Sharing Joint and Multinational Command and Control (C2) Performance Assessment Tools

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ABSTRACT

The recent evolution of Command and Control (C2) in Irregular Warfare has seriously challenged warfighter performance readiness by directly affecting how decisions are allocated, how information is distributed, and how the execution of common C2 processes are carried out. Ineffective C2 can jeopardize the overall mission and potentially lead to dire, if not fatal consequences. In recent years, great emphasis in research and development has been placed on increasing warfighter readiness, but developing the needed C2 assessment tools to understand performance improvements are costly and time consuming. To address this problem, a North Atlantic Treaty Organization (NATO) research and technology working group has completed a repository of C2 assessment tools. As a taxonomy of human performance measurement in the C2 domain, it incorporates measures, instruments, methods, and tools used by NATO and across U.S. military branches.

In this paper we first describe the C2 Repository development and distribution. Sharing information across military branches and nations has been crucial for promoting C2 readiness. This information has potential to result in 1) standardization and consistency of C2 assessment, 2) reduced duplication of effort, 3) a definition and established baseline of the current state of C2 assessment, and 4) an identification of limitations and measurement gaps. Secondly, we discuss implications for deploying the C2 Repository into the NATO military environment. In order for the database to adapt to changing C2 environments, options for continuously updating the Repository are explored. One such option is the Navy's Human Performance Analysis Tool (HPAT). Other enhancements include 1) sharing measures across the Services within the U.S. (e.g., Joint Knowledge Online [JKO]), 2) developing a systematic method to evaluate current assessment tools, and 3) identifying opportunities for validating current measures included in the database.

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INTRODUCTION

The ongoing war on terrorism requires today's warfighter to deploy to unfamiliar territory and engage in non-traditional war tactics. Due to this fact, there is an increase and change in mission requirements. These new missions place enormous pressure on ensuring warfighter performance readiness, leading to a heightened need for training. Shrinking budgets and aging warfare systems are challenges that have resulted in the need to increase efficiency in the performance readiness process. The U.S. Department of Defense (DoD), as an example, has targeted the assessment of warfighter performance as one of the areas where great strides are possible for increasing efficiency and effectiveness.

A North Atlantic Treaty Organization (NATO) Human Factor and Medicine (HFM) Panel was appointed in October of 2006 with a life-span of three-years. The group was tasked to analyze the current state of Command and Control (C2) assessment tools utilized by the NATO Alliance. This paper describes the steps that HFM-156 took to develop a C2 Assessment Knowledge Base that catalogues current and emerging measurement and assessment capabilities.

The benefits of this tool are that it facilitates the reuse of C2 assessment capabilities by sharing operationalization possibilities, measures, methods, instruments, model, technologies, and facilities across international boundaries and across military services. For our purpose, operationalization possibilities are defined as items that are more general in nature, describes how one might go about measuring a construct/variable, but is not as well developed as a measure). The knowledge Base also promotes consistency, standardization, and reduction of duplicated efforts, which will ultimately lead to efficiency and cost savings. This Knowledge Base will provide NATO countries with an understanding of current assessment capabilities within the C2 arena important for mission success. The results of the repository will help to identify the current state of C2 measures, what gaps exist within the Knowledge Base, and areas needing to be developed. Over time, the creation of this Knowledge Base should improve the effectiveness of future C2 assessments and continually move the 'state-of-the-art' forward, ultimately leading to improved performance, and mission readiness.

This report will first describe the development process of the C2 Knowledge Base. Second, we will discuss implications for deploying the tool into the NATO military environment and also present recommendations for updating and maintaining it. Third, we will explore some options for identifying opportunities for validating current measures included in the database. Fourth, we will touch upon some limitations associated with the Knowledge Base. Finally, we will discuss lessons learned associated with the development and transition process of the tool.

C2 ASSESSMENT KNOWLEDGE BASE DEVELOPMENT

Framework

The NATO HFM-156 group laid the foundation by first narrowing the scope of the project to focus on C2 assessment tools. This was due partly to the important role that C2 plays across the NATO countries and partly to the limited time span and resources available to the NATO team. Second, the group decided to leverage prior work done by Working Group SAS-050 (under the NATO Studies, Analysis and Simulation Panel). SAS-050 had produced a C2 Conceptual Reference Model which contained more than 300 C2 variables displayed in a hierarchical format. There were ten variables at the highest level, 30 variables at the second level, and 318 variables at the third and lowest level. It was designed to facilitate new C2 approaches, while supporting analysis of traditional approaches. The model was later refined by Working Group SAS-065. As a result of these revisions, the model grew to ten Level One variables (C2 Approach, Quality of Actions, Decision Making, Quality of Decisions, Entity Characteristics & Behaviors, Sensemaking, Information, Quality Of Information, High Level Measures of Merit, and State), 33 Level Two variables, and 414 Level Three variables (Level Three sublevels included). This revised model served as the underlying taxonomy for the Knowledge Base. Third, the NATO Code of Best Practice (COBP) for C2

Assessment (2002) was another product used to guide the foundation of the Knowledge Base. It was developed by the SAS (System Analysis and Studies) 026 Working Group. It captured and enhanced best practices and outlined a structured process for operationalizing assessment for the C2 arena.

Knowledge Base Format Selection

Next the group had to select a potential format to use for building the knowledge base. This was a difficult task because the software had to be suitable for the database and accessible to all the participating NATO members. Many options were considered, such as the U.S. Navy's Human Systems Performance Assessment Capability (HSPAC), Microsoft EXCEL, Microsoft ACCESS, Plone, and the U.S. Navy's Human Performance Analysis Tool (HPAT).

HSPAC was initially a likely candidate because it was created to be a measures repository. However, it was housed on a U.S. military website, to which the public did not have access. It also included U.S. Navy personnel performance data, which constrained its release due to security implications. Last, funding would be required to build it out. Another option, Plone, is a prototype housed on an accessible Web server for unlimited access and use. It presented the knowledge base in a simpler and more practical way than EXCEL. Variables were presented in a hierarchical format and were easy to modify. Although it was a potential tool to use, pursuit of the Plone demonstration system was terminated when development support was lost.

Considering these limitations, it was decided that Microsoft EXCEL and ACCESS would be better suited for the effort. In the end, EXCEL was chosen because of its familiarity within the communities. Also, EXCEL's filtering capacity would facilitate the process of searching, adding, updating measures, and identifying capability gaps. ACCESS was rejected on the premise that few NATO members had access to it and even fewer understood how to use it.

depicted as columns (see Figure 1). The first three columns are the C2 Reference Model Variables (Levels 1-3), laid out according to the hierarchy in the SAS-050 C2 Conceptual Reference Model. In the spreadsheet, each Level Three variable (including sublevels) has an associated comment that contains the definition of that variable, and lists the variables within the model that it influences, or by which it is influenced. The fourth column is the name of the instrument itself and an "X" is placed in the appropriate following column(s) (5-11) that best describes the capability. In the twelfth column (i.e., details), a description of the capability is provided along with additional information such as definitions, scales used, any validation or norming information, and context in or for which the capability was created.

The next column (i.e., keywords) provides a list of possible terms or names by which the item could be identified in a search. The last two columns (14 and 15) provide any associated agencies and sources in order to research more information about the capability.

Besides the mapping of C2 measures within the taxonomy, the Knowledge Base also contains definitions of the column headers in which the assessment tools are categorized. These definitions describe the premise of how distinctions were made between capabilities--operationalization possibilities, measures, methods, instruments, model, technologies, and facilities. This will provide insight to understand current capabilities included and how to label new ones being added.

The Knowledge Base also includes a mapping of the Level Three variables from the taxonomy within the four Domains of Warfare--physical, cognitive, social, and information (see Alberts & Hayes, 2003). The 414 Level three variables included in the C2 Conceptual Reference Model and column three in EXCEL were first mapped to the Domain of Warfare. This was to show the relations between the C2 variables and the domains. Some variables may be mapped to more than

C2 Reference Model Variables			Name	Operationalization Possibilities	Measure	Method	Instrument	Model	Technology	Facility	Details	Keywords	Nation / Agency	Source/ References
Level 1 (10)	Level 2 (33)	Level 3 (414)												

Figure 1. NATO C2 Assessment Knowledge Base

Knowledge Base Layout within EXCEL

The Knowledge Base, in its EXCEL version, is populated according to 15 categories of information

one domain where appropriate. Later this information was used to take a tally of capabilities associated with the 414 variables which were displayed in a chart

external to EXCEL. This in turn allowed for an analysis of assessment capability gaps to be done within the Domain of Warfare. These gaps are only based on the information gathered in the knowledge base thus far and in no way represent performance deficiencies.

Sources of Information and Population

The group then decided on how to gather the information needed to populate the repository. Data were collected using interviews (group and individual), literature searches (university search engines), conferences (e.g., Interservice/Industry Training, Simulation and Education Conference (I/ITSEC)), government laboratories (e.g., Defence Research and Development Canada (DRDC)), and other NATO groups (e.g., NATO HFM-163).

The 'divide and conquer' methodology was not utilized to populate the taxonomy. Instead, members were allowed to provide assessment tools for any parts of the repository, as each nation or military service had potential contributions in all areas. There were also no limitations placed on how to solicit the needed information.

Challenges to the Knowledge Base

There were three main issues faced during the population of the repository. The first dealt with what should be the most appropriate (or effective) level to which assessment tools should be mapped… "Do we map the items to the first, second, or third level C2 variables?" (NATO HFM-156, in press) This became a bigger concern in reference to mapping an instrument because a variety of instruments contained many measures that addressed different constructs. In these situations, the item could simply be mapped to the higher level variable which addressed all of the constructs within the instrument, or the instrument could be dissected and the individual measures mapped to the lowest level variables possible. The group's solution was to map the instrument to the higher level variable and map the measures within to the lowest (third) level variables to the extent possible.

Although that approach required greater effort, it was necessary because of the detailed nature of the C2 Model, and to aid in identifying assessment capability gaps. It was also understood that validation data provided for instruments could not transfer to its dissected measures, but these measures can provide a starting point to develop future instruments (NATO HFM-156, in press).

The second challenge that arose was the application of psychometric criteria. The group debated on which types of tools would be suitable to include in the repository and if they should meet certain criteria (e.g., reliability, validity, diagnosticity). If the group chose inclusion based on specified criteria, this would eliminate a significant number of measures within the repository. Currently, there are numerous criteria in use, but few measures will meet the criteria because most measures are not validated (NATO HFM-156, in press). The group ultimately decided that it would be in the best interest of the C2 world to identify and populate existing measures, regardless of the lack of psychometric data, then caution the users of the Knowledge Base to do future research on the measures before using them.

The third concern was whether or not to include performance norms and standards. Performance norms and standards are metrics that are specific to a particular subject area or domain. It is difficult to generalize or interpret them outside of that domain without providing an excessive amount of detail. With that said, the sensitive nature of some metrics would affect their inclusion as well. Finally it was agreed that, although important, the Knowledge Base would not focus on performance standards or norms. Including them was acceptable, only if there was a value/need for performance standards to make the tool more useful and/or if they were readily available.

ADVANTAGES OF THE C2 KNOWLEDGE BASE

This C2 Assessment Knowledge Base features a number of potential benefits that are listed below:

- It helps NATO officers understand what current C2 assessment capabilities are available by enabling the sharing of these tools across international boundaries and military services. This increase in C2 awareness can provide needed information by referencing past data to set performance standards.
- It identifies specific areas where C2 measures are lacking and need to be developed. With that information provided, future research can be done to fill in those gaps and continually move the 'state-of-the-art' forward.
- It provides a library of possible instruments that can facilitate future experimentation with C2 concepts, which in turn will provide validity and reliability information for each capability. The data collected will give a more accurate view on which capabilities will be more effective when used in different contexts.
- It enables the swift search, reuse, and tailoring of C2 assessment tools. Leveraging tools from the knowledge base will bring more standardization

and consistency to the measurement process, thereby resulting in improved process efficiency. Moreover, standardization of these tools can facilitate performance comparisons across time.

- It reduces duplication of efforts, which leads to the decrease of cost and labor expenditures required for assessment activities.
- It facilitates better decision-making, because better measures generate more valid assessment results. Better assessments also lead to better strategic and trend analysis, which leads to improved performance and mission readiness.
- It bridges the gap from theory (NATO C2 Reference Model) and guidance (NATO Code of Best Practice for C2 Assessment) and provides practice (via application of HFM-156 C2 Assessment Knowledge Base).
- It lays groundwork for future NATO studies of human performance. It also provides sample measures available as templates, as well as software language to instantiate measures in simulations, etc.
- It builds measurement expertise by guiding users through the process of selecting or authoring appropriate performance measures, considering psychometrics, purpose, context, and practical considerations.

Arguably, this Knowledge Base can provide important contributions to C2 measurement in that it allows practitioners to evaluate, utilize, and build off of current available capabilities. Ultimately, leveraging from this tool will help reduce expenses and resources associated with developing C2 assessment measures.

LIMITATIONS OF THE KNOWLEDGE BASE

It has not been possible to cover all C2 measurement efforts within the Knowledge Base. There might be existing tools and approaches for variables that are not included in the data base. Additionally, it is heavily populated with U.S. assessment measures, more so than those of other NATO countries. Further, the repository does not include measures from non-NATO countries. Having greater national diversity in the populated measures would provide a more comprehensive database and would perhaps fill current gaps within the Knowledge Base. This stresses the importance of finding a solution to successively maintain and develop the tool further. Another constraint is the absence of psychometric data (e.g., validity, context, scale) for some tools. Not having this information may make it difficult for practitioners to use measures without doing additional research prior to use.

ASSESSMENT CAPABILITY GAPS WITHIN THE KNOWLEDGE BASE

To assess capability gaps within the Knowledge Base, each of the 10 Level One variables is examined individually to determine which of the Level-Two and Level-Three variables can be considered gaps. For the purposes of the analysis completed by HFM-156, a variable that is only represented by one or two "Operationalization Possibilities" or has no items mapped to it is considered a gap. Assessment capability gaps are only based on the information gathered thus far by the HFM-156 effort and in no way represent performance deficiencies. This analysis is essential because it suggests what areas the next working group should focus on to gather more capability information and advance the C2 Knowledge Base forward.

C2 KNOWLEDGE BASE IMPLEMENTATION

Human Performance Analysis Tools (HPAT)

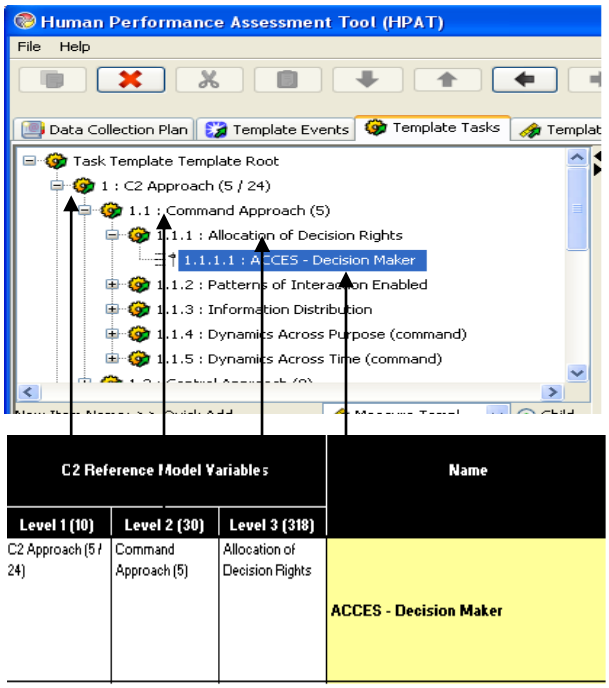
The current format of the tool (EXCEL) is too cumbersome to navigate and search. It was strictly used as a framework to gather initial assessment capabilities and to serve as a research tool. One option presented to the NATO group for operationalizing the Knowledge Base was the Human Performance Analysis Tool (HPAT). HPAT can be used by trainers or operational personnel to store measures, which could be identified and pulled into an assessment plan. It can also be used in evaluations for training or operational exercises. HPAT is specifically designed to support the classic model of human performance observation within the military. To obtain meaningful results from an observation event, it is necessary to develop an observation plan, make observations, and analyze the results. HPAT is comprised of three interoperable technologies. The first tool in the suite, "Planner," supports creating data collection plans (DCPs) for opportunities such as training exercises, usability testing, and systems testing. The second tool, "Observer," imports Planner DCPs for use by one or more observers. The last tool, "Analyzer," reads in data collection results from one or more observers and allows the performance analyst to review and catalogue performance along several attributes (NATO HFM-156, in press). HPAT provides proof of how the HFM-156 database can be imported into an operating tool.

At a more detailed level, the tools in the repository are uploaded within the Planner module (see Figure 2). The Planner supports creating and managing the building blocks for observation. The user can craft

scenarios, events, tasks, measures, and subjects with appropriate relationships between these data. The more users employ the data from the Planner, the more event- and task-based data collection elements will be available to assemble into future DCPs. Below is an illustration on how the knowledge base corresponds within HPAT.

HPAT will provide a place where practitioners can search for assessment measures, continually update the psychometric data, and add new assessment measures.

Figure 2. Knowledge Base in "Planner" HPAT



Online Sharing Options

Another concern with deploying the Knowledge Base is finding an online location where practitioners can access the tools. It is recommended that the Knowledge Base be hosted on the web; thus, installing a point of reference through a web portal is needed. Moreover, by using a website, various documents associated with measures (research papers, tutorials, etc,) can also be stored and made accessible for further research. Another suggestion is to post the Knowledge Base in wiki/web 2.0 format, to allow users to suggest best or validated measures when multiple measures are documented for a particular variable (NATO HFM-156, in press).

One option that should be considered is the Joint Knowledge Online (JKO) because it is accessible to all U.S. military branches. It is the enterprise portal system that provides convenient access to online joint training and information resources. JKO integrates with other DoD systems and uses the latest advanced distributed learning technologies to provide training courses and resources that better prepare warfighers for joint exercises and integrated operations. JKO could aid in sharing this tool across U.S. branches, which will eventually standardize the capabilities being used.

A second option for an online location was presented by a contractor (Sonalysts) who created HPAT. Their technical capabilities are aligned with understanding the "business" of both government and commercial projects. In addition to being contracted to build out HPAT, they have also offered to house the tool on their corporate website. This would include access registration for NATO members, software upgrades, and repository maintenance. It would be left to stakeholders to build it out. A third possibility for sharing the Knowledge Base internationally is by having one of the NATO nations take the lead on uploading the repository on their military website and become point of contact to access it.

CHALLENGES IN DEPLOYING THE C2 KNOWLEDGE BASE

For this effort to move forward, support (i.e., buy-in) is required from all communities. The best way to obtain this is by developing awareness for the database. It is understood that visibility for the tool is enhanced if multiple communities promote it concurrently, thus enabling faster implementation. This is difficult because individual organizations will not share C2 information if they fail to see a direct benefit for their organization. Additionally, there may be a reluctance to release information outside of an organization—especially information connected to evaluations of performance (which are currently excluded from the tool).

There are also a few logistical limitations associated with the implementation of the Knowledge Base such as funding and security. Unfortunately, no matter the importance of a database, it cannot mature unless there is an appropriate amount of funding to maintain it throughout its life cycle. Another concern to be addressed and resolved early in development deals with security and IT. The repository may require multi-level access, spanning different security levels. Security precautions need to be taken into account especially if performance data are incorporated into the tool.

In order to overcome some of these obstacles, formal agreements, policy mandates, and incentives might be required to stimulate use. NATO nations would be

more likely to release information on capability tools if they were granted easy access to the Knowledge Base and assurance that any confidential information is protected. Moreover, if functionality, organization, and content support the needs and goals of the projected users, resistance may be overcome in due time (NATO HFM-156, in press).

LESSONS LEARNED

One lesson learned is that having similar concurrent efforts may disengage some stakeholders from participating in building out the repository. This type of attitude should be prevented if the desire is to have a library that applies across nations, communities, and organizations. Therefore, the ideal approach is to create a knowledge base with organizational support, resources, and direction from the top, rather than try to integrate already existing individual systems (NATO HFM-156, in press). It is also important to communicate to the stakeholders up front details on how the information provided will be protected. This may have increased the contribution of other NATO countries in populating the database. Further, usability studies should be done, both in terms of format and usefulness. This would give a better sense for the ease of the data entry process to predict the willingness of users to update the system.

SUMMARY AND CONCLUSION

The Knowledge Base is meant to be a living and evolving knowledge management tool. The goal is to have users share assessment tools, with annotations or comments based upon their experiences. HFM-156 wants the tool to be the "go-to baseline" for C2 assessment measures. Users will be able to locate any specific C2 variable within the repository and cite a number of identified measures, methods, instruments, models, technologies, or facilities that could be used to assess that specific variable. In the end, the reality is that creating assessment capabilities is time consuming, labor intensive, and expensive. More so during times of war, these resources are not readily available. This Knowledge Base would serve as a base to identify current C2 assessment tools and be instrumental in ensuring warfighter readiness.

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