness was not displayed). The C2 responsiveness metric is the estimated proportion of the threat/opportunity space to which timely response by the C2 capability can be provided. Note that other elements of the endeavor may prevent the endeavor as a whole from being able to respond effectively to emerging threats and fleeting opportunities; when measuring C2 responsiveness, the focus is on the ability of the command and control capability to recognize the threat or opportunity, generate response options (if needed), select an effective option or set of options, and facilitate synchronized execution across the endeavor.

Measuring C2 Flexibility

The previous three agility components focused on maintaining success in the face of a changing environment, or in the face of the effects of that environment on the system of interest. In contrast, flexibility, innovation, and adaptation are internal concepts that deal with the ability of the object of assessment to maintain freedom of action, to generate new options, and to change itself as appropriate. These attributes are more complicated to assess, and have a different tenor than the first three components, which were outwardly focused.

C2 flexibility is defined as the ability to employ multiple ways to succeed and the capacity to move seamlessly between them. This attribute is an aspect of the decision making element of the C2 capability, capturing the degree to which processes and organizations have explored (or are capable of exploring) alternative ways and means to achieve success. C2 flexibility is of greater value when an endeavor faces a consciously agile adversary, which seeks to understand the endeavor's intentions and makes moves to respond to them in ways that exploit vulnerabilities. Flexibility widens the range of possible endeavor actions, and increases the difficulty of predicting endeavor activities, forcing opponents to prepare for a spectrum of possibilities. C2 flexibility is also valuable when the endeavor faces uncertainty in the environment, as in an inability to know how a natural disaster will unfold. Flexibility gives the endeavor access to multiple ways to operate successfully, and the ability to move among options at the situation demands.

As an illustration of the concept of flexibility, Paul Phister of AFRL makes use of the concept of a *flexibility cone*, reflecting the idea that the farther out in time one considers, the more flexible (more options to succeed) one can be, but as the relevant time horizon diminishes, options likewise diminish. Phister invokes in-flight targeting of munitions as an example: the farther out the munition is, the more re-targeting flexibility is retained.[42] In this context, increasing flexibility could mean: changing the aerodynamics or fuel consumption of the munition to make it re-targetable for a longer period of time, and for deeper into its planned flight; reduction of time delays between decisions to re-target and execution of the decision by the munition, providing more available decision time; increasing the accuracy and precision of the munition, to increase the number of targets feasible and available during its re-targeting window; or many others. Increasing options for success is a key element of increasing flexibility.

Measuring C2 flexibility is challenging. An assessment of the C2 flexibility of an endeavor currently in or having completed an operation examines the alternative potential success paths considered by the command and control of the endeavor. Examining how well the object of assessment performs as it moves from one course of action to another provides a sense of how "seamless" transitions between different success paths are or were enabled.

Measurement of C2 flexibility outside the conduct of an operation requires looking at those processes that are posited to prepare an endeavor to have access to multiple options to succeed and to transition smoothly between them. Examination of doctrine (is consideration of multiple alternative courses of action an integral part of command and control activities?), plans and planning processes (do planning documents contain multiple options from which appropriate selection can be made by decision makers?), experience (do C2 personnel have experience in multi-option planning and execution), and training (are personnel trained to execute course of action changes without loss of effectiveness?) can provide insight into how flexible the C2 of the object of assessment is. Currency of options is also an important consideration: Are there mechanisms to ensure that obsolete options are recognized as such?

Suggested metrics for C2 flexibility include the number of relevant (and different) courses of action considered (whether developed in situ or in plans); the degrees of freedom maintained by the assessment object over time, which probes the ability of the assessment object to keep options open; the number of contingencies put into place; and

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[42] Paul Phister, AFRL, private email correspondence, 14 August 2007.

the effectiveness retained by the assessment object during and after transition between courses of action.

Measuring C2 Innovation

Like C2 flexibility, C2 innovation reflects an aspect of the decision making element of the C2 capability of the object of assessment. However, while flexibility deals with having multiple ways to succeed, C2 innovation specifically addresses the capability of doing new things and carrying out activities in ways that are different than how they have been done before.

C2 innovation is defined as the ability to do new things and the ability to do old things in new ways, and is one of the most difficult attributes of agility to objectively assess. Evaluation of C2 innovation during or at the completion of an operation requires looking at how activities were executed and determining whether new activities or types of activities were generated during the operation, and at whether new ways were found to execute old activities. That is, rather than assessing the number of different recipes that the assessment object has in its cookbook, the goal is to determine the ability of the assessment object to prepare new and novel dishes for whatever meal it is preparing.

By direct observation, C2 innovation can be assessed by examining the development and implementation of operational approaches that fall outside of established tactics, techniques, and procedures (TTPs), and that lie near the boundaries of established doctrine. The C2 innovation metric in this case is the number of new options generated during the operation. Objective measurement of innovation by observation can be challenging, as what is considered to be new and different may vary by observer, and what one considers to be “outside established TTPs” may simply be a different interpretation of TTPs.

Another pitfall of measuring C2 innovation by direct observation is similar to one discussed earlier: innovation is only likely to be displayed by those endeavors that are in operational situations that require it, and it will only be displayed to the extent that it is required. To capture the full potential for C2 innovation in an object of assessment—whether or not it was drawn out in a particular situation—it is necessary to look for relevant *indicants*, rather than directly for innovation itself. These innovation indicants measure the presence and extent of likely precursors of innovation, such as broad collaboration and the presence and active engagement of a diversity of thought in command and control entities and processes. A potential C2 innovation indicant metric is the degree of variety in the perspectives represented in C2 collaboration processes.

Indicants for C2 innovation are, of course, only as good as the underlying understanding of how innovation is generated, so there is risk associated with this approach. It is imperative that measurement efforts that employ these approaches make explicit what indicants are selected and why, so that assumptions are apparent and may be evaluated for validity and for future use by others.

Measuring C2 Adaptation

As was suggested by Dodd et al., adaptation involves both process and structural aspects. The definition of C2 adaptation can be divided into two distinct types of adaptation:

- C2 Process Adaptation: The ability to change C2 work processes
- C2 Structure Adaptation: The ability to change the composition of and/or relationships between and among constituent entities in a C2 capability

Before discussing measurement of C2 adaptation, it is useful to place the concept of adaptation into the context of how different approaches to command and control can be characterized.

Understanding Command and Control defines the C2 approach space to be bounded by five dimensions: the composition of the endeavor, the allocation of decision rights, patterns of interaction, distribution of information, and the ability to change the other four dimensions. This enables a generic description of the C2 approach, whatever the particulars of instantiation in a particular organization's form might be. Given a particular endeavor with defined elements, this space is illustrated in Figure 3.

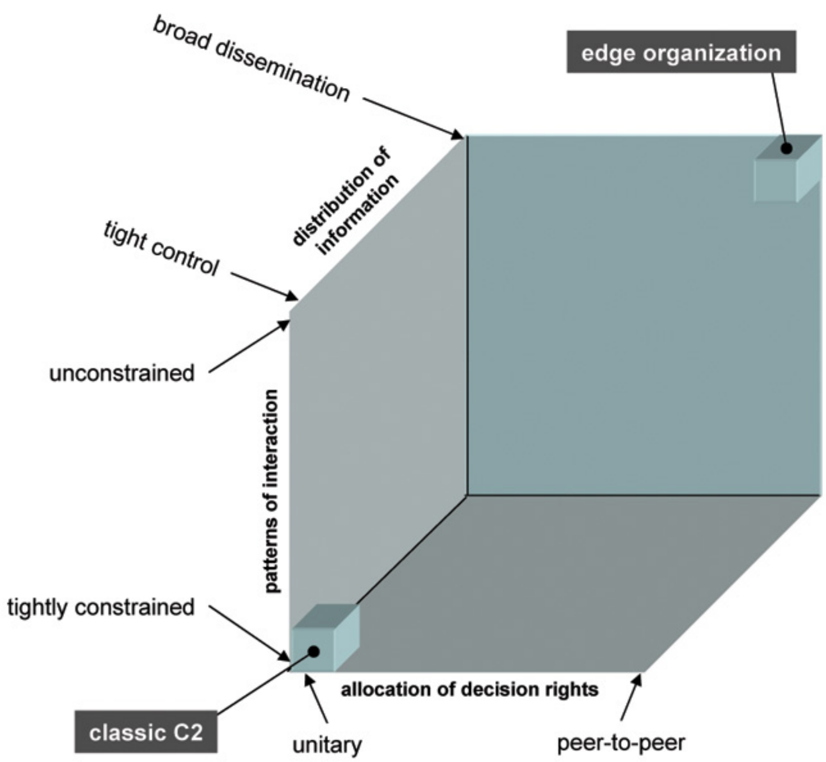

Figure 3. C2 Approach Space (source: Alberts and Hayes, *Understanding Command and Control*, 2006).

C2 adaptation can be considered to be the region of the C2 approach space to which the object of assessment has timely and relevant access, and the ease with which it can effectively transition between C2 approaches. Greater C2 adaptation enables access to more regions of the C2 approach space.

Measurement of C2 adaptation can take two forms: one involving a space sampling approach similar to one applied earlier, and one leveraging a view of enablers (indicants) of adaptation.

For the direct observation approach, a set of C2 approaches are specified that sample the C2 approach space, and each assesses the ability of the object of assessment to transition between and execute each. These assessments are then used to estimate the proportion of the C2 approach space to which the object of assessment has timely and relevant access. Note that this assessment is not necessarily just the ability of a static organization to move around in this space, but must also account for the fact that in some cases, depending on how the object of assessment has been defined, the object itself may be changing over time: adding new components, deleting others, etc.; this is part of the space that must be sampled.

The indicant-based approach evaluates the ability of the object of assessment to execute what are postulated as enablers of adaptation:

- Ability to monitor the environment and recognize the need for change
- Ability to identify implications of recognized change for C2
- Ability to generate options and select appropriate changes to process or structure
- Ability to synchronize changes across constituent elements

The assumption is that an endeavor with these abilities will also be able to adapt effectively; one’s best judgment is used to interpret how capabilities in these enablers will lead to an adaptation capability. However, in some cases, historical data may exist that would allow some direct observation of these indicants to be made (e.g., if an enterprise has been in existence for some time), as well as observation of past adaptation, if in existence.

Note that there are other models of adaptation that may also be used for the purposes of defining indicants, including a DSTO-generated model of adaptivity[43] that describes mechanisms for adaptivity based on complex adaptive systems research, and that is being integrated into Australian capability development thinking[44] and operational doctrine.[45]

Measuring C2 Agility

C2 agility is a capstone metric, capturing information associated with all of the agility attributes discussed above. Earlier, C2 agility was defined as *the potential for robustness, resilience, responsiveness, flexibility, innovation, and adaptation and the capability to synergistically exploit these components to achieve and maintain effectiveness in a dynamic, uncertain, and risky environment*. Thus, C2 agility is a synthesis of the components of agility, and is a multi-dimensional concept. An endeavor with greater C2

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[43] Grisogono, A.M. “Co-Adaptation.” Invited paper 6039-1, *Complex Systems Conference, SPIE International Symposium on Microelectronics MEMS and Nanotechnology, Conference 6039: Complex Systems*. Brisbane. 2005.

[44] Mark Unewisse and A.M. Grisogono, “Adaptivity Led Networked Force Capability,” *Proceedings of the 12th International Command and Control Research and Technology Symposium*, Command and Control Research Program, 2007.

[45] A.M. Grisogono and Alex Ryan, “Operationalising Adaptive Campaigning,” *Proceedings of the 12th International Command and Control Research and Technology Symposium*, Command and Control Research Program, 2007.

agility has more options for maintaining effectiveness as the environment changes and as uncertainty is resolved over time. In a fundamental way, C2 agility can be thought of as the resistance of the assessment object to degradations in effectiveness, regardless of their source.

Figure 4 suggests how the agility of two illustrative objects of assessments might be visualized. In this example, zero-order agility scores were generated using assumptions about how endeavors associated with a response to a natural disaster and with a counterinsurgency effort might be assembled and organized.

This type of chart is useful for visualizing agility, as it avoids “rolling up” the scores from assessment of the individual agility metrics into a single scalar. Users can maintain a sense of how an assessment object is agile, and in what ways it is not, and can compare two or more agility assessments dimension by dimension, gaining richer insight into how alternative systems or approaches are agile than would be possible by simply comparing scalar agility scores. Further, by comparing this information with the ways in which operational situations are likely to stress the C2 capability of the assessment object, judgments can be made about whether requisite agility is present to meet the needs of a situation and how it might evolve.

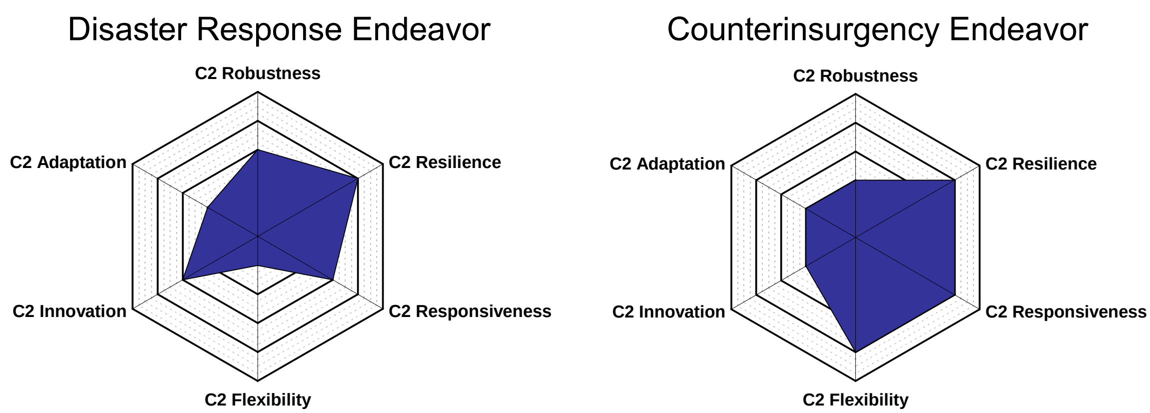

Figure 4. Possible displays of notional C2 agility measures for illustrative endeavors associated with disaster response and counterinsurgency efforts.

Observations and Future Research

Agility of command and control is vital for enabling effectiveness in the uncertain, dynamic, and high-risk operating environments increasingly faced by the United States and its allies and partners. The ability to measure the agility possessed by a force or an endeavor can be of great value in determining what organizational components, structural forms, planning processes, command and control procedures, training, and leadership may be needed to engender the agility called for by particular operational environments.

These concepts are increasingly being recognized in the future operating concepts and doctrine in militaries throughout the world. The U.S. explicitly discusses agility in its National Defense and National Military Strategies, and agility is called out as an attribute of the net-centric environment and command and control capabilities of the future Joint

Force. In addition, close allies, such as Canada, the United Kingdom, Australia and others have adopted some form of network-centric operations or network-enabled capability as a conceptual framework to guide the design of agile forces and capabilities for the future.

In particular, the NATO Study Group, SAS-065, is developing a *NATO Network Enabled Capability Command and Control Maturity Model* to facilitate assessment of the progress of command and control to higher levels of maturity—with the ultimate state being agile command and control.[46] While this maturity model does not distinguish among the six attributes of agility discussed in this work, it does build on them: there are relationships between achieving greater levels of C2 maturity and the achievement of higher levels of the agility attributes. Figure 5 shows this relationship at a high level. Future work to map these relationships in more detail is underway and will be useful, both to describe the value added by the attainment of higher levels of C2 maturity and to suggest alternative ways of measuring C2 agility components.

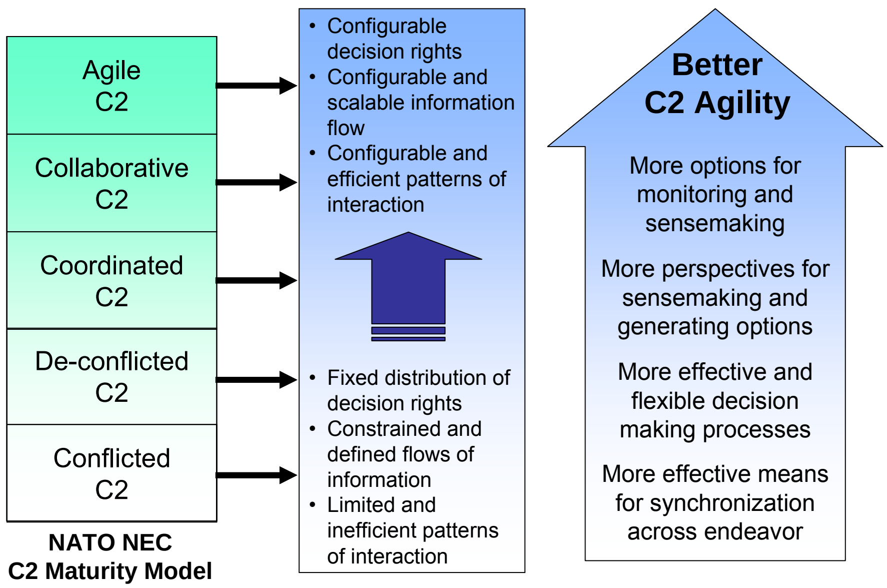

Figure 5. Relationship between NATO Network Enabled Capability Maturity Model and Agile Command and Control.

The measurement approaches described in this paper are intended as a starting point to help evaluators link agility concepts to corresponding observables or indicants in the assessment objects they are evaluating. In applying these approaches and metrics in particular circumstances, operationalization to support assessment activities will need to be tailored for systems of interest, the purpose of the assessment, and any constraints that may be in place on measurement activities. The approaches here are intended to serve as illustrative guides that can be applied in more specific implementations by others in the community and refined as experience is gained.

In conducting these specific assessments, users of these measurement approaches should be aware of, and make explicit where possible, the risks of measuring agility in particular

[46] James Moffat and David S. Alberts, *Maturity Levels for NATO NEC Command*, Defence Science & Technology Laboratory UK, 2007.

ways, which may include possible biases due to how the object of assessment is defined, uneven or incomplete definition of the problem or response spaces associated with specific agility attributes, or the way that indicants have been constructed from models or assumptions of agility enablers. As is apparent from the discussion above, appropriate scoping and characterization of the use cases that are leveraged in many of the attribute measurement approaches are key to effectively measuring those aspects of agility.

In closing, including assessments of agility in research and experimentation is critical to appropriately responding to the essence and complexity of twenty-first century operations. While the concepts and approaches described in this work are first steps toward enabling agility measurement, the methods posited here need to be applied to real-world problems, generating feedback and discussion that allow for refinement of the approaches and examples of how they might be extended. Experience will help us not only understand how to measure agility, but also allow insight into whether organizational, process, training, and systems design approaches are actually leading to greater C2 agility. More fundamentally, this kind of practical understanding will help determine if the ways in which this effort has defined agility are useful and meaningful to operators and planners in C2 contexts.

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As always, errors and omissions are the sole responsibility of the authors.

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