An Information Processing Taxonomy for FCS Task Analysis

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ABSTRACT

Information centric systems, such as the Future Combat Systems (FCS), require leaders and battle staff members to perform activities that span an information processing continuum. These activities are primarily cognitive in nature. This continuum begins with the Soldier accessing critical information from the battle command network. The information is analyzed and managed to enable the leaders and/or battle staff members to gain insight into a multitude of events shaping the operational environment. With the necessary insight, a course of action is planned in a collaborative fashion. As the course of action is implemented the leaders or battle staff members seek acknowledgement of the status of the action and distribute pertinent information resulting from the action.

The use of a taxonomy to define an information processing continuum is a new and evolving approach that is being used by three teams conducting task analysis for leaders and battle staff members for FCS equipped Brigade Combat Teams (BCT). The taxonomy was developed by examining the activities that are part of the operational architecture for the weapon system. The taxonomy is being used in the development of task performance steps in preparation for the design of training products for FCS. By using the operational architecture as the foundation for the taxonomy two exceedingly important outcomes are being realized. First, the language of the FCS engineer is being merged with the language of the FCS BCT Soldier. Second, gaps in what the Soldier expects the system to do and what the system is being designed to do are being identified. This systematic process is helping to ensure the ultimate design outcome; that is, when FCS is delivered the Soldier will be designed into the system

ABOUT THE AUTHORS

David Olsen is a Senior Systems Analyst for Dynamics Research Corporation. He has 22 years experience designing and developing military training systems. His work has included examination of training, human factors, manpower, and cost issues impacting training system design and implementation. He has been involved in the design of numerous training systems encompassing various configurations of embedded training, multimedia, and virtual and constructive simulation. Recent work has focused on user interface design and usability assessment for WARSIM, JSIMS, and CCTT. His current assignment as Deputy Program Manager for DRC's effort is to guide process issues for the development of Training Support Packages (TSPs) for the Future Combat Systems (FCS).

Judith Converso is a senior manager of instructional systems for Computer Sciences Corporation, currently serving as a member of the Future Combat Systems (FCS) Leader and Battle Staff Integration Team. Her interest and experience have dealt with large-scale educational/training reform efforts which focus on a systems approach to the design and diffusion of innovation via change management and leadership principles and methodologies. Dr. Converso has an extensive background in instructional design and, in addition to her work with CSC, serves as an adjunct online instructor for FSU and Nova Southeastern University in their masters and doctoral programs.

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INTRODUCTION

Task analysis activities are currently underway for the Future Combat Systems (FCS) to identify the tasks for leaders and members of the battle staff of the FCS equipped Brigade Combat Team (BCT). The qualitative nature of these tasks differs significantly from traditional operator and maintainer tasks. These tasks reflect a great deal of cognitive activities that are integral to mission execution. Within the FCS BCT, command and control at echelons platoon through brigade will take place primarily through the capabilities provided by a sophisticated digital battle command system and accompanying suite of robust tools. Collaboration on planning and preparation tasks will be enabled by a shared Common Operational Picture (COP). These tasks involve analyzing, interpreting and synthesizing large amounts of information. The information provides the basis for formulating a course of action (COA) and other decision making activities. In truth, these tasks are difficult to develop for experienced task analysts and exceedingly difficult for domain experts who are wearing a task analyst hat for this project in addition to their domain expert hat.

For the FCS program, task data was being developed concurrently with engineering design activities. This was viewed as a great opportunity to leverage the analysis data to support the ongoing engineering efforts. Those who have seen the movie *Cool Hand Luke* starring Paul Newman will remember the oft-repeated line from the prison warden. "What we have here is a failure to communicate." Language is critical during task development, particularly if the task data will provide information that will drive engineering as well as training decisions. The various system engineering and training teams rarely speak the same language, even when they appear to be talking about the same thing. One senior program manager describes this phenomenon as various *tribes* trying to communicate, much of which is lost in translation.

The current phase of the project involves 45 Army subject matter experts who are conducting the detailed task analyses. Since the data will be made available to various engineering teams, getting the language right was a priority. To build consistency in the use of the language and to assist analysts in the actual process of development, the use of an information processing taxonomy was proposed. The intent was to provide a taxonomy to be used by training analysts to guide the development of task performance steps, a critical step in the task analysis process

ANOTHER CHALLENGE AND OPPORTUNITY

During the development of the information processing taxonomy, another challenge was identified. This challenge was how to use the task data to support validation of the operational architecture for FCS, in particular the battle command component that will be integral to all FCS platforms.

The use of training related data to support engineering activities is not new for FCS. One of the key products from training analysis that is being integrated into engineering activities is detailed collective task information, referred to as the Collective Single Integrated Task List (C-SITL). The C-SITL is being used to support design of the battle command capabilities.

The use of task data to validate the architecture for battle command capabilities was a new challenge and a challenge for which an information processing taxonomy was potentially valuable. It appeared that the use of a taxonomy that would be used in task development could possibly be leveraged to assist in validating the architecture.

Validating the Architecture

The Department of Defense Architectural Framework (DoDAF) is a model-driven approach to architectural framework based on architectural blueprint languages such as Unified Modeling Language (UML). Within DoDAF, the architectural descriptions are defined in terms of multiple views, each of which conveys different aspects of the architecture in several products (descriptive artifacts or models). Of specific interest to our effort were two views:

- **Operational View (OV)**. The OV describes tasks, activities, participating nodes, and associated information exchanges required to perform a mission. One of these specific views is OV-5, Operational Activity Model. This model results in UML activity and sequence diagrams. Each of the operational activities has a corresponding narrative description.
- **Systems View (SV).** The SV describes the systems of concern and their connections in the context of the OV.

To support the validation effort, a third view was added, which was the **Task View (TV)** (see Figure 1). While there is much commonality between the content of the OV and TV, the TV provided critical activity information not detailed in the OV. This detail was provided via the task analysis process that forced a detailed descriptive process, well beyond the detail provided in the OV. The TV was also generated by Army subject matter experts who have carefully thought through a multitude of operational issues impacting the capabilities that need to be available to the Soldier using the battle command capabilities for the emerging weapon system.

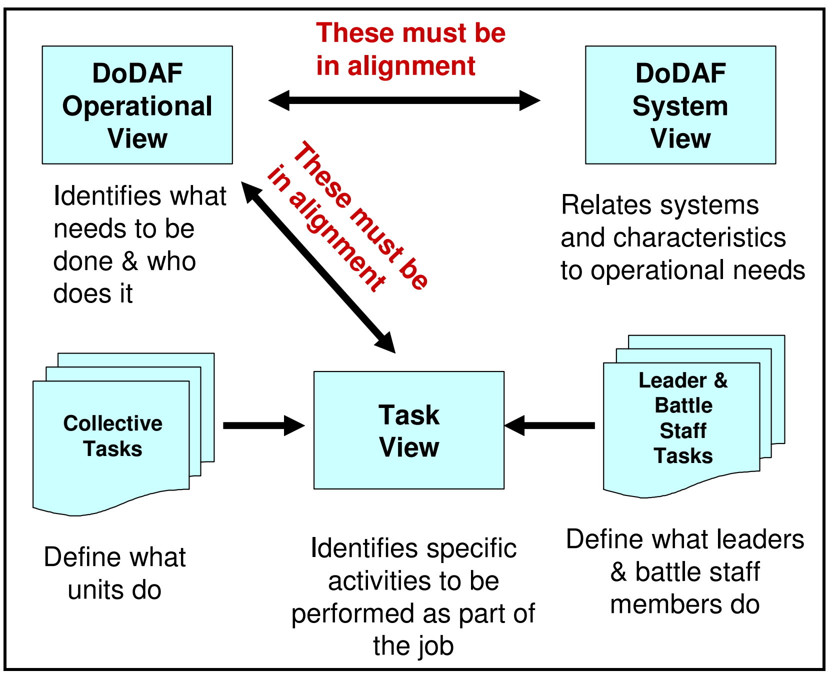

Figure 1. Relationship between Tasks and Architecture Views

The concept of validating the architecture through the task view was relatively simple. The premise was that in order to perform all the identified FCS tasks and their supporting performance steps, there must be requisite system functionality. This functionality is defined within the systems architecture, which is driven by activities/operations in the operational architecture. That is, there is a defined linkage between activities Soldiers perform (operational view) and functions that are provided by the system (system view). This linkage is contained within SV-5, which is the operational activity to systems function traceability matrix. If all the tasks that need to be performed by Soldiers can be linked to activities identified in the operational architecture (OV-5), and these activities have corresponding system functions then, by logical deduction, the operational architecture is considered valid and complete; i.e., all Soldier tasks can be adequately supported through the functionality that is on the drawing board. If there are gaps between tasks and the activities from the operational architecture, it is likely that there are missing system capabilities. These will need to be identified and incorporated into the architecture.

Linking the TV to the OV is critical to ensure all gaps have been identified. It is from the architecture that a series of successive system and software engineering activities are born. Once a bow-wave of engineering activities gets started, it is much more costly to modify the architecture to account for missing pieces. The use of task analysis data may help mitigate the risk of missing critical functionality.

METHODOLOGY

Developing the Information Processing Taxonomy

Taxonomy is the science of classification according to a pre-determined system, with the resulting catalog used to provide a conceptual framework for discussion, analysis, or information retrieval. Taxonomy comes from the Greek word **taxis** meaning arrangement or division and **nomos** meaning law. (http://en.wikipedia.org/wiki/Taxonomy). Some have argued that the human mind naturally organizes its knowledge of the world into such systems. This view is often based on the epistemology of Immanuel Kant (1978).

The development of a taxonomy should take into consideration the value of separating elements of a group (taxon) into subgroups (taxa) that are mutually exclusive, and unambiguous. When viewed as a whole, the taxonomy should include all possibilities. In order to be useful to the analysts developing the tasks, the goal was to build a taxonomy that would be simple to use, and tailored for information processing as it relates to command and control functions. The focus on information processing was considered key because it encompasses the key activities performed by leaders and members of the battle staff using the capabilities of the battle command system being developed and thus supports the additional challenge of validating the operational architecture.

Prior to the additional challenge of validating the architecture, Field Manual (FM) 6-0, Mission Command: Command and Control of Army Forces (2003) was evaluated as a potential starting point for building the taxonomy. In particular, the team focused on Chapter 5, the Command and Control System and the information processing activities identified. It became apparent early on that these activities were too broad and did not provide a level of discrimination among information processing activities that would help with task development. However, the activities provided a structure in the form of a continuum, which was seen as potentially very useful.

With the task of validating the architecture now on the plate of the project team, an additional source for creating the taxonomy became readily apparent; the operational architecture itself. For the emerging system, about 1300 activities have been identified that are comprised in the operational architecture. For each activity, a description is provided that places the activity in context. Essentially, this is like a use case that defines an operational use for the activity. Each activity begins with a measurable action verb; e.g., track, compare, monitor.

To begin the development of the taxonomy, the team created .what was termed an *information processing continuum.* This continuum represented what was envisioned as a flow of activities of how the task performer would process information as part of performing the task. Since the leader and battle staff tasks involve using the capabilities of the battle command system, processing or managing information is integral to each task. Figure 2 identifies this first (highest) layer of the continuum. This first layer helps to understand the basic continuum of how the information will be processed by the task performer. The continuum begins with the Warfighter acquiring critical information from the battle command network. The information is dissected such that it will enable the identification or synthesis of critical data. The data is then managed to enable the leaders and/or battle staff members to gain insight into a multitude of events shaping the operational environment. With the necessary insight, a course of action is planned and implemented. As the course of action is implemented the leaders or battle staff members seek verification that the action has been performed. Finally, the task performer disseminates pertinent information resulting from the action.

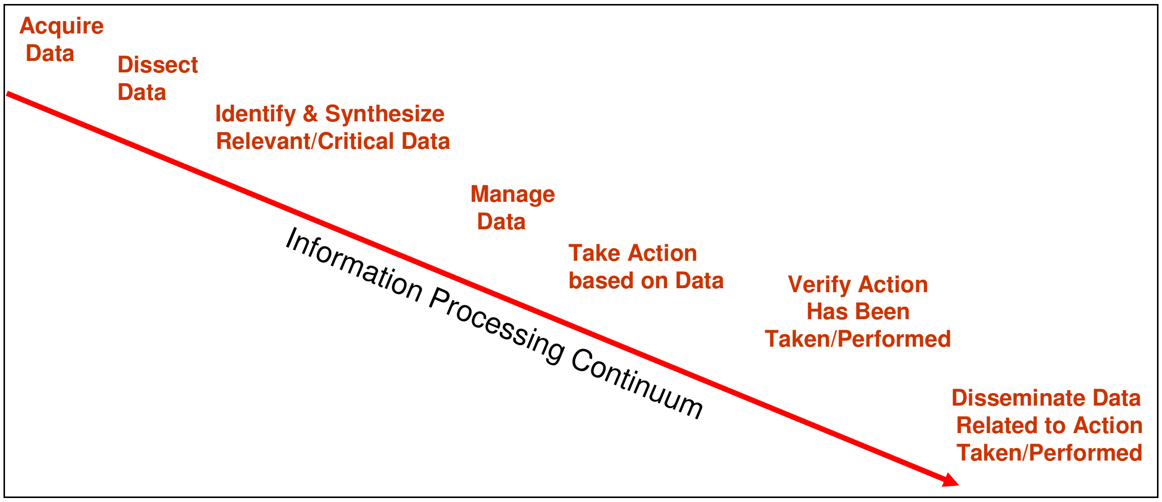

Figure 2. Information Processing Continuum

The second level of the continuum was developed to refine the continuum such that it would provide a greater level of specificity thus enabling the user to more confidently select an action verb that matched the information processing activity. This resulted in 9 capstone verbs corresponding to the information processing continuum. Identification of these capstone verbs was a subjective process involving the grouping or categorization of all 1300 activities from the operational architecture. The goal was to identify buckets or categories that all of operational activities could fall into. After considerable discussion and trial and error, the 9 verbs identified in the arrows in Figure 3 were selected.

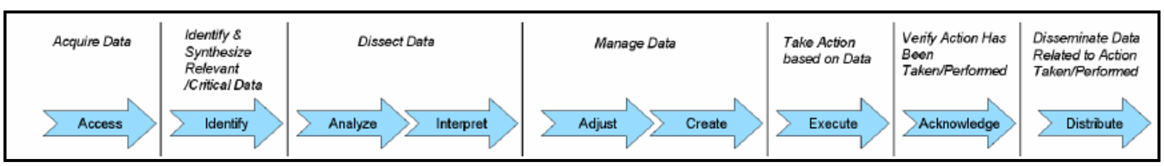

Figure 3. Information Processing Continuum – Second Layer Containing Capstone Verbs

Each of the 9 verbs was then defined in the context of an information processing description. For example Assess was defined as “The process of gathering or requesting information.” Interpret was defined as “The process of refining, filtering or assessing information.”

As part of the development activities, the training analysts (target audience for the taxonomy) were asked for suggestions on modifications to the taxonomy, particularly to align the information processing actions to better reflect military activities by leaders and members of the battle staff. A number of suggestions were received and these were incorporated into subsequent versions of the taxonomy.

Applying the Taxonomy to Task Development

Training analysts were strongly encouraged to use the information processing taxonomy for developing and sequencing task performance steps. Training on the use of the taxonomy was provided. Analysts were instructed to sequence their performance steps using the information processing continuum provided by the taxonomy. For example, if the Warfighter, (task performer) needed to gain situational understanding as one of the initial performance steps, it was very likely that he/she needed to *acquire data* from the battle command network. In this case it was recommended to the analyst to use *Access* as the initial action verb for the performance step or one of the other verbs that appeared beneath the Access category (see Figure 4). (**Note:** It was not possible to depict a readable version of the taxonomy in a single figure. The description and contents of the taxonomy are provided at the end of this paper).

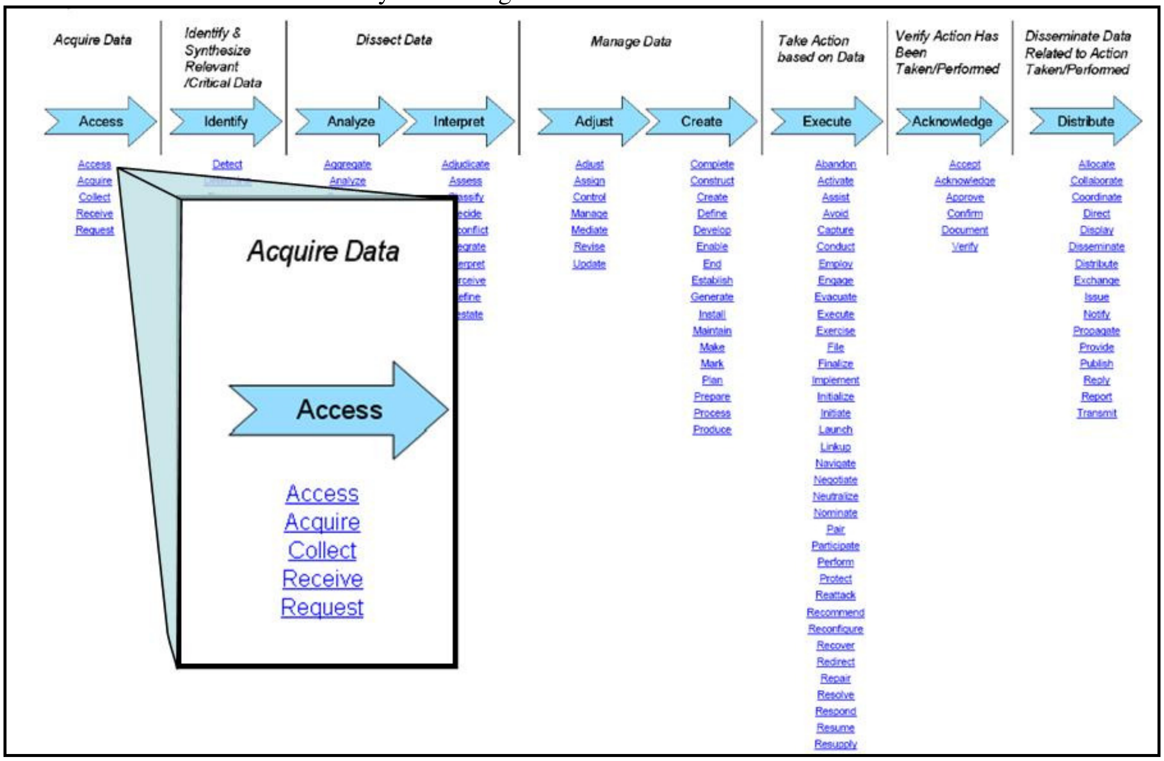

Figure 4. Taxonomy and Supporting Verbs

These verbs were extracted from the verbs used to describe the activities within the operational architecture (i.e., OV-5). The reasoning was that to the extent possible the same verbs used to describe the architecture should be used. Two important outcomes were desired. First, in using the same verbs there would be a merging of the language of the Soldier with the language of the engineer, a sharing that would provide great dividends if our task data was used as part of subsequent engineering modeling activities. Second, it was critical that the analysts developing the tasks become familiar with the activities within the operational architecture since these activities identify capabilities that must be incorporated into the task as part of the performance steps. To assist in familiarization, an HTML tool was created with hyperlinks to descriptions of the activities from the operational architecture.

Applying the Taxonomy to Validation of the Architecture

To meet the challenge of validating the operational architecture, analysts were required to determine if a linkage could be made from each task performance step to one or more of the operational architecture activities. The goal was to verify that no gaps exist between the actions that Soldiers will need to perform as part of the task and the operational architecture that impacts the functionality that will be built.

The linkage of task steps to the architecture was a logical extension of using the information processing taxonomy for task development. The organization of the taxonomy provided a structured mechanism to identify and sequence task performance steps. This same structured mechanism would assist the analyst in identifying the associated operational activities. For example, if the analyst needed to find the operational activities related to the performance step entitled "Evaluate terrain", a starting place would be to look under the *Analysis* heading for *Evaluate* or a related verb that conveys the process of evaluation. The analyst could then click on the hyperlink for the verb and browse the list of operational activities and their associated descriptions to see if a linkage could be made.

If this identification strategy was not successful, a key word search capability was available to examine all the operational activities and their descriptions for possible linkages.

Specifying the Link Strength

During an early tryout of the methodology it was discovered that while linkage could be established between many of the task performance steps and operational activities, the linkage at times was very weak. That is, the operational activity was only vaguely connected to the performance step. While a link could be confidently documented, it was not possible to say that the operational activity sufficiently captured the activities described in the performance step. To address this problem, the process was changed to force the analyst to specify a *Link Strength* between each performance step and operational activity. A five point scale ranging from Poor to Superior was developed. Each of these values was defined. For example *Poor* was defined as the following:

"Only a very weak link between the performance step and the operational activity can be established. Descriptive information supporting the performance step is completely insufficient for identifying the needed system functionality."

A report capability was developed that provided a listing of which tasks and performance steps had linked operational activities and the strength of these linkages. Other reports were developed that identified task and performance steps with no linkage or poor linkage. Analysts were also given a text field to enter enhancements to description of the operational activity that would better support the development within the systems.

RESULTS

Two outcomes were desired through the use of an information processing taxonomy 1) A structured methodology to develop task performance steps that would help build consistency across various teams in how tasks were developed; and 2) A methodology using task analysis data to support validation of the architecture.

For both of these desired outcomes, the results were mixed. With respect to using a structured methodology for developing task performance steps, it was successful for those analysts who chose to use it and provided a useful and effective job aid. Comments from analysts who did not use it indicated that the methodology was easy to follow and it made sense, but it restricted how they structured their task performance steps. Most of the analysts surveyed indicated that it provided ideas of how to structure their task steps but not to the extent that it was a definitive source for developing their tasks.

As for the validation of the architecture, this work is still ongoing. One of the challenges has been the dynamic nature of the operational architecture. As it changes, the impact ripples through validation activities already accomplished forcing analysts to revisit work previously performed. Processes are needed to account for the impact of changes to the architecture.

DISCUSSION

Taxonomies can be extremely useful tools. However, they are rather like exercising. If you force yourself to do it, it is likely to help you. Getting started and staying with it is another matter. Bloom's taxonomy for developing instructional objectives is one such taxonomy (Bloom, 1956) that has stood the test of time. Those individuals who learn to use it effectively find it exceedingly beneficial in developing effective instruction. However, in practice, it is used very sparingly. Using our information processing taxonomy may be an acquired taste that we did not sufficiently foster through training.

System engineering teams speak a different language than Warfighters. Engineers do not speak Army doctrine and Army subject matter experts do not speak UML. By the time they end up exchanging information and realize there are disconnects, the system has been nearly fully developed and required functionality is missing. The use of an information taxonomy offers promise to reduce the risk of such outcomes by fostering clearer communications between diverse communities of experts. Further refinement of the taxonomy and implementation process is needed. The mission remains the same; that is, ensuring the soldier is in the system.

THE INFORMATION PROCESSING TAXONOMY

The taxonomy is divided into two levels, the Information Continuum and Information Processing. The Information Continuum level is simply a high level description of the associated information processing activities. It was created to help the user develop a mental model of a continuum of information processing that could be integrated into task development. The Information Processing level of the taxonomy is marked by 9 capstone verbs/actions, each of which has associated verbs/actions. Each of these verbs/actions was identified from the operational view of the FCS architecture. The capstone verbs are defined below (see Table 1). The associated verbs/actions have been defined, however due to the amount of information, definitions are not provided in this paper. These may be requested from any of the authors.

Table 1. Information Processing Taxonomy

Information Continuum Level	Information Processing Level Definitions	Associated Measurable, Performance Verbs
Acquire Data (Access)	***Access*** – The process of gathering or requesting information	Acquire, Collect, Receive, Request
Identify and Synthesize Relevant/Critical Data (Identify)	***Identify*** – The process of recognizing or uncovering information that will support task performance	Detect, Determine Discover, Gather, Project, Recognize, Specify, Track
Dissect Data (Analyze, Interpret)	***Analyze*** – The process of evaluating or comparing information ***Interpret*** – The process of refining, filtering or assessing information	Aggregate, Compare, Diagnose, Evaluate, Exploit, Fuse, Inspect, Monitor Adjudicate, Assess, Classify, Comprehend, Decide, Deconflict, Integrate, Perceive, Refine, Restate, Visualize, Review
Manage Data (Adjust, Create)	***Adjust*** – The process of controlling, managing, updating or revising information ***Create*** – The process of preparing, producing or developing information	Assign, Configure, Control, Manage, Mediate, Revise, Update Complete, Construct, Define, Develop, Enable, End, Establish, Generate, Install, Maintain, Make, Mark, Plan, Prepare, Process, Produce

Take Action Based on Data (Execute)	***Execute*** – The process of performing or conducting an action or activity as a result of information that has been analyzed, interpreted, adjusted, or created	Abandon, Activate, Assist, Avoid, Capture, Conduct, Employ, Engage, Evacuate, File, Finalize, Implement, Initialize, Initiate, Launch, Linkup, Navigate, Negotiate, Neutralize, Nominate, Pair, Participate, Perform, Protect, Reattack, Resolve, Respond, Resume, Return, Schedule, Select, Submit, Supervise, Support, Synchronize, Task, Terminate, Transition
Verify Action has been Taken/Performed (Acknowledge)	***Acknowledge*** – The process of confirming, accepting or approving information	Accept, Approve, Confirm, Document
Disseminate Data Related to Action Taken/Performed (Distribute)	***Distribute*** – The process of publishing, reporting, replying, coordinating or collaborating	Advise, Allocate, Collaborate, Coordinate, Direct, Display, Disseminate, Exchange, Issue, Notify, Propogate, Provide, Publish, Reply, Report, Transmit

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