10th International Command and Control Research and Technology Symposium on the Future of C2

"A Systems Engineering Approach to Metrics Identification for Command and Control"

Topic: Assessments, Tools, and Metrics

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ABSTRACT

Command and Control (C2) is an important eliminate to military operations. This is a concept that has been around for a long time and is recognized for its importance on military effectiveness. However, identifying the scope of C2 and the effectiveness as a component of a system is difficult. Differing opinion exists as to what really contributes to C2 and how to measure C2 performance. There is a significant need as new C2 concepts and systems are being developed for a systems approach to define and measure C2.

It is helpful to define C2 in the context of a system and develop an approach to Metrics identification for evaluating C2 performance and effectiveness. The metrics must be dynamic to account for the different goals of C2 systems. This paper provides a recommended approach to help solve this problem by viewing C2 as a component of a system. Metrics need to help identify effectiveness and performance measures to help indicate C2 performance. Metrics can be used to help identify system requirements and testing and evaluation for the effectiveness of the C2 approach.

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Introduction

Command and control (C2) is a term that lacks consistent definition and is difficult to analyze due to the complexity of the impact on warfare. Determining the effectiveness of command and control systems is difficult without an understanding of C2 within a system and understanding C2 functions within the context of different missions. The scope of C2 affects what needs to be measured.

In addition to the lack of definition of C2, an approach for identifying metrics for evaluating the effectiveness of C2 needs to be better defined. The goal of C2 in military organizations is to create superior command and control to accomplish missions. However, it is difficult to evaluate this without understanding and measuring performance and effectiveness of C2 in different system designs and applied missions. Command and control are functions that can be accomplished in many ways. Identifying metrics to evaluate the performance of command and control allows for better understanding effectiveness of different C2 options.

There is a need to consider command and control in the context of a system to help identify C2 functions integrated with the warfare system and metrics needed to evaluate performance and mission effectiveness. In this systems approach, all domains of command and control need to be considered as an integrated system: physical, information, cognitive and social. The challenge is that C2 goes beyond hardware and software systems and deals with the human and organizational interactions. This requires consideration of new metrics for C2 performance evaluation.

There is clearly a need to continuously improve and measure the performance of C2 systems. Command and control metrics can be used to help identify system requirements and support testing and evaluation of the effectiveness of the system design. Secretary of Defense Rumsfeld identified the need in the Iraq war to "accelerate the speed of command and control." (Cordesman 2003) Continued focus of Net-centric warfare to improve C2 capability is a priority in military capability. This is clearly an important area in need of measurement and continuous performance improvement.

Defining Command and Control – Systems Perspective

There are several definitions of command and control that help scope the meaning.

Joint Publication 1-02 defines command and control as "The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, commutations, facilities, and procedures employed by a commander in the planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission."

Another definition of command and control is defined in the Naval Doctrine Publication (NDP 6) "Naval Command and Control." This document says "Command is the authoritative act of making decisions and ordering action; control is the act of monitoring and influencing this action."

Command is defined by Alberts and Hayes (2003) as "the creative expression of human will necessary to accomplish the mission." Control is also defined by Alberts and Hayes (2003) as "those structures and processes devised by command to enable risk reduction."

There is no dispute in the military community that command and control is an essential element of warfare. However, there is not general consensus on a well defined boundary of C2 to help define appropriate metrics for performance. Input to C2 is command intent which identifies what needs to be done. (Alberts and Hayes 2003) Command and control refers to both the process and systems the commander uses to support executing decisions and observing that decisions are being carried out. Command is influenced by leadership, authority, responsibility and accountability which are part of command. Leadership is an important element which affects the quality of command through inspiring commitment to a common goal. Control is the means in which actions are monitored and influenced by a commander. The commander monitors and influences the actions of the forces and resources at hand through command and control. The commander needs to monitor and provide feedback when the plan needs to change or is observed to not being executed properly.

Systems Approach

Systems engineering provides a structured approach to identify system requirements and develop a solution that meets system performance requirements. Elements of this same approach can be used to help define C2 systems and identify metrics for performance evaluation. To help evaluate the performance of C2 systems, a systems approach is necessary which includes an understanding of humans and how they interact in command and control functions. The system must include an understanding of humans, what functions they perform and how they interact with other components of the system.

One important element of systems engineering is functional identification. This general process is shown in **Figure 1 (IEEE1220-1998)**. Identifying the key elements of C2 functions helps to scope what metrics must be considered for performance evaluation.

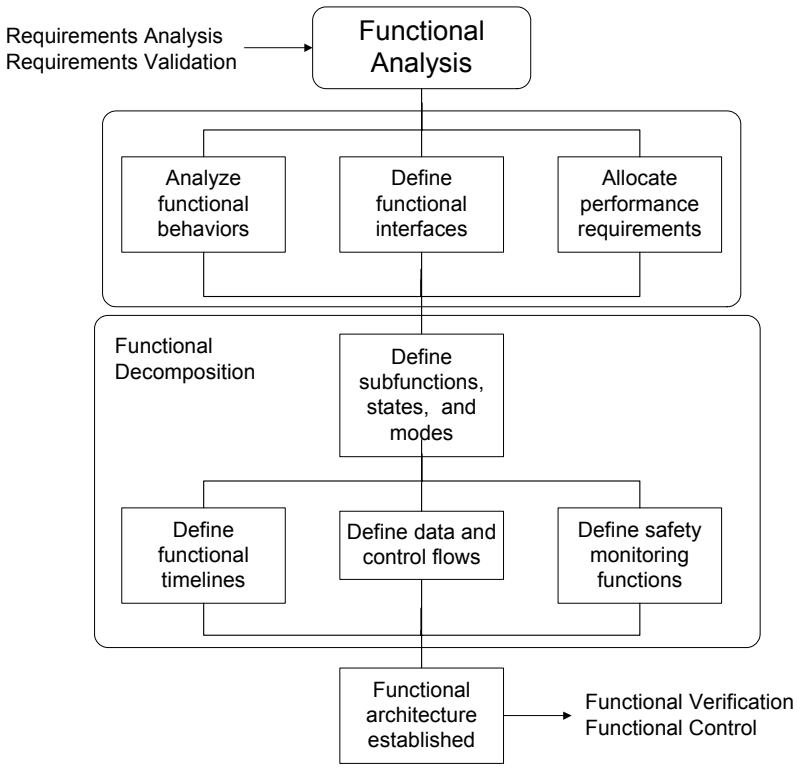


Figure 1. Functional Analysis in Systems Engineering

The functions of C2 needed to achieve information and decision superiority are the critical elements that need to be considered. C2 is an element of the overall military system that is supported by people, information and technology which also need to be considered in evaluation of C2 performance. Evaluation of the entire integrated system is needed to determine overall effectiveness.

In systems engineering, it is useful to develop a context diagram to identify things that influence C2 system performance. This is shown In **Figure 2**. It is important to note that C2 needs to look beyond the technologies to support the functions and include cognitive and behavioral factors as well as information. The term, Cognitive Behaviors, refers to how people think and act. This includes considerations for the environment in how information and knowledge are developed and used to make decisions. (Glasow 2004) Command and control relies on human judgment and this needs to be considered in performance evaluation.

It is also important to develop a concept of operations in systems engineering. However, this is not detailed here since a concept of operations is for a particular system application.

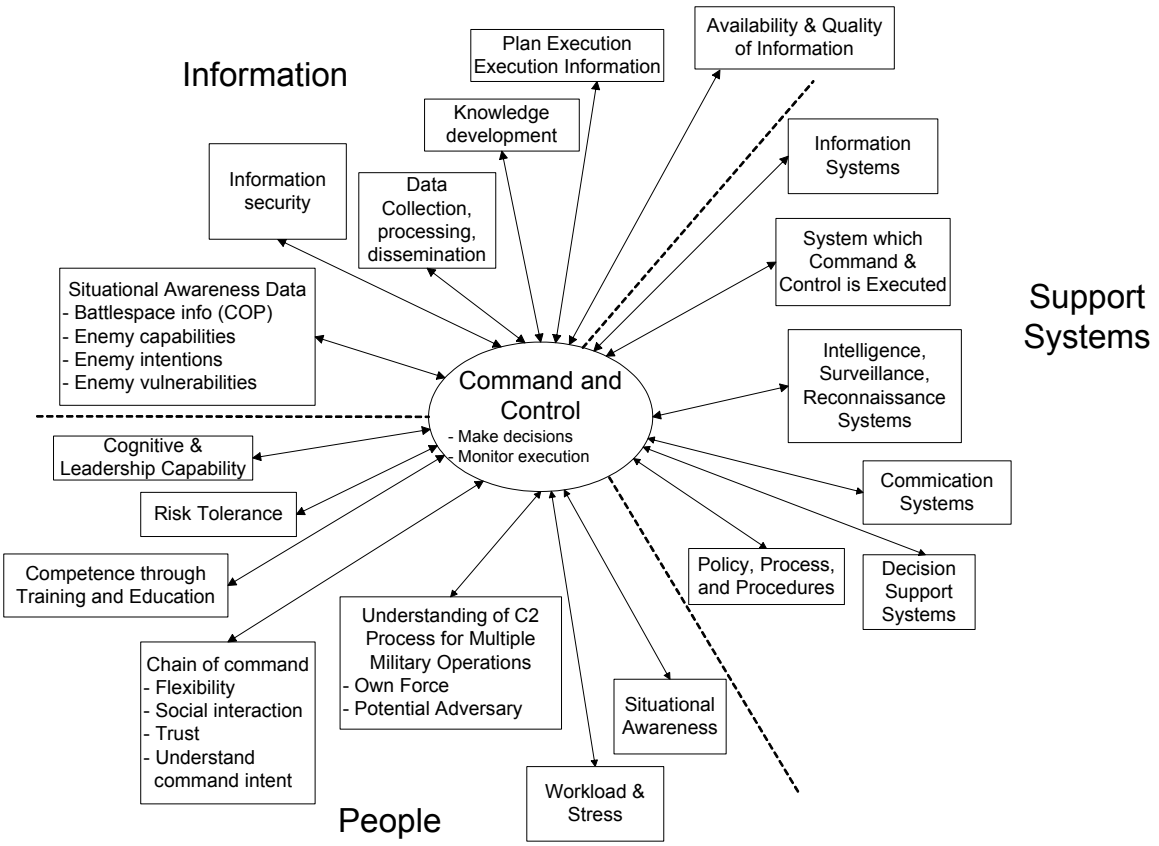


Figure 2. Context Diagram for Command and Control

People are an essential part of command and control. The ability of organizations to effectively implement command and control will depend on the training, personnel qualities, and cognitive ability. Organization structure needs to support C2 tasking. Procedures, policies, and processes need to support effective command and control.

Information effectiveness will depend on the availability, display, and timely retrieval. Plans need to account for mission objectives, asset locations, responsibility boundary, schedule, and contingencies. Determination of timely blue and red force locations is important to developing situational awareness.

Support systems help to facilitate information development, support people and C2 activities. This may include physical systems as well as policy and procedures.

Command and Control identifies the responsibility, authority, and accountability for making, implementing and monitoring the execution of decisions.

C2 Characteristics

Here are several taxonomies that have been developed that provide insight into C2.

Admiral Bill Owens in his book "Lifting the Fog of War" envisions joint forces as seeing, telling and acting. These are key tasks that are part of C2.

Kaye and Galdorisi (2001) identify seven functional imperatives for C4ISR capability. Although these include elements beyond C2 it identifies key functional tasks that are part of command and control. The functional areas include:

- Focused Sensing and Data Acquisition
- Dynamic Interoperable Connectivity
- Universal Information Access
- Information Operations Assurance
- Consistent Situation Representation
- Distributed Collaboration
- Resource Planning and Management

OODA Loop

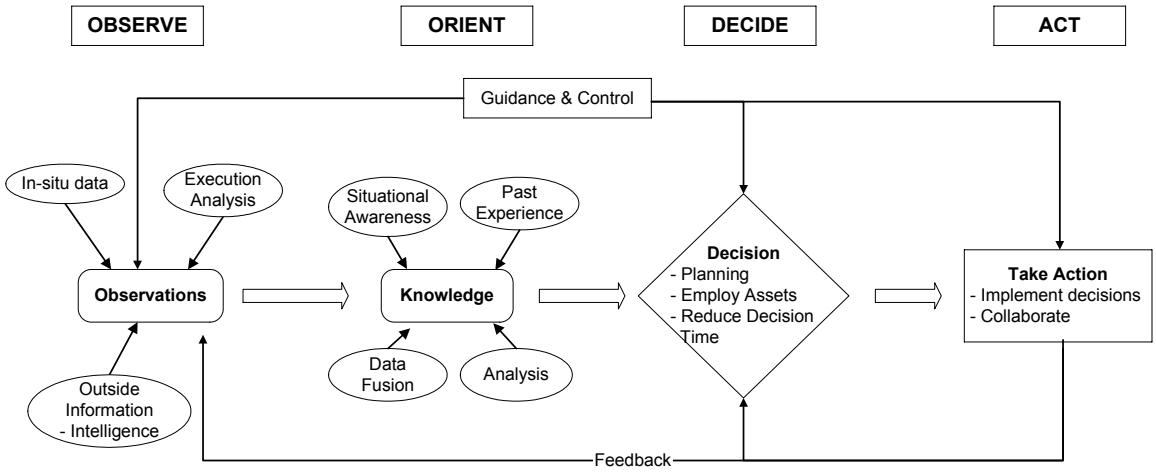
Another taxonomy, the well-known "OODA Loop" (Observe, Orient, Decide, Act.), is shown in **Figure 3**. The seven functional imperatives by Kaye and Galdorisi (2001) identified above will directly influence the speed of the OODA Loop. The OODA loop, developed by Col. John R. Boyd (1987), provides an example of key functions and the process of command and control. This model identifies the decision maker as the key component of command and control. Identifying the ability to perform these functions in command and control provides a framework for metrics identification.

"Observe" is to collect information about the environment (enemy position, status, intent, friendly forces position).This data may be used to develop a Common Operating Picture. The effectiveness of this phase relies on the amount, quality, appropriateness, and timeliness of information.

"Orient" is to develop knowledge and judgments about the situation. This is where the awareness of the situation is developed and is based on cognitive processes of knowledge development. The ability to convert data into information that develops knowledge that supports understanding is what is taking place in this cognitive process.

"Decide" is the course of action taken that develops in some plan. The ability to make sound and timely decisions is an important part of effective command and control. The ability to make good decisions faster considering the uncertainties provides an advantage. Good decision making can be determined from what information was considered, the alternatives selected and the criteria for selecting the final alternative. This process may be more analytical or intuitive.

"Action" is then taken to convey the commander's intent through orders. This may be through detailed orders or by passing along high level objectives allowing for more freedom of subordinates actions. This also includes monitoring the execution of operations that required information in the "Observe" phase of command and control. Selecting the right level of orders and communication means will have an effect on the command and control effectiveness. There are times when more freedom by subordinate units will allow for quicker execution of actions. The best alternative may depend on many different influences.



Advantage comes from speed and effectiveness
of OODA sequence of activities.

Figure 3. OODA Loop

Command and Control Functions/ Tasks

To better understand command and control it is helpful to understand what functional tasks are included in the C2 system element. **Figure 4** shows a list of some high-level functions that are part of the command and control system.

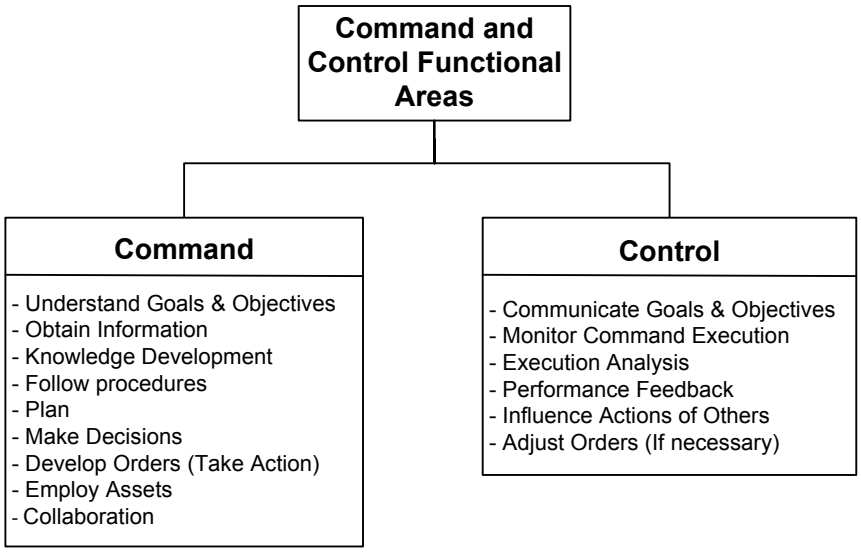


Figure 4. Command and Control Functional Areas

Metrics Definition

Once the context of the system is defined, metrics can be determined by understanding the performance needs of the system functions necessary to support C2. Command and Control metrics need to help support answering the question: is C2 effective in achieving the mission? Numerous other questions will also need to be answered to help support C2 evaluation. These additional questions can be determined based on the specific functional needs of the system. Measures of Effectiveness and Measures of Performance are used to help answer these questions.

Measure of Effectiveness (MOE) is defined as… "Tools used to measure results achieved in the overall mission and execution of assigned tasks. Measures of effectiveness are a prerequisite to the performance of combat assessment." (JP-01) Measure of Effectiveness is also defined by the DAUE Glossary as "Metrics used to measure results achieved in overall mission and execution of tasks."

Measure of Performance is defined as…. "Measures of a system's technical performance expressed as speed, payload, range, time-on-station, frequency, or other distinctly quantifiable performance features. Several MOPs may be related to the achievement of a particular MOE." (DAU Glossary)

It is important to recognize that metrics may be evaluated both quantitatively and qualitatively. The ability to be flexible in the evaluation considering both of these approaches is necessary due to the different levels of information available to support the evaluation of the metric.

Identifying Metrics – GQM Method

Metrics should have purpose and need to be linked to needed information about the system. One technique to help do this is the Goal-Question-Metric Method. (Rombach and Basili 1990) This approach is shown in **Figure 5**. The goal can be represented by the intended function of system and the question identifies what needs to be answered by the metric. In C2 one of the goals is "mission success." Each goal should evoke questions about how its accomplishment can be measured. (Perkins 2003). Questions need to elicit information on the progress in achieving the goal. A question corresponding to C2 is "How effective is C2 in achieving mission success?" Metrics are the information needed to help answer the questions. Each question may have multiple relevant metrics. A metric should generally need two or more measures for evaluation.

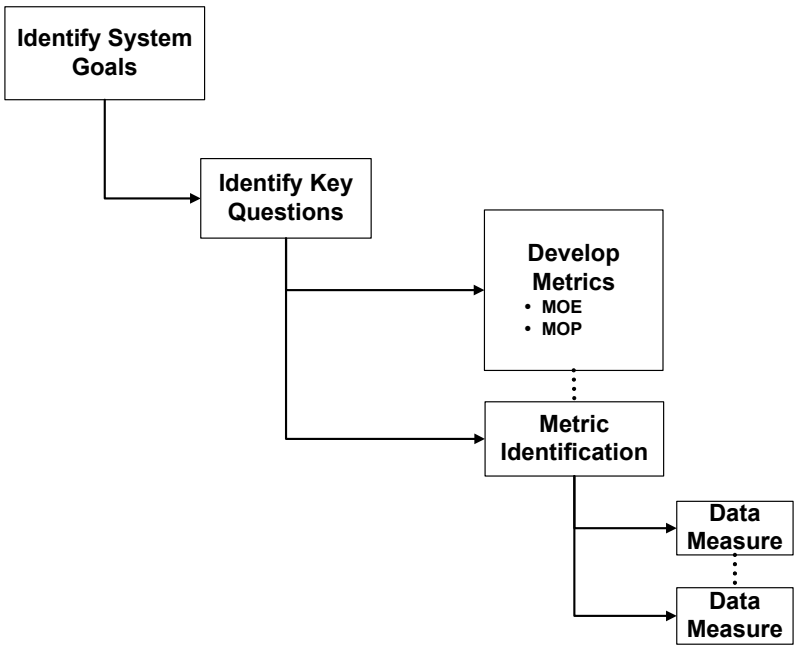


Figure 5. Goal- Question- Metric

Metrics affect the ability to evaluate the effectiveness of different C2 systems and improvements in system performance. Metrics can help to determine if requirements have been met and support testing and general performance evaluation.

Once the system is defined, performance metrics can be determined by understanding the goal and functions of the system necessary to support C2. The goal will depend on the mission. Several questions that C2 Metrics need to answer are:

- Is C2 effective in helping to achieve the mission?
- Is information and knowledge development successful in supporting C2?
- Are good and timely decisions being made regarding C2?
- Is the commander's intent and direction being implemented by other units?
- Is command effectively monitoring and controlling assets to achieve goal?
- Does the command organization support C2 objectives?
- What are the risks of a C2 system in an operational environment?

C2 Metrics Taxonomy

Figure 6 shows a list of possible metrics to be considered for C2. This is only a starting point for metrics consideration. Ultimately the effectiveness of C2 on the combat outcome is the ultimate measure of effectiveness of concern.

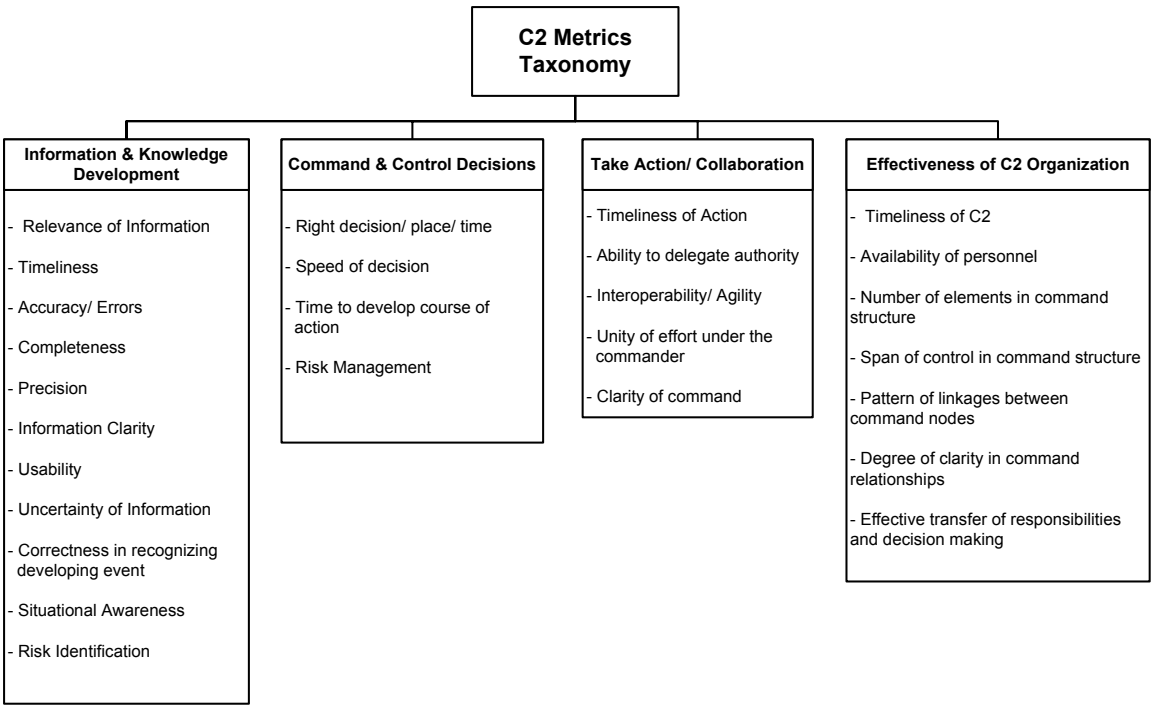


Figure 6. Command and Control Metrics Taxonomy

Time is a constraint that may affect the uncertainty and quality of decisions made as well as execution of actions. It takes time to gather and process information into knowledge, make decision and execute decisions. The timeless of the information that is gathered is may have a significant impact on the quality of decisions being made.

Uncertainty of Information and time are key metrics of concern to command and control systems. There is uncertainties in information gathered, intent of threats, and possible actions by own force. Reducing the uncertainty is a way to effectively make better decisions and improve C2 effectiveness.

There is a tradeoff between time and uncertainty that the commander needs to control in making decisions. This balance is important to the effectiveness of C2.

Information must also contribute to the commander's knowledge and understanding. On a qualitative since, the measurement or evaluation of these metrics provide some assessment of effectiveness of the information. Generally- imprecise information is better than having no information, untimely information is the same as having no information, irrelevant or inaccurate information is worse than no information at all. *(NDP-6)*

Dynamic Considerations of Command and Control

The performance of C2 systems depends on the context of the situation and C2 capabilities of potential adversaries. Command and control capability must provide some advantage in the way that command and control is performed that provides an improved

capability over an adversary. This improvement may gain advantage in speed, accuracy, and overall effectives of employing assets.

The type of command and control approach selected and its potential effectiveness will depend on the circumstances of the environment as shown in **Figure 7.** Some environments require less or more decision making ability to be passed along to units as part of the orders developed in command. Dynamic situations requiring fast decision making may require more decision making to be performed at the distributed unit level than the higher level command.

It is important to realize this dynamic nature of C2 needs since achieving a specific performance capability in one environment may actually result in failure in another. This will also affect what metrics are important.

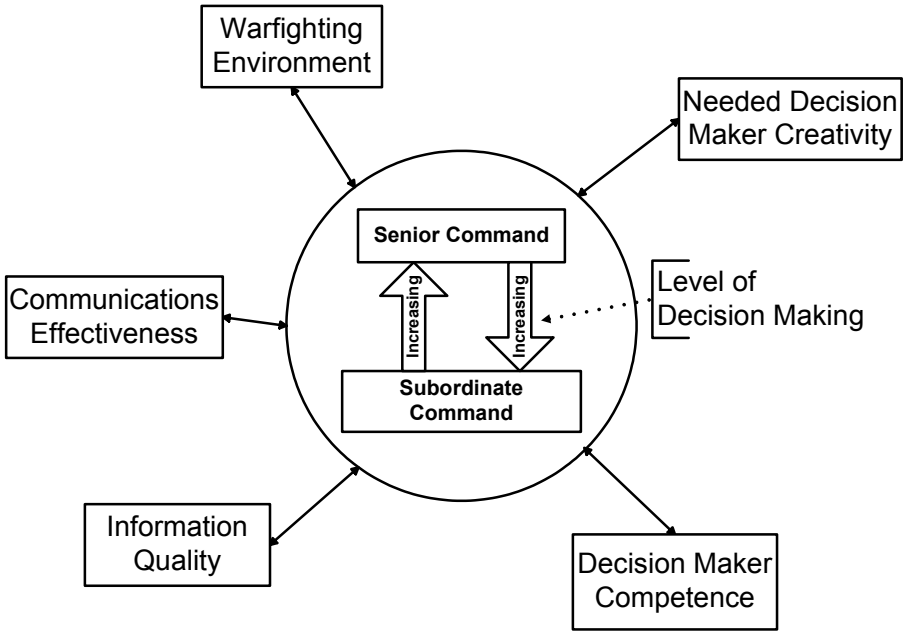


Figure 7. Command and Control Needs Based on Environment

Conclusions

Identifying C2 using a systems engineering approach helps to scope the metrics needed to evaluate the effectiveness of C2 systems. By considering Command and Control as a component of a system, a better understanding of the influence of C2 functions and dependencies affecting mission effectiveness is defined. The approach presented in this paper provides a systematic way to identify metrics and allows for C2 system performance evaluation. This identifies cognitive and behavioral metrics affecting human performance which may be considered by many to be non-conventional for C2 consideration.

Each C2 system may be different and have different goals in the context of a specific environment. Therefore, a dynamic development of metrics to support the unique goals of each command and operation should be considered.

Risk identification and effective management is an important metric needed to help compare the performance of different C2 solutions. An initial taxonomy for metrics including the major categories of information, supporting technologies and systems, people and command and control decisions is proposed. It is important to note that information to support metrics may need to be qualitative based on data limitations.

Continued application of a systems approach to C2 performance evaluation should link the performance metrics of the C2 functions together to help determine overall system effectiveness.

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