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The Future of C2

Documenting Workflow, Tasking, and Collaboration Flow of Current Command and Control (C2) for Future C2

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Abstract

To improve Command and Control (C2) in the future, it is necessary to understand what C2 "really" does now. Current C2 must be analyzed to determine the workflow, the tasks required, how the information is processed and by whom, and what collaboration occurs, in order to identify where C2 can be enhanced. Once analyzed, a baseline can be established, laying the groundwork for empirically quantifying improvements for this and succeeding generations of C2. This paper provides a description of a systematic approach to analyzing workflow and tasking across different levels of C2, within the context of the tactical information processing and collaboration.

A workflow outlines high-level missions in time-sequence and serves as the infrastructure for subsequent analyses. The task analysis is documented as a task allocation matrix (TAM), which comprises an exhaustive set of ordered tasks based on doctrine and operational/tactical experience. Capturing the context within which the tasks are performed, through analyzing the tactical information process and collaboration flows is essential. Collectively, the documents created via this process support spiral development as a repository for new concepts, tactics, and priorities. Hence, the analysis serves to streamline both the development process and the products, thereby reducing risk and increasing quality.

Introduction

The catch words in system design and development these days are "to provide improved situation awareness that supports decision-making while simultaneously reducing manning". The Operator Machine Interface (OMI) design task is to make the system easy to operate, use, and learn to use such that it provides decision-makers with timely information in which they have confidence. To do this successfully requires Human-System Integration (HSI), such that the computer does what it does well (e.g., process, store and transfer data) and the operators do what they do well (e.g., recognize patterns, evaluate information and make decisions), and together they provide a synergy that is beyond the capabilities of either alone. The goal is to integrate users, machines/computers and the operational environment into a single, integrated, working system that provides warfighter tools to meet mission requirements which operate in an easy and natural fashion. Done correctly, the warfighter will never notice; he/she will fight the war and not the system.

The design and development of future Command and Control (C2) systems requires thoroughly understanding current C2 systems. A critical first step to this understanding is gained by documenting both the work and the workers' interactions (i.e., the context). Specifically, once the roles and responsibilities across different levels of C2 are documented, critical paths, decision points, and automation opportunities can be quickly identified. A systematic approach to creating a workflow, performing a task analysis, and documenting the context as both a tactical information process and a collaboration flow is presented below. These upfront analyses serve to reduce manning and development costs while increasing overall mission speed and accuracy. Task analysis alone has resulted in reduced manning, for example by cutting a team of three to seven people down to two or three, and shaved an estimated two years off of delivery schedules (Beecher, 2003).

Another issue that task analysis addresses is the comprehension gap between developers and users. Specifications written by engineers and developers generally use technical language that is difficult for the layperson to decipher. This forces user verification and validation to be done on the displays and prototypes. More often than not the user doesn't evaluate the system until it is fielded, a time when flaws, errors and omissions have the highest impact. Unfortunately, requirements discovered late in the implementation are difficult to incorporate into the product because it is costly to do so. Hence, to ensure that a complete and fully integrated human-system is created at the lowest possible cost, requirements must be documented early and in collaboration with the users.

The analysis techniques for workflow, task analysis, and the context are defined in separate subsections below. Examples are provided to illustrate the analysis deliverables. All figures are for illustrative purposes only; they are *working drafts* drawn from current work. Techniques for developing and reviewing the products are discussed. And finally, since these analyses have multiple uses, some of the uses are described.

Background Information

There are three prerequisites to doing the analyses described herein. First, the users must be identified and their knowledge, skills and abilities (KSAs) understood. Novices, experts, casual and occasional users must be considered. Second, the written documentation, like doctrine and training scenarios, must be collected. Finally, the fleet review team, comprising subject matter experts (SMEs) must be established. Observation opportunities at training facilities and on-site (e.g., shipboard) should also be identified early.

The three main types of users considered are operators, direct users, and indirect users. The operator operates ("fat fingers") the equipment, for example manually entering information into the system. The direct user uses the outputs of the operator and proposes plans / courses of action based on that information. The indirect user works with the direct user, often in a review and approval capacity (e.g., rejects or accepts the decisions made).

Sometimes the users must be grouped by function; for example, if the product is a collaboration tool intended to be used within two groups such as the command cell and on the platforms. Figure 1 provides a pictorial example of USW users. Operators are depicted at the base of the triangle because they support the direct and indirect users. In this instance, in the Command Cell, the operator (in blue) comes from the support staff, direct users (in yellow) include the ASW Officer (ASWO), and indirect users (in orange) include the Commodore and the Staff Watch Officer (SWO). (Although the colors are consistent with those used in Figure 6, the colors themselves were arbitrarily selected to distinguish between user types.)

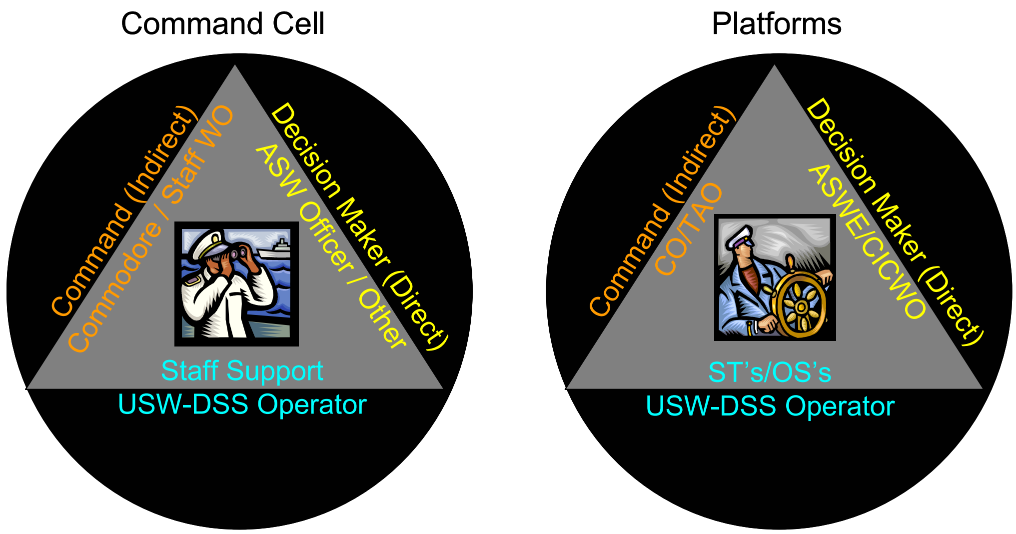

Figure 1. Operators, Direct Users and Indirect Users.

Fleet involvement is critical and their time is limited. Hence, written documentation, like doctrine and training scenarios, can provide the majority of analysis inputs. It is essential to identify these materials up front.

Human system integration experts work closely with the SMEs throughout the analysis process. SMEs are drawn from each user community and specialized domain. The SME teams include representatives drawn from each platform, tactical operations, doctrine development, training, and the programming office. For example the teams for USW are: command and control, ASW surface, ASW submarine, ASW air, mine warfare, fixed arrays, environmental analysis and threat analysis.

Using representative mission scenarios the HSI engineers and SMEs work together to incorporate additional data from the domain that is under study. These additions include heuristics, techniques, and procedures not found in the books. SME contributions include verifying task order, defining task attributes, locating critical tasks, providing shortcuts, identifying users and documenting the data flow. The amount of SME time required depends on how well the tasking for a given mission was documented by the doctrine and how well the scenarios reflected the full scope of tasking. Trainers/instructors add techniques learned in the classroom and tasks that enhance learning, such as training and simulation tools and aids.

Field observation is essential to verifying and validating the analyses. Onboard, the HSI engineers work with the operators to learn hands-on how to do the particular mission. Mission activities are observed and the analyses updated to reflect any new information. The compiled products provide a baseline of the existing system, representing tasking in a real context/environment with actual users.

Going shipboard also provides an opportunity for the users to review display designs and use prototypes. The design team can directly compare the various design options with respect to functionality, speed, accuracy, ease of use, importance, etc. Existing operations and techniques can be compared with new operations and techniques; hence the operational uses and impacts can be assessed early. Comparing the existing baseline system with the proposed designs provides information about whether or not requirements are met, uncovers difficulties with the new system, and provides insights into new uses (leading, for example, to revisions in training or doctrine).

In sum, identifying the users, the doctrine, and the SMEs must be done before the analysis work can begin. Field observation is the final analysis step.

Workflow

A workflow provides the flow of work and forms the framework of the task analysis and collaboration flow. Figure 2 contains a simplified version of an area search planning workflow being developed for USW. The workflow is generally a diagram comprising the high-level tasks or "work" required (represented as boxes) and the flow of the work (represented as arrows between the boxes) presented in time-ordered sequence. It documents the work from the beginning to its completion, including alternate paths and optional work. Each mission within a given warfare area is documented as a separate workflow.

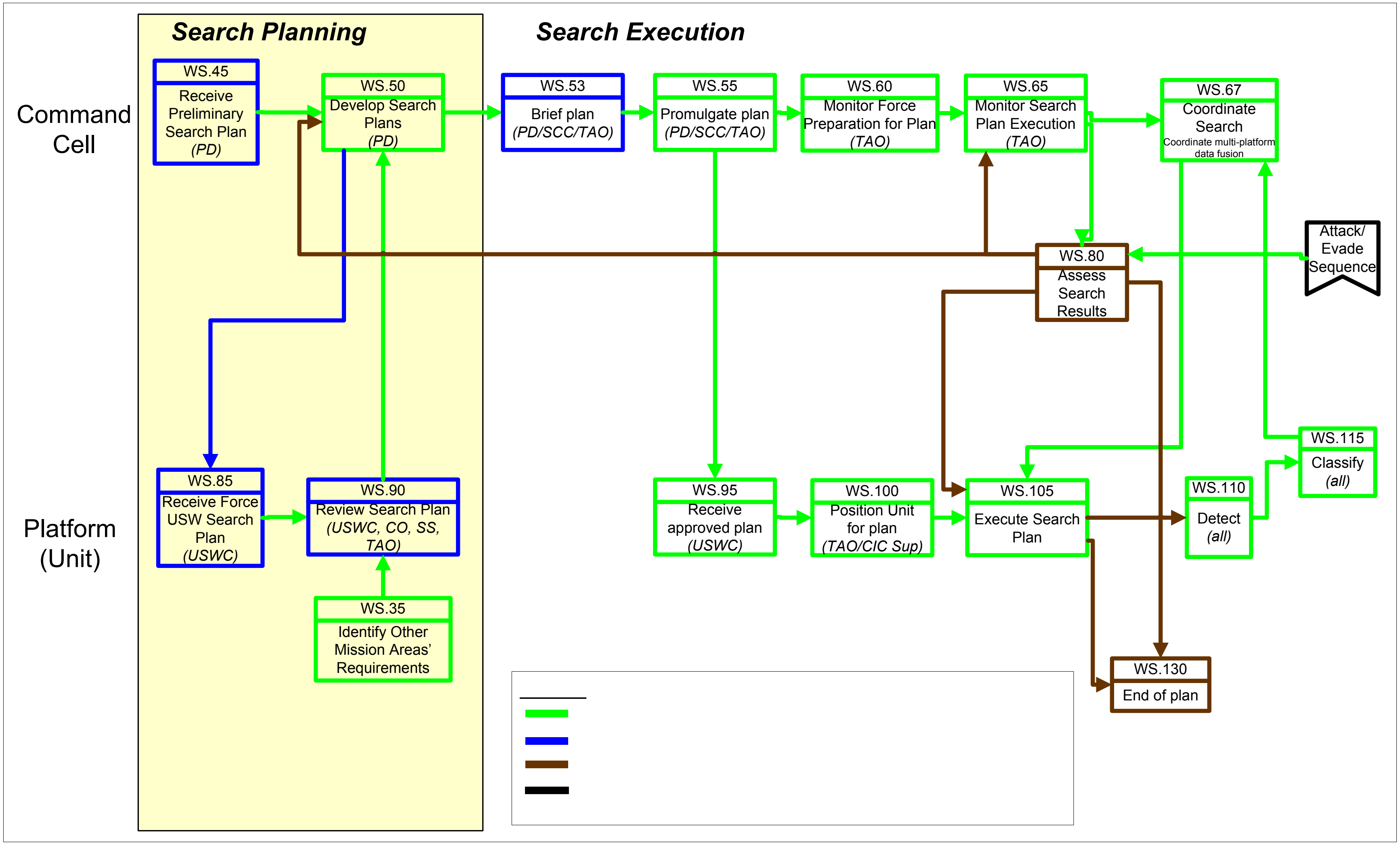

Figure 2. Simplified Workflow for USW Search Planning/Execution.

(Staff)

The workflow also provides the command hierarchy interlinked with temporal aspects. The work management structure, or command hierarchy, is partitioned in distinct layers within the workflow. The highest command level is represented at the top-level (partition/row) and each level down is on successively lower layers, with the operator at the lowest level. In Figure 2, the horizontal line provides an example of this partitioning. The work order (sequence) is represented horizontally from left to right. Within each partition of this hierarchical command representation, sequential work paths for that command level are displayed across the paper and parallel paths are represented as separate sub-layers. Optional work, arising for example from the different C2 strategies (i.e., by-direction, collaboration and autonomous action), is designated within the workflow itself.

Separate workflows are done for each distinct type of work, even though the work itself can occur concurrently. In USW, for example, area, barrier and datum searches can be conducted simultaneously and can include an attack phase, yet each is documented as a separate workflow. Hence these workflows support multi-mission environments. Each workflow is also partitioned into logical groupings using shaded boxes as separators. Mission planning, search planning, and search monitoring are logical groupings within the area search workflow.

The first draft of the workflow is compiled from the doctrine in collaboration with SMEs. The doctrine includes the Universal Task List (UTL), Navy Tactical Task List (NTTL), Mission Essential Task List (METL), and Navy Mission Essential Task List (NMETL). Knowledge acquisition (KA) with domain experts and observations during training serve to augment these documents by capturing any necessary modifications. The workflow is reviewed and validated by subject matter experts (SMEs) and intended fleet users, and verified via observations collected in the field.

For project management purposes, workflows provide insight into project size and scope, in a format that is easily partitioned for modular design and spiral development. Frameworks for system-level specifications, storyboards and use cases can be developed using the workflow. Course outlines, training scenarios, and the contents of operating manuals can be provided as well. Primarily, workflows provide a framework for task analysis (TA).

Task Analysis and Task Allocation Matrix (TAM)

The TA is a systematic collection of the operators' and decision makers' tasks and subtasks required to achieve a goal. A TA concentrates on the explicit elements of human-system performance, and decomposes each workflow element and task into the smallest possible task unit. Figure 3 illustrates the TA process.

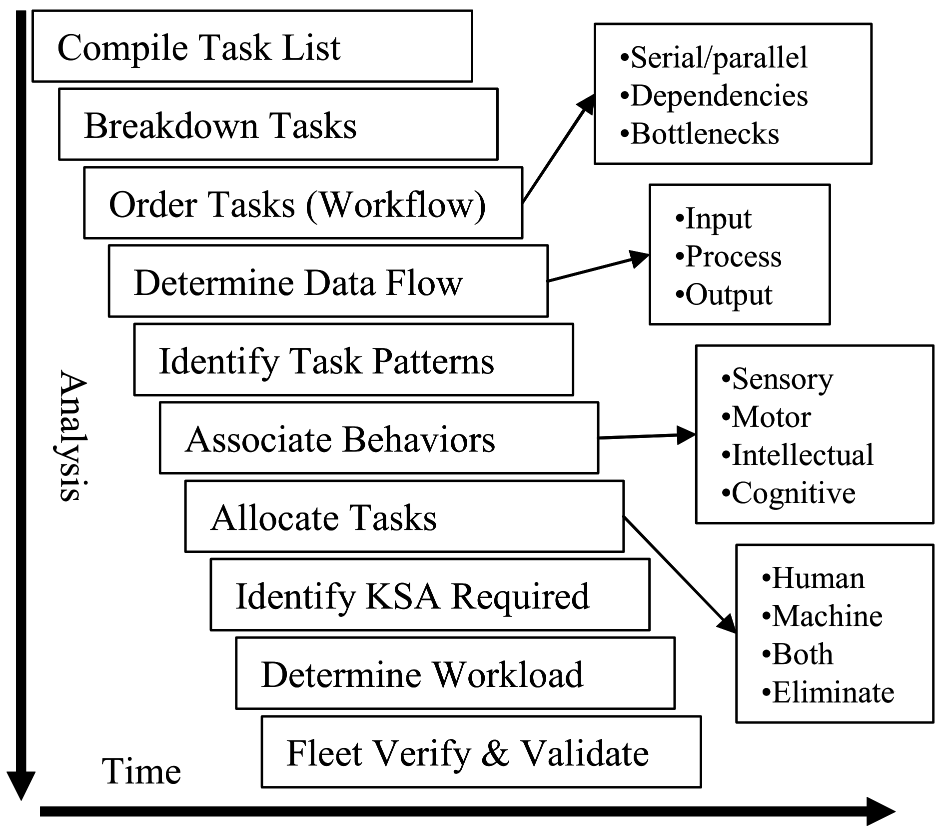

Figure 3. The Task Analysis Process.

A task analysis provides input to the various requirements specifications. The task analysis is compiled into a task allocation matrix (TAM) and provides drill-down of the workflow. Initially it consists of a complete, exhaustive set of time-ordered tasks based on doctrine and user inputs. (Later analysis provides for consolidating tasks and in regrouping the strict time-order is lost.) The TAM is a spreadsheet customized to meet the requirements collection needs in an easy-to-read format. Because it contains explicit detail, the TAM is usually classified. A sample format for a TAM is provided in Figure 4 (provided herein as a rough draft). Specifications are difficult for SMEs and users to interpret and evaluate and a TAM, formatted for easy review by the Fleet, eases the Fleet validation and verification process.

The TAM initially contains the task-order, tasks/subtasks, tools, personnel and workstations, notes and references. Based on the objective of the analysis, information flow, reference numbers, alternate tasks, notes and other items are often incorporated. The TAM is appropriately named because contains a detailed matrix of the tasks, organized in columns and comprising the following:

- the tasks themselves
- the references for each task
- the workstation where the task is performed
- the tools used to perform the task

The TAM also includes analysis information like the kind of human processing required to do the task and the allocation of the task within the system. The human processing required to do the task includes psychomotor, haptic, visual, aural, oral, intelligent (e.g. calculate) and/or cognitive (e.g. decide) processing tasks. The task allocation includes determining if the task is fully human (operator does), fully automated (machine does), or interactive (human uses system to do), or obsolete (eliminated).

Like the workflow, the first draft generally comes from the doctrine. Navy doctrine for example, includes the Naval Warfare Publications (NWPs), Navy Tactics Techniques and Procedures (NTTP), Navy Tactical Reference Publications (NTRP), Allied Tactical Publications (ATPs), tactical memos (TACMEMOs), and instructions. Sometimes the personnel qualification standards (PQSs) and extended personnel qualification standards (EPQSs) can be used.

ID	Task	Users & Operators																											Type (TBS)					ALLOC (TBS)				Tools (TBS)	Notes	References
						DESRON			TSC			MIN-RON		Platforms																										
		IWS	TSCWO	SCC	SWO	CSO	SCC	ASWC	APO	CUS	SUBRON	MIWC	CSO	TACCO	ASTAC	TAO	ASWC	ASWE	Conn O	IUSS	TAGOS	CWC	SS	SO-sub	SO-surf	Plotter	TMA	FC	Motor	Visual	Aural	Oral	Cognitive	Human	System	HSI	Eliminate			
WS 50	Develop Search Plan			P																									√	√			√			√				
50.1	(U) Replan: SCC alternatives when search objectives are not attainable.			P																									√	√			√			√				SCC Employment Concept (U) 2-1, 2.2.1
50.1.1	(U) Modify/increase search asset availability			P																									√	√			√			√				SCC Employment Concept (U) 2-1, 2.2.1
50.1.2	(U) Reduce probability of detection within specified force defense areas			P																									√	√			√			√				SCC Employment Concept (U) 2-1, 2.2.1
50.1.3	(U) Reduce size of search areas			P																									√	√			√			√				SCC Employment Concept (U) 2-1, 2.2.1
50.2	(U) Define Specific Sea Combat Missions			P																									√	√			√			√				SCC Employment Concept (U) 2-3, 2.2.1 Figure 2-1
50.3	(U) Assess Maritime ASW/SUW Threat Potential			P																									√	√			√			√				SCC Employment Concept (U) 2-3, 2.2.1 Figure 2-1
50.3.1	(U) Assess relative to the existing AO and assigned subordinate mission areas			P																									√	√			√			√				SCC Employment Concept (U) 2-4, 2.3.1
50.4	(U) Develop SCC Plan and Branch Plans			P																									√	√			√			√				SCC Employment Concept (U) 2-3, 2.2.1 Figure 2-1
50.4.1	Develop Pre-planned Responses			P																									√	√			√			√				TR CSG Optask
50.4.1.1	RADAR Riser/Sinker			P																									√	√			√			√				TR CSG Optask
50.4.1.2	ES Line of Bearing			P																									√	√			√			√				TR CSG Optask
50.4.1.3	HFDF Line of Bearing			P																									√	√			√			√				TR CSG Optask
50.4.1.4	EO/Visual (Ship)			P																									√	√			√			√				TR CSG Optask
50.4.1.5	EO/Visual (Aircraft)			P																									√	√			√			√				TR CSG Optask
50.4.1.6	Acoustic Active (Ship)			P																									√	√			√			√				TR CSG Optask
50.4.1.7	Acoustic Passive (Ship)			P																									√	√			√			√				TR CSG Optask
50.4.1.8	Flaming Datum			P																									√	√			√			√				TR CSG Optask
50.4.1.9	Hydrophone Effects/Emergency Tango			P																									√	√			√			√				TR CSG Optask
50.5.	(U) Prioritize Possible Targets			P																									√	√			√			√				SCC Employment Concept (U) 2-3, 2.2.1 Figure 2-1
50.5.	(U) Define SCC ASW/SUW Surveillance Areas			P																									√	√			√			√				SCC Employment Concept (U) 2-3, 2.2.1 Figure 2-1
50.5.	(U) Develop Surveillance Plan			P																									√	√			√			√				SCC Employment Concept (U) 2-3, 2.2.1 Figure 2-1

Figure 4. Format for the Task Analysis Matrix (draft contents).

Using the workflow as a guide, HSI engineers extract the detailed tasks relevant to the work. The tasks are initially time-ordered and sequentially numbered. As task patterns arise, they are grouped and consolidated. The TAM is annotated with the tools used, and with the workstation providing the input, doing the work and using the output. During a second pass, the human processing requirements and the allocation is determined. Cognitive tasks (including decisions) are flagged for an in-depth cognitive task analysis (CTA). Sensory tasks (visual, aural, oral, and haptic) are used to identify the hardware (e.g., visual displays, printers, head phones, etc.) and motor tasks are flagged for possible automation. In particular, manually intensive operations, like record/log and plot, which are slow and prone to error, are good candidates for automation. The tools in current use are also automation candidates. For collaborative search planning and execution, for example, the tools include status boards, clocks, headphones, reference information, environmental overlays, calculators, charts, paper, colored pencils and the all-important eraser.

The review by subject matter experts (SMEs) is a critical step in the validation process because it provides a mechanism for capturing the unwritten rules, called heuristics. Knowledge acquisition (KA), using scenarios representing the broad spectrum of missions, is probably the most effective and efficient way to capture this information. Briefly, the SMEs are given a representative scenario and asked to work through the TAM row-by-row to ensure that all the tasks necessary to do that mission are represented therein.

The last step of validation is performed shipboard via HSI observation to compare the documented tasks (TAM contents) with those tasks occurring during actual operations. A TAM is optimally validated shipboard to capture the tasks within their real context. This entire process of creating a TAM is called a task analysis (TA).

The TAM provides for identifying, and thereby addressing, task dependencies, identical tasks and bottlenecks. Task dependencies occur where data must be moved between tasks. An operator or automated function, for example, cannot calculate course and speed for a track unless the position data is available over time. Identical tasks result in the same output, called multi-use data. A common storage for and automated updates of critical or multi-use information creates a faster flow. For instance, an area of uncertainty (AOU) is essential to both navigation (collision avoidance task) and fire control (target location task) and the most recent AOU should be automatically updated and accessed from a common store. The task patterns and common tools are also identified using the TAM, and form a set of core requirements that must be implemented. Identifying identical subtasks within multiple workflows and tasks allows for them to be consolidated into a single implementation, thereby saving time, cost, and user sanity.

The TAM supports the creation of storyboards, use cases, and ultimately the OMI. Operator manuals and training materials, like PQSs, can be developed using the TAM; and workload and manning reductions can be estimated based on the TA using simulation and modeling tools.

Context: Tactical Information Process and Collaboration Flow

Context, the backbone of any human-system integration, often goes undocumented. It is essential to document the context within which the work is being done. This context is often implicit in the workflow and it provides situational awareness and forms the basis of the tasking. Two contextual components resident in the workflow are the tactical information process and the collaboration flow.

Search planning and execution, for example, are done within the context of an ever changing tactical situation that includes a geographical-situational plot (Geosit) and other tactical information (e.g., operational tasking, rules of engagement, weather, asset locations and the like). Much of this information, and hence the tactical information process, is used to simultaneously support multiple missions and warfare areas. The workflow for this tactical information process (TIP) can be found in Figure 5.

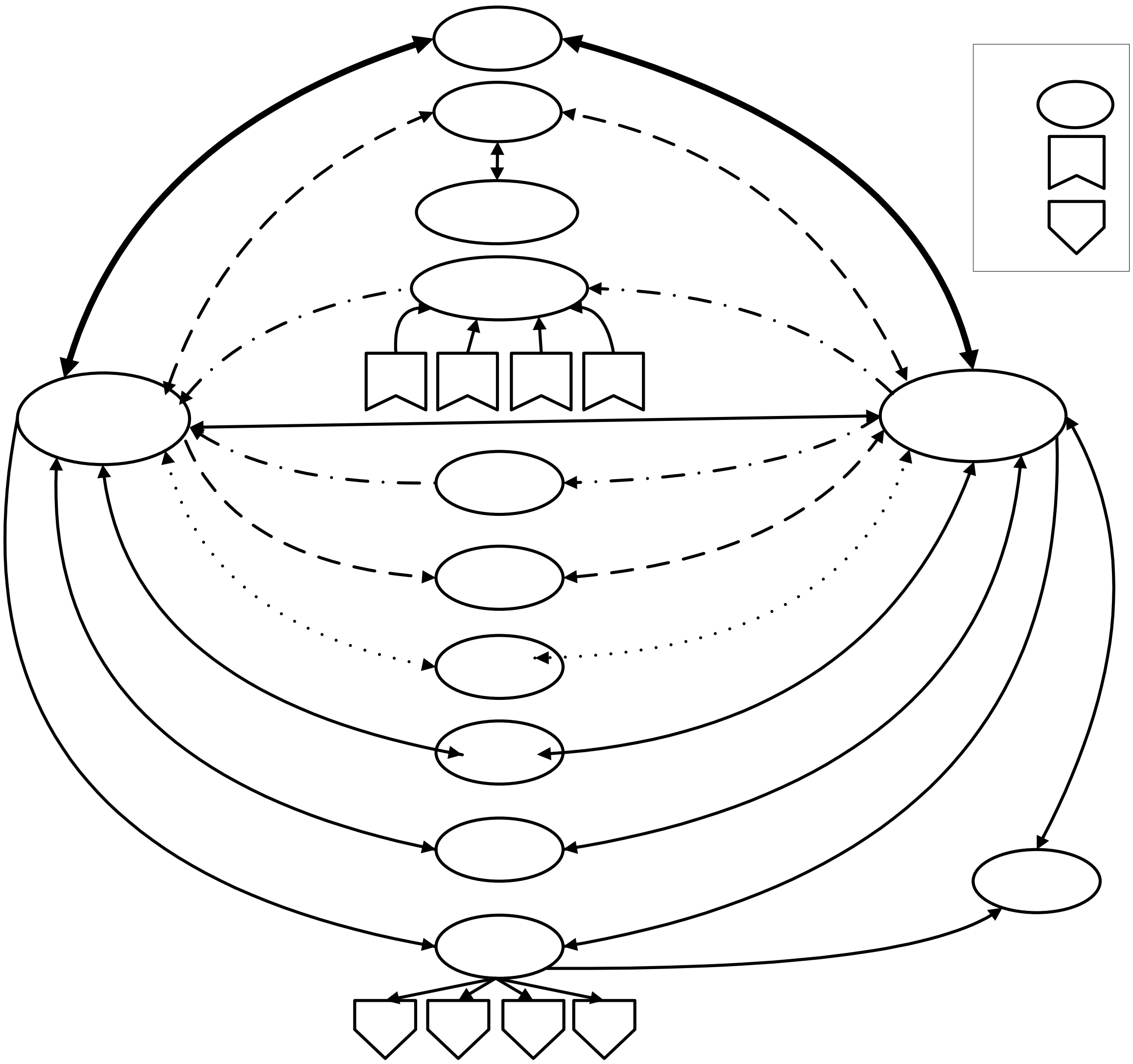

Figure 5. The Tactical Information Process (TIP).

The TIP is a collaborative process in that there are multiple contributors and information users who are doing various and multiple tasks simultaneously. More simply put, information comes in and out of the TIP at any time and from multiple sources. Specifically, the TIP is affected by and is used to manage the effects of multiple concurrent workflows and tasks (e.g., searches, attacks, etc.) upon each other, hence is circular rather than linear. More simply put, the TIP is both an input to and an output of the other workflows. The TIP provides information vital to maintaining situation awareness (SA). This information includes: the static information at a given time, the dynamic changes to that information over time and space, the patterns present/absent in that dynamic

TP.15 Display Tactical Information

movement and the effects of those dynamics on the present and future plans and actions. TIP supports users' ability to maintain, monitor, evaluate, and command and control the situation. In other words, the current situation must be perceived, how the situation is changing must be comprehended, the patterns present in the changing situation must be assessed, and how those changes effect the future must be anticipated.

Another implicit context is provided in the vertical and horizontal communications that occur at both the platform and the command levels. Succinctly, not only is it important to capture the C2 tasks and how they are performed, but it is vital to capture the interactions between platform members and among different levels of command. Because of this, JHU/APL has coined the term "collaboration flow" to describe these intercommunications. Collaboration flow must be documented, including who is communicating with whom, the subject of the communication, and the tools used.

The collaboration flow is an important piece of contextual data because it shows communication paths, alternate communication channels, cueing points and bottlenecks. Hence, it can be used to determine the networking and whether the communications are effective. Keep in mind that collaboration flow is not the same as chain of command.

Figure 6 provides a notional diagram of collaboration flow in USW. The users include indirect command/users (in orange), direct command/users (in yellow) and operators (in blue). The physical tools are represented by boxes and the data/information exchanged by pages. In this diagram, the focal point for tools is the shared displays and for communications it is the Tactical Action Officer (TAO). These focal points are potential bottlenecks if the data are not available, incorrect or mismanaged, or if the individual is not forth coming with C2 information. Hence, it is critical to provide tools to the human focal point, data to the shared displays, and to pair the two in a central location. To quote an indirect user on a collaborative system during a recent exercise, "When everything is working (input from other units), it's hard to beat the effectiveness of the displayed information."

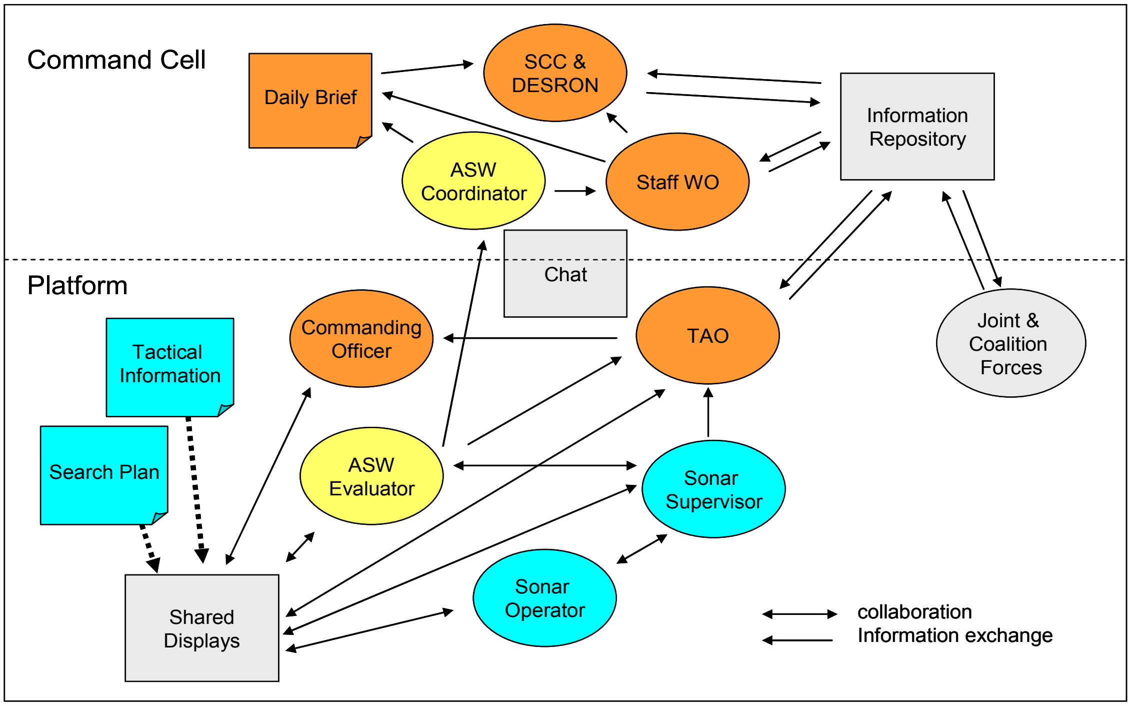

Figure 6. Example of Collaboration Flow (partial).

Documenting the collaboration flow complements both the workflow and the TAM. Together they provide the backbone for creating the system and tools required to effectively support situational awareness. Training tools like PQSs and manning/crewing concepts can be quickly and efficiently created based on these vital analyses.

Summary and Conclusions

The methodologies used to document workflow, tasking, tactical information processing and collaboration flow across different levels of C2 can be used to capture the current state of C2, identify areas of improvement, and measure baseline C2 effectiveness to compare to future C2. In spiral builds, these documents can provide support because they document new tasks and priorities (e.g., based on lessons learned that have been flagged for incorporation in C2) and hence continue to reduce risks and quantify improvements.

Our design strategy includes a top-down requirements analysis combined with a bottom-up requirements collection driven by user survey data and display/prototype evaluations. The requirements analysis, driven by the mission needs statement (MNS) and operational concept, includes workflow, task analysis (TA), cognitive task analysis (CTA), and workload assessments. The bottom-up data includes situational awareness assessments, knowledge skills and abilities (KSA) analysis and ergonomic studies. The strategy provides for modular design and incremental/spiral development, with the most important and frequently used functions addressed first.

The workflow provides a framework within which the task analysis and collaboration flow documentation can be done. The task analysis culminates in a TAM that provides a comprehensive, consolidated, ordered list of tasks reflecting requirements from a variety of users. The TAM provides specifications supporting user requirements consistent with user needs, improving both users and systems processes and products, reducing user workloads (sensory, motor, memory, intellectual, etc.), streamlining workflow and removing bottlenecks. The tactical information process workflow provides for understanding the data/information level context allowing situation awareness. The collaboration flow provides for understanding the collaboration process and the tools that form the basic context within which a given mission is accomplished.

By systematically compiling the requirements, and finding and correcting omissions and problems early, the overall cost is reduced, specifically, the development cost, retooling cost, and those costs arising when users make errors. A whole host of documents can be created using the outputs from this process, including the system/software requirements specifications (SRS), manning/crewing concepts, system operating manuals (SOMs), personnel qualification standards (PQSs) and other training.

The overall process involves acquiring fleet feedback, early and at every step, focusing on the human part of the Human-System Interface. Fleet involvement produces a substantially better system, resulting in reduced manning. Fleet review of the analysis documentation uncovers flaws, omission and errors. The reviews provide opportunities for measuring Fleet satisfaction and the process itself provides for Fleet ownership.

C2 is complex and becoming more so and it is critical to tease apart these complexities with workflows and task analyses. C2 is not linear and is highly dependent on context. Situation awareness, central to C2, depends on both the tactical information process and collaboration flow. These four analyses will empirically improve existing and future C2 by reducing manning and costs while increasing speed and accuracy… this is the mark of success.

References

Beecher, M. E., “A Case Study: Fleet Participation in the Design of the TDSS and CADRT Systems”, Human Systems Integration Symposium, 2003.

Endsley, M., B. Bolte, and D. Jones, Designing for Situation Awareness: An Approach to User-Centered Design, Taylor and Francis Inc., 2003.

Endsley, M. R., and D. J. Garland (Eds.), “The Theoretical Underpinnings of Situation Awareness: A Critical Review,” Situation Awareness Analysis and Measurement, Mahwah, NJ: Lawrence Erlbaum Associates, 2000.

Ericsson, K. A., and H. A. Simon, Protocol Analysis, Cambridge, MA: The MIT Press, 1984.

Gladwell, M., The Tipping Point: How Little Things Make a Big Difference, New York, NY: Little, Brown and Company, 2002.

Hancock, H.E., “Task Analysis: Applications within the Human-Machine System”, www.cc.gatech.edu/classes/cs6751_97_fall/projects/gacha/holly-final.html, 2003.

Hutchins, E., Cognition In The Wild, Cambridge, MA: The MIT Press, 1996.

Hutchins, S. G., P. L. Pirolli, and S. K. Card, “A New Perspective on the Use of the Critical Decision Method with Intelligence Analysts,” Command and control Research and Technology Symposium, 2004.

Jones, D. G., M. R. Endsley, and M. Bolstad, “The Designer’s Situation Awareness Toolkit: Support for User-Centered Design,” Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting, 2004.

Malone, T. B., and C. C. Heasly, “Functional Allocation: Policy, Procedures and Process,” ASNE Human Systems Symposium, Knowledge Warfare: Making the Human Part of the System, November 2001.

Marsh, H. S., “Beyond Situation Awareness: The Battlespace of the Future,” Draft, Office of Naval Research, March 2000.

Nofi, A. A., “Defining and Measuring Shared Situational Awareness,” CRM D0002895.A1/Final, Center for Naval Analyses, November 2000.

Rasmussen, J., A. M. Pejtersen, and L. P. Goodstein, Cognitive Systems Engineering, New York, NY: John Wiley and Sons, Inc. 1994.

Riese, S., “Quantifying Information Availability for Situational Awareness,” MORS Workshop on Decision Aides/Support to Joint Operations Planning, Nov 2003.

Shattuck, L. G., and N. L. Miller, “A Process Tracing Approach to the Investigation of Situated Cognition,” Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting, 2004.