13th ICCRTS
C2 for Complex Endeavors

Enhancing Maritime Domain Awareness

Track(s) in priority order: Topic 1: C2 Concepts, Theory, and Policy; Topic 9: Collaborative Technologies for Network-Centric Operations; Topic 8: C2 Architectures

Susan G. Hutchins, Shelley P. Gallup, Doug MacKinnon, Gordon Schacher, and Scot Miller

Naval Postgraduate School, Monterey, CA
Graduate School of Operational and Information Science
589 Dyer Road
Monterey, CA 93943
Off Ph: 831.656.3768

Jared Freeman
Aptima, Inc., Woburn, MA

Dan Dunaway
SYS Corp, Waashington, DC

Brad Poeltler
Poeltler Consulting, San Diego, CA

Enhancing Maritime Domain Awareness

Abstract

A complex mosaic of forces will affect maritime security through 2020. These include economic forces such as (*i*) illegal international migration–fueled by tremendous population increases in developing countries, (*ii*) drug smuggling, and (*iii*) weapons proliferation, as well as (*iv*) military threats posed by hostile states, failed states, and transnational organizations engaged in intelligence gathering or terrorist activities. The President's National Security Strategy indicates that diverse threats such as these must be countered through an integrated approach: Maritime Domain Awareness (MDA). MDA will engage and shape this dynamic and expansive environment by detecting anomalies and deviations from established trends and patterns in commercial and military traffic, and enabling commanders to take appropriate action before security is compromised or crises erupt. In line with the theme for this year's symposium, C2 for complex endeavors, MDA encompasses a diverse set of organizations, complex processes, and a variety of analytic and collaborative tools. This research reported here will advance organizational structures, procedures and C2 technologies to enhance global MDA. Our approach is to document current MDA capabilities, compare them with the next phase of expected capabilities based on integrating new technologies, and document the gains.

INTRODUCTION

A confluence of forces will affect maritime security through 2020. These include economic forces such as (*i*) illegal international migration–fueled by tremendous population increases in developing countries, (*ii*) drug smuggling, and (*iii*) weapons proliferation (Stubbs & Truver, 1999), as well as (*iv*) military threats posed by hostile states, failed states, and transnational organizations engaged in intelligence gathering or terrorist activities (White House, 1998). The President's National Security Strategy indicates that diverse threats such as these must be countered through an integrated approach: Maritime Domain Awareness (MDA). MDA will engage and shape this dynamic and expansive environment by detecting anomalies and deviations from established trends and patterns in commercial and military traffic, and enabling commanders to take appropriate action before security is compromised or crises erupt (DoN, 2007). In line with the theme for this year's symposium, C2 for complex endeavors, MDA encompasses a diverse set of organizations, complex processes, and a variety of analytic and collaborative tools. This research reported here will advance organizational structures, procedures and C2 technologies to enhance global MDA. Our approach is to document current MDA capabilities, compare them with the next phase of expected capabilities based on integrating new technologies, and document the gains.

The MDA Prototype Acceleration Project is focused on initial capability fielding of prototype tools developed to assist with various aspects of MDA. After the initial assessment, conducted in 2008, selected tools will subsequently transition to current and/or new Programs of Record in FY10 and beyond. Two fielding spirals, Spiral 1 and Spiral 2, were designated for the acceleration effort, with Spiral 1 commencing with the publication of the SECNAV

memorandum on 17 May 2007. The Spiral 1 effort focuses on establishing a set of core net-centric capabilities that, at multiple levels of security, will feed and fuse many data streams into a coherent common operational picture for Spiral 1 assessment while providing improved analytical and collaboration tools.

The purpose of this research is to develop a comprehensive assessment plan and conduct an assessment of the MDA Spiral 1 technologies and associated capabilities to ascertain the value added by the various tools. Our approach is to conduct the assessment at the system of systems (SoS) level, in keeping with performance and effectiveness areas identified in the MDA Prototype Capability Acquisition Strategy (v1.1) of 17 August 2007. This entails working with the MDA Spiral 1 planners, functional area managers, site managers, labs, and test organizations involved with developing, validating, and assessing definitions, requirements, and designs and reporting test and evaluation activities for MDA FY08 Spiral 1.

Background

MDA was initiated by a Presidential Initiative (White House, 1998) which stimulated a requirement for a Quick Reaction Assessment (QRA) to be conducted for MDA Spiral 1 Acceleration leave behind capabilities. A Secretary of the Navy Project was promulgated and is managed by Program Executive Office (PEO), command, control, computers, communications, and intelligence (C4I) to increase the United States maritime security. MDA will develop an enhanced capability to identify threats in the Maritime Domain as early and as distant from our shores as possible by integrating intelligence, surveillance, observation, and navigation systems into a common operating picture (COP) accessible throughout the U.S. Government. The MDA Science and Technology (S&T) Prototype effort is in the formative stages such that the prototype capabilities have broadly stated capability thresholds and objectives.

Various assessment events will be conducted to evaluate the existing system of systems ability to meet MDA requirements (with selected technology insertions, as they are available at different venues of opportunity). These FY08 scheduled events will provide opportunities to establish how well the MDA tools meet the MDA stated capabilities, measures of effectiveness, and measures of performance. Various venues of opportunity offer events that permit collecting, collating, analyzing, and documenting performance and effectiveness data related to the MDA tasks to establish a baseline of effectiveness and performance parameters. This baseline data will provide opportunities to establish more specific and measurable effectiveness and performance parameters for future MDA efforts in the stated focus areas of monitoring, collecting, fusing, analyzing, and disseminating MDA data to the decision makers.

MDA Objectives

The campaign plan lists the following National and Navy MDA objectives and critical tasks. At the national level, MDA objectives include the ability to persistently monitor in the global maritime domain, vessels and craft, cargo, vessel crews, and passengers. This monitoring capability applies to all identified area maritime situation awareness areas of interest, and includes gaining access to and maintaining data on vessels, facilities, and infrastructure. A critical capability entails the ability to collect, fuse, analyze, and disseminate information to decision makers to facilitate effective understanding among all nodes in the organization, and to access, develop and maintain data on MDA-related mission performance.

Navy MDA Objectives include the ability to:

- Create a global network of unclassified regionally-based maritime information exchange partnerships (with framework) which net-centrically integrates regional maritime situation awareness into global maritime situation awareness.
- Establish an institution of worldwide standards and cooperation/coordination for broadcast of vessel position and identification.
- Improve maritime change detection, the capability to discern patterns, changes, and potential threats.
- Improve threat awareness (TA) and alert maritime partners of suspicious behavior and potential threats.
- Secure the United States from direct attack by confronting early and at safe distances, those who threaten us.
- Secure strategic access and retain global freedom of action by ensuring that key regions, lines of communication and the global commons remain accessible to all.
- Strengthen existing and emerging alliances and partnerships to address common challenges.
- Establish favorable security conditions by countering aggression or coercion (including corruption) targeted at our partners, interests, and operating forces – including coalition.

METHOD

Our approach was to document the current MDA process, as it is currently conducted, so that we can measure the operational impact of new Spiral 1 MDA technologies. Our objective is to define and assess future MDA processes and technologies and then develop a refined version of the process. We began by viewing the overall MDA process in the context of a tracking scenario and a boarding scenario to document the current, present state of MDA processes and capabilities. The 'to be' (expected) version of MDA workflow for the future will be used to develop techniques, tactics, and procedures (TTPs) and to make recommendations for other related changes, e.g., training, staffing, etc. These documents were validated in a process engineering workshop held in January 2008 at the Naval Postgraduate School, Monterey, CA, and a February 2008 workshop to align the model with the current process model for Maritime Headquarters with Maritime Operations Centers (MHQ w/ MOC). The workflow was also translated into a DoD Architectural Framework (DoDAF) process database (OV-6c). The workflow product will inform experiments and fielding of an initial operating capability. Specifically, a set of potential stress points within the MDA workflow have been identified. These will be a focus of upcoming experiments, and process recommendations concerning these stress points have been drafted.

Developing Workflow Process Models

Initial visits were made by NPS project team members to Commander, Third Fleet (C3F), Commander, Seventh Fleet (C7F), U.S. Naval Force, Central Command (NAVCENT), and Office of Naval Intelligence (ONI). Interviews were conducted with MDA subject matter experts (SMEs) and MDA workflow process models were developed. SMEs were asked to describe in as much detail as possible how MDA is accomplished and a semi-structured set of interview questions was used to obtain detailed information about: (1) MDA tasks, (2) the entities that

execute them, (3) the precedence relationships (or flow) between those tasks, and, when possible, (4) the media used to communicate between tasks, (5) the products of those tasks, and (6) the potential application points for Spiral 1 technologies. Table 1 lists the questions posed to SMEs regarding the current 'as is' MDA process workflow.

Table 1. Questions Posed to Subject Matter Experts Regarding the Current 'As Is' MDA Process Workflow.

1. What information do you request from external sources?
2. What information do you produce internally at this point?
3. What information do you pass to external entities at this point?
4. Which information sources (people, technologies) have the greatest value or priority?
5. How do these steps fail, when they fail (e.g., timeliness, completeness, accuracy, confliction)?
6. What is the frequency of each task?
7. What is the duration of each task?
8. How many full-time staff are required by each task?
9. Which Spiral 1 technologies would improve your operations most? How?

Our general framework for developing an understanding of the overall MDA process is illustrated in Figure 1. This comprehensive approach considers the constraints that will affect personnel while performing the tasks in addition to the data/ information inputs and outputs for each node in the organization as well as a detailed description of the required resources.

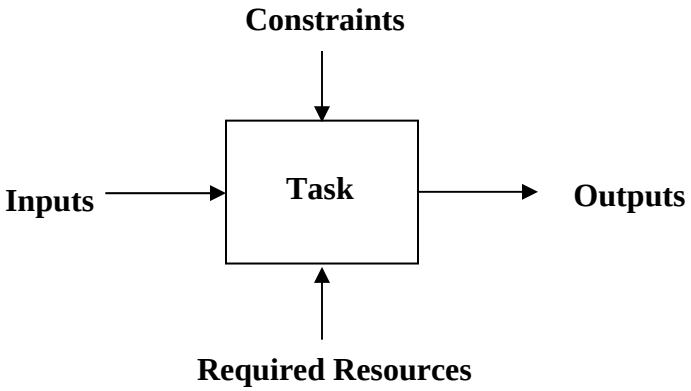

Figure 1. General Framework Used for MDA Task Workflow Definition.

The NPS research team elicited additional information about workflow and technology-related issues in interviews with Commander, Pacific Fleet (COMPACFLT), Maritime Intelligence Fusion Center, Pacific (MIFCPAC), ONI, and NAVCENT. Two types of analyses were conducted using interview data. A qualitative analysis was performed to identify areas of concern and generate recommendations. A process analysis was performed to define the current – or 'as is' – workflow. The objective was to define the current – or 'as is' – flow of MDA tasks in a representative sample of organizations, and to capture issues of concern to those organizations regarding MDA Spiral 1 technologies. Representatives of more than 20 organizations reviewed and revised the workflow products in two workshops.

Figures 2-4 present the current version of the 'as is' MDA workflow process model. Using the observe, orient, decide, act (OODA)-loop model as a framework for presenting the MDA process, Figure 2 shows the MDA process begins with generation of 'tipper' information, which can occur at several locations, or commands. The 'decide' phase of the overall process begins when the Maritime Operations Center (MOC) Director, directs either current operations (COPs) or future operations (FOPs) to process the vessel of interest (VOI). This process includes several requests for information (RFI), as well as several other steps: defining the course of action (COA), and handoff of the mission to another MOC. Finally, the 'act' portion of the process, involves conducting a visit, board, search, and seizure (VBSS) on the VOI. Each step depicted in the boxes included in Figures 2-4 has a code next to the box for the step to indicate the method of communicating the information: briefs, chat, email, face-to-face, message traffic, phone, or other (to be determined).

Figure 3, depicts the boarding process as it is currently done ('as-is'). The commands that have a role are listed along the left axis and the steps involved are depicted in the corresponding rows for each command, with arrows indicating where the outcome of a process connects to the next step, and the method used to communicate information. Spiral 1 capabilities and technologies that are expected to be added to enhance the various steps in the MDA process are also listed in each box in the model. These were determined during interviews with SMEs at the commands included in the MDA process. Figure 4 continues the depiction of the MDA workflow process model by showing the steps entailed in a handoff of a VOI from one MOC to another MOC.

The workflow model that was developed focuses mainly on NAVCENT and represents the relatively efficient processes used by NAVCENT. (The decision to focus on NAVCENT was made following site visits to C3F, C7F, NAVCENT, and ONI). The workflow model illustrates the processes required to execute two scenarios: (1) tracking a vessel of interest (VOI) and (2) handing off the VOI from one numbered fleet commander to another. These scenarios implement the first two scenarios envisioned in the draft MDA Spiral 1 Scoping Document[1], and they arguably incorporate several of the remaining Spiral 1 scenarios. We will expand the workflow models to address additional scenarios as needed.

[1] The draft Scoping Document for Navy Maritime Domain Awareness (MDA) Spiral 1 Prototype, version 2, 11 OCT 2007 specifies the following scenarios: (1) Track vessels via fusion of multiple data sources across the maritime knowledge base, incorporating both current and archived data; (2) Vessel Tracking handoff across Fleet Areas of Responsibility (AORs); (3) Collaborate between nodes; (4) Establish a near-real time maritime Common Operational Picture that provides access to tactical, operational, and strategic data elements; (5) Improve timely transfer of vessel data collected at the tactical level to appropriate operational and strategic nodes (e.g., Expanded Maritime Interception Operations (EMIO), AARs, and track updates); (6) Enable participating Navy commanders to network globally through real-time collaboration and information sharing, supporting decision making at the strategic, operational, and tactical levels across the range of military operations (ROMO).

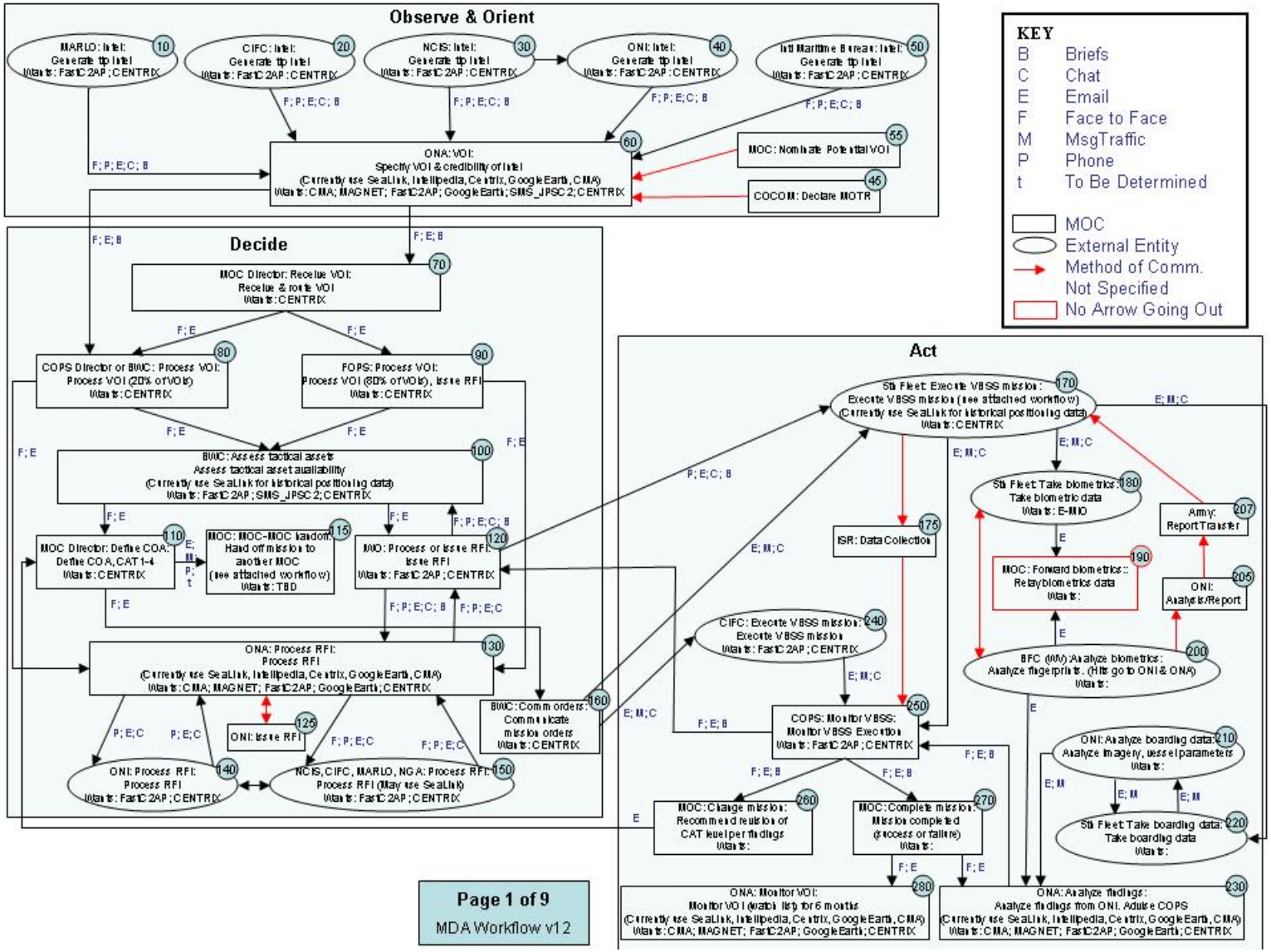

Figure 2. MDA Workflow for Observe, Orient, Decide and Act.

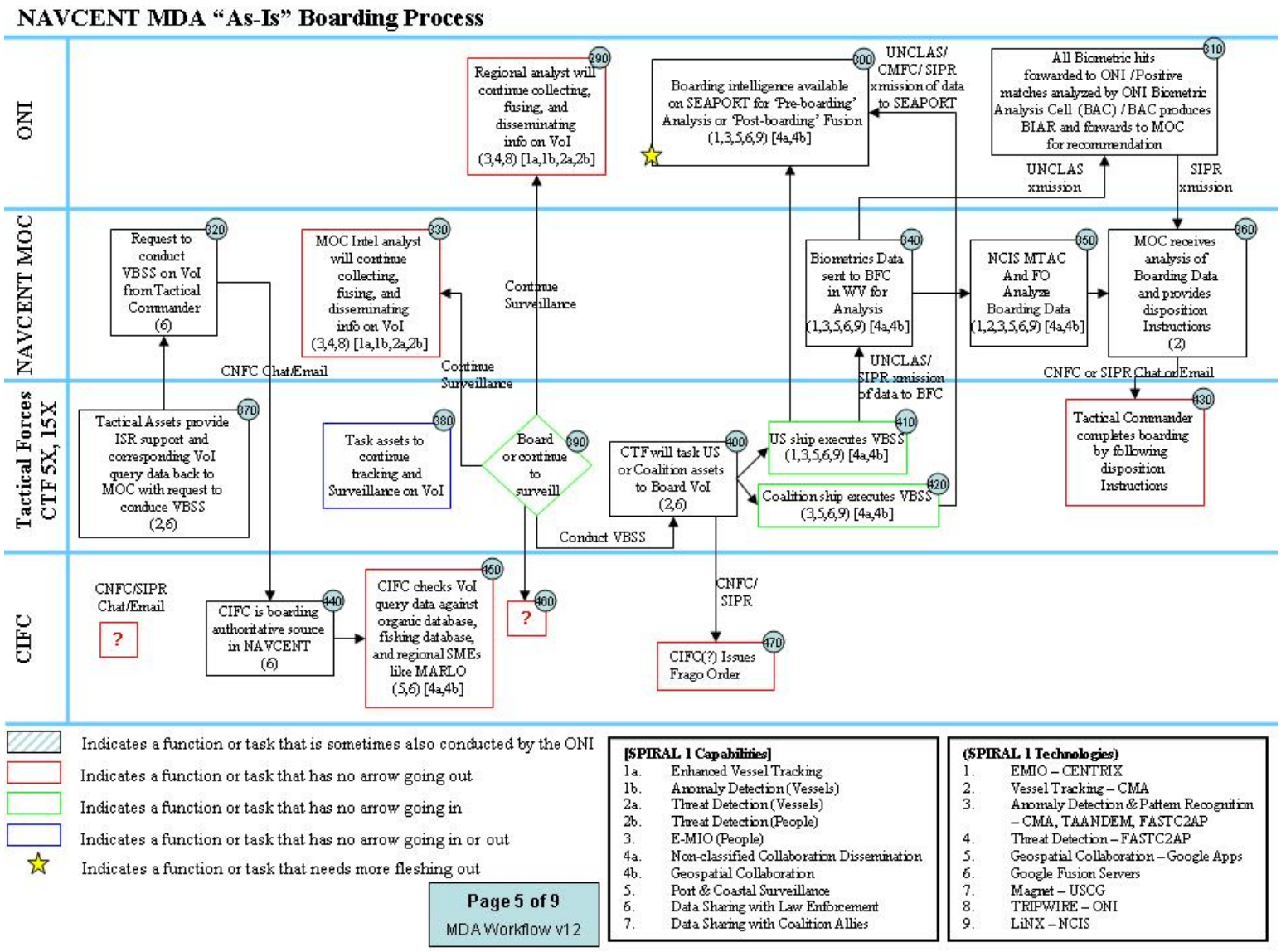

Figure 3. NAVCENT MDA Process Workflow for Current ('As Is') Boarding Process.

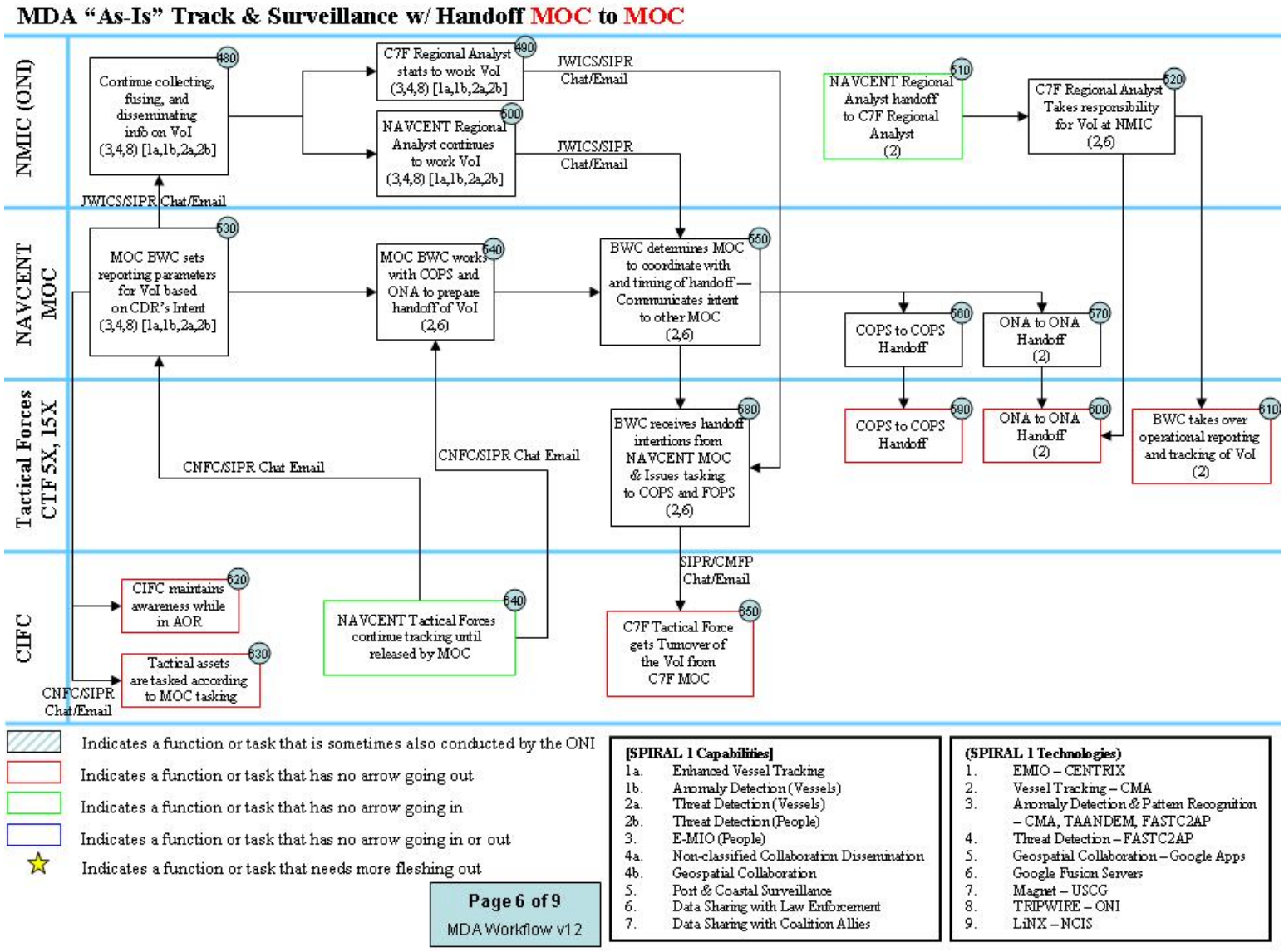

Figure 4. MDA 'As Is' Track and Surveillance w/ Handoff from MOC to MOC.

A second round of interviews was conducted to refine these workflow models with site visits to ONI, NAVCENT, and MIFC. Specifically, the interview protocol for these site visits was designed to: (1) identify additional tasks and task-task relationships, define them operationally, and identify potential failure points; (2) identify information input requirements, (3) identify information outputs, (4) specify requirements regarding human resources, technology, and time; and (5) specify constraints regarding human resources, technology, and time. These attributes on MDA tasks are represented in scenarios as needed.

Process Engineering Workshop

A process engineering workshop (PEW) was held at the Naval Postgraduate School (NPS), Monterey, CA, 15-17 January 2008 to accomplish several critical steps. The objectives of the PEW were to:

- Refine, extend, and validate a process model of Maritime Domain Awareness
- Define attributes of the activities that constitute MDA, specifically information requirements, processing activities, products, and resource (time, manning) requirements (reported in Freeman, Heacox, and MacKinnon, 2008)
- Specify which MDA activities may benefit from Spiral 1 technologies
- Develop concepts for assessing the effects of technology
- Identify barriers to fielding MDA Spiral 1 technologies

Representatives of the following organizations participated in the PEW: Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN RDA), Commander, THIRD Fleet (C3F), Commander, Operational Test and Evaluation Force (COTF), Office of the of the Under Secretary of the Navy, Defense Information Systems Agency (DISA), HFE LLC, Joint Interoperability Test Command (JITC), METRON, Maritime Intelligence Fusion Center, Atlantic (MIFCLANT), Maritime Intelligence Fusion Center, Pacific (MIFCPAC), U.S. Naval Force, Central Command (NAVCENT), Naval Network Warfare Command (NNWC), Naval Criminal Investigation Service (NCIS), United States Northern Command (NORTHCOM), NPS, Naval Research Laboratory (NRL), Naval Warfare Development Center (NWDC), Office of Naval Intelligence (ONI), staff of the Chief of Naval Operations (OPNAV), PMW 120, and Space and Naval Warfare Systems Center (SPAWAR). Also participating were subject matter experts (SMEs) from several of the MDA Spiral 1 technologies, domain experts (‘gray beards’), representatives from the Trident Warrior 2008 (TW08) operational experiment where many of the MDA Spiral 1 technologies will be assessed, and members of the assessment team (NPS, Aptima, Pacific Science & Engineering, WBB Inc.).

Workflow review. The PEW participants reviewed several MDA OV-6c workflow diagrams developed by NAVNETWARCOM from NPS workflow data. These diagrams were: ‘NAVCENT MDA Process’ (as well as a summary diagram for this workflow (version 11)), ‘Provide MDA Info-NMIC’, and ‘RFI Processing-NMIC’. Participants recommended revisions to the activities, activity-activity precedence (links), and clustering of activities. The number of revisions was modest, and participants indicated that these workflows are generally correct. PEW participants recommended revisions to the NAVCENT MDA Process workflow to generalize it so that it potentially serves MOCs and organizations other than NAVCENT.

Goals for the PEW were to: (1) validate the initial workflow models of the process with subject matter experts (SMEs) from the representative commands, (2) discuss how the new tools

developed for MDA will change the process, and (3) develop new process workflow models to depict the envisioned processes once the tools are incorporated into the MDA process. Questions that were posed to the subject matter expert (SME) attendees are listed in Table 2.

Table 2. Objective Translation of User-Defined Measures.

Number of Tracks	1. What is the range of the number of vessels the watch team must track at any given moment?
	2. How often must track data be updated?
	3. If required, how often is manual track updating needed?
	4. What sorts of vessel data (cargo, destination, crew, hull type, flag) are required as part of track data?
	5. How many AIS tracks are typically received?
	6. How many AIS tracks are typically displayed?
	7. Does the source of track data need to be easily discernable?
	8. Do sources of track data need to be filtered?
	9. How many tracks from radar can be displayed?
	10. How many tracks from radar need to be displayed?
	11. How many tracks from ELINT can be displayed?
	12. How many tracks from ELINT need to be displayed?
Data Archival	13. What is the current capability to archive vessel data?
	14. How much more storage, if any, is required to archive vessel data?
	15. What is the maximum number of collating (fusing) events a watch team can coordinate?
	16. What is the maximum number of collating (fusing) events that ONA could coordinate?
	17. How many tracks would have been identified earlier if harbor or port information (underway times, arrival times, cargo, crew) were readily available?
	18. How many "heads-up" vessel track (cargo, destination, crew, hull type, and flag) events from a nearby MOC, have taken place over a given month?
Information Reachback	19. How many requests for vessel data have been made which require global accessibility?
	20. How many ONI (Office of Naval Intelligence) requests for information are typically made in a given day?
Overarching Technical	21. How many conflicts have occurred in a given week, over releasability of the present MDA technology (GCCS-M, Centrix, SIPR, chat, JWICS, etc.)
	22. How many conflicts have occurred in a given week, over usability of the present MDA technology (GCCS-M, Centrix, SIPR, chat, JWICS, etc.)
	23. How many conflicts have occurred in a given week, over reliability of the present MDA technology (GCCS-M, Centrix, SIPR, chat, JWICS, etc.)?
	24. How many conflicts have occurred in a given week, over automation of the present MDA technology (GCCS-M, Centrix, SIPR, chat, JWICS, etc.)?
	25. How many conflicts have occurred in a given week, over supportability of the present MDA technology (GCCS-M, Centrix, SIPR, chat, JWICS, etc.)
	26. How many conflicts have occurred in a given week, over maintainability of the present MDA technology (GCCS-M, Centrix, SIPR, chat, JWICS, etc.)

Scenario for Spiral 1 Assessment of Technologies

The MDA Spiral 1 effort focuses on a single scenario with the following six identifiable goals: (a) track vessels via fusion of multiple data sources across the maritime knowledge base, incorporating both current and archived data; (b) vessel tracking handoff across Fleet areas of responsibility (AORs); (c) collaborate between nodes; (d) establish a near real-time common operation picture (COP); (e) improve transfer of vessel data collected at the tactical level (extended maritime interdiction operations (EMIO)); and (f) enable Navy commanders to network globally through real-time collaboration and information sharing, supporting decision making at the operational and tactical levels across the range of military operations (ROMO). (PEO C4I) The scenario involves information sharing across multiple areas of responsibility (AORs) of a suspect vessel in transit from the Middle East to the vicinity of Hawaii. Ultimately, the information sharing and collaboration would result in an order to board a tactical unit, such that each of the goals stated above would be tested.

Using the process described above, the NPS team documented the workflow of Maritime Domain Awareness for a select set of organizations: Afloat Units; Biometrics Fusion Center (BFC); Boarding Party; MIFC; COMPACFLT; Combatant Commanders (COCOM); Maritime Liaison Officer (MARLO); MIFCLANT; MIFCPAC; NAVCENT MOC; NCIS; Naval Maritime Intelligence Center (NMIC); and Subordinate Commanders and Staff. These organizations were chosen in part because the scenario used in interviews involved a suspect vessel en route from the Middle East towards the West Coast of the U.S. Other scenarios might, in the future, engage other organizations and invoke other activities. The workflow represents the activities of the NAVCENT MOC (109 activities) and Naval Maritime Intelligence Center (NMIC) (50 activities) in the greatest detail. The remaining organizations are represented by a dozen tasks or fewer.

TOOLS TO SUPPORT MDA

A suite of tools have been developed for the Spiral 1 phase and the prototypes will be assessed during the Trident Warrior 08 experiment where various venues exist to assess the level of improvement, as well as other venues. The Spiral 1 effort focuses on establishing a core net-centric set of capabilities that, at multiple levels of security, will feed and fuse many data streams into a coherent common operational picture while providing improved analytical and collaboration tools. The following section describes the tools and the capabilities they provide for the Spiral 1 phase of MDA.

Comprehensive Maritime Awareness (CMA). Comprehensive Maritime Awareness (CMA) was developed to support anomaly detection by collecting track information and identifying behavior that deviates from normal patterns of behavior, e.g., relationships between vessels and cargo. CMA supports sharing information across all CMA nodes from NMIC, Coast Guard, Combatant Commanders, Coalition partners, and tactical level commands and supports a number of tasks and functions that are part of the overall MDA process. CMA supports generation of tipper information (the initial step (first box) in the workflow diagram) via its object tracking capability: objects include people, cargo, financial transactions, vessels, vessel ownership and flag, etc. For example, connecting the name of a crew member, to related persons, to financial transactions, to a terrorist group can be accomplished in a much shorter time to provide tipper information on a vessel of interest (VOI), person of interest (POI), cargo of interest (COI), and

so on. CMA extracts information from a wide range of sources and integrates this multi-source data. CMA is expected to improve the process by automatically correlating across many information sources to reduce the time required to perform critical tasks (e.g., reduce the time required to accomplish a task that currently takes many hours, down to minutes).

CMA is expected to perform a more comprehensive correlation across multiple sources of information (~350 databases) due to automation of this process. For example, the correlation process is accomplished in near-real time as opposed to taking many hours. An explanation is provided to the user along with any tipper information, including all sources used by the system that have information that contributed. CMA will be installed and used at all levels depicted in the workflow diagram, i.e., from ONI, NAVCENT, CFIC, to tactical level forces, and will be used in slightly different ways depending on the organizational level depicted in the workflow diagram.

It is anticipated that the ability to automate the search and correlation process across multiple sources represents a paradigm shift in that a significant reduction is expected in the amount of an analyst's time that will be required for this part of the process. By automating this portion of the overall task it should free up the analysts to do the higher level analysis that is critical. An additional feature incorporated in CMA is persistent tracking of 200 vessels. This history of a track can be pulled into the analysis, e.g., ports visited along the route of the vessel. CMA is based on the premise that greater transparency of existing data will translate into greater security.

Track Assessment and Anomaly Detection – Maritime (TAANDEM). TAANDEM is a track processing system to identify motion that is inconsistent with previous behavior patterns. This feature is based on processing archived data to determine key parameters of motion, and to design key detection statistics. The prediction and activity monitoring component provides real-time track processing, the ability to identify deviant tracks, and facilitates the preparation of drill down evidence data for display. TAANDEM provides input to CMA in the form of annotated tracks.

Alerts are generated by a specific factor that violates a boundary, which can involve anything that can be computed on a track. TAANDEM generates the degree of deviance from normalcy for any of these factors. The current plan is to let the user reconfigure settings (such as, parameters for boundaries, degree of deviance acceptable).

MAGNET. MAGNET uses agent logic to obtain data, using a web browser to query other data sources. MAGNET is installed at the Coast Guard, MIFCPAC. The web browser is used to query the system, regarding such topics as weather, ships in a specific area, and so on.

Fast Connectivity for Coalition Agents Program (FastC2AP). FASTC2AP uses agent technologies to create "watch stander composeable automation," where watch standers use agents to define and automate information management tasks. FastC2AP is based on a Defense Advanced Research Projects Agency (DARPA) developed predecessor tool, and uses PACFLT databases. The FASTC2AP tool set is web-enabled and uses data from incoming e-mails, Chat, Global Command and Control System–Maritime (GCCS-M), and various databases from around the

world. Outputs include on-screen alerts, e-mails, and over-the-horizon (OTH) Gold messages that update GCCS-M tracks.

FastC2AP is a collection of software tools, implemented through a web portal, which supports operators as they manage situational awareness and track behavior within their AOR. FastC2AP supports watch standers and analysts by automating many of the maritime track data management tasks they typically perform now. The FastC2AP portal allows watch standers to (a) process vast amounts of a data, (b) access multiple databases, and (c) return relevant data for processing by analysis, fusion, and exploitation agents.

E-MIO Wireless. Electronic Maritime Interdiction Operations (E-MIO) Wireless provides satellite transmission and reception for non-biometric boarding data (manifests, etc.) and automatically ingests data into authoritative databases.

Google Applications and Chat. Google Applications and Chat provide a collaboration tool that includes alerts, chat, blogs, calendar, tabbed web portal, and productivity tools. Data are stored in a secure Navy enterprise maintained by Google; this tool supports sharing between the Navy, Department of State, Department of Justice, etc.

Global Trader. Global Trader supports queries about cargo data and several types of automated analyses: anomaly detection (including both statistical and machine learning), pattern matching, and clustering, and provides alerts with supporting evidence.

TRIPWIRE. TRIPWIRE mines unstructured text data and alerts analysts to messages of interest, based on user-defined, persistent alerting rules. This tool can perform more than 1.5 million transactions in a growing database.

Many questions remain regarding the effectiveness of the prototype MDA tools. These questions include where to set detection thresholds for anomaly detection, i.e., how many degrees of difference are appropriate? Other issues also pertain to the tradeoff between false alarms rate and missing a critical event. Reliance on databases raises the issue of the reliability of databases and their associated update rates.

Technical Capabilities: Description of Technology Features

From the MDA Scoping Document, the Spiral 1 effort focuses on establishing a core set of net-centric capabilities that, at multiple levels of security, will feed and fuse many data streams into a coherent common operational picture while providing improved analytical and collaboration tools. Table 3 presents a brief summary of the MDA tools, features provided, and their associated benefits.

Table 3. Spiral 1 Tools, Features Provided and Benefits of Tools.

MDA Tool	Features Provided	Benefits of Tool
CMA	Anomaly detection	• Automates a previously manual process
	Information sharing across organizational nodes	• Facilitates collaboration
	Object tracking	• More tracks can be monitored
	Integrates multi-source data, includes search agents, confidence reporting, and remote access	• More comprehensive correlation across multiple sources of information

	Automatic data correlation	• Reduced time to perform tasks
FASTC2AP	Defines/ automates information management tasks	• Generates alerts, emails, OTH Gold messages that update GCCS-M tracks
	Helps manage situational awareness	• Access to multiple databases
	Processes large amounts of data by analysis, fusion, and exploitation agents	• Helps manage situation awareness and track behavior in an area of responsibility
TRIPWIRE	Mines unstructured text data and alerts analysts	• Increased relationships analyzed
	User-defined persistent alerting rules	• Reduced latency
MAGNET	Intelligent agent logic	• Faster access to data
	Web browser to query other data sources	• More sources queried in less time
	System queries regarding topics of interest in area	• Increased number of analytic models
		• Increased archived data for analysis
TAANDEM	Real-time track processing	• Prediction and activity monitoring
	Identify deviant tracks	• Real-time track processing
	Provides annotated tracks with alerts	• Rule-based anomaly detection
E-MIO Wireless	Provides satellite transmission/ reception for unclassified boarding data	• Automatically inserts data into authoritative databases
Google Applications and Chat	Collaboration tool: Alerts, chat, blogs, calendar, tabbed web portal, and productivity tools	• Supports sharing between the Navy, Dept. of State, Dept. of Justice, etc.
Global Trader	Anomaly detection, pattern matching/ clustering, and provides alerts with supporting evidence	• Supports queries regarding cargo and data analyses

MARITIME DOMAIN AWARENESS SPIRAL 1 ASSESSMENT PLAN

The NPS assessment plan provides assessment guidance for the FY08 Spiral 1 events of the MDA Science and Technology (S&T) Prototype Acceleration effort.

Spiral 1 Assessment Strategy

The MDA 2008 Spiral 1 assessment efforts focus on identifying baseline performance parameters associated with the broadly stated capabilities for the present state of MDA technologies. Our approach was to develop an overarching assessment plan to refine objectives, develop measures and design data collection instruments so that analysis of the tools can be conducted and the results and recommendations can be forwarded to decision makers for continuing improvement in MDA. The NPS assessment effort includes developing performance metrics related to availability, reliability, timeliness, usability, and accuracy. Data on these attributes will be collected along with other specific parametric data that will be used to define the existing MDA performance capabilities. The assessment strategy was also developed to assist in establishing the operational baseline against which future improvements can be measured. This data will be collected at various MDA or MDA-related events, and other venues of opportunity listed in the schedule for Spiral 1.

The NPS assessment plan combines input from many sources to develop an assessment plan built on previous studies that will enable decision makers to determine MDA effectiveness and shortcomings. We began by developing an understanding of the 'present state' of the Spiral-1 technologies as documented in the MDA Scoping Document. This was followed by the scenario development that is presented in the scoping document. The scenarios were then used to formulate anticipated workflow models that were refined from both theoretic scenarios and multiple real-world site visits. The goal is to provide decision makers a concise, repeatable, and

highly-refined methodology to improve MDA capabilities and to provide input that will support future budgetary allocations based on this analytical framework.

The Spiral 1 assessment goals include the ability to: (a) understand the capabilities and limitations of the present state MDA prototype functional areas; (b) establish a baseline of operational parameters traceable to the MDA test and evaluation plan; (c) execute a Risk Reduction Limited Objective Demonstration prior to the initial operational capability (IOC); and (d) identify areas for improvement that may be employed in follow-on Spiral efforts.

Use case development and use in planning. The purpose for the use case analysis is to create a set of representative use cases (threads) that examine MDA as a system to include people, elements of doctrine, concept of operations (CONOPs), information exchange needs, methods for transporting information requirements, and tasks that will stimulate the tasks and various exchanges to reveal Spiral-1 performance capabilities and future needs requirements. An OV-5 workflow model (IDEF view in UML) and an OV-6c event trace model are the primary mechanisms by which to create the use cases, with a data-flow model (OV-7) providing the information exchange requirements that meet the needs of watch standers and decision makers.

The range of tasks at the user level, within MHQ/MOC is being defined in a data pull from NAVCENT, Commander, Pacific Forces (CPF), ONI, and other organizations at this time. Results of the data analysis provide an input to the development of the DoDAF views, and will be used by the Architecture Working Group which will in turn produce the models described above. A necessary component to be developed is the scenarios or vignettes that encompass those tasks and activities needed in IOC demonstrations.

Metrics and Measures. MDA objectives have been organized into a three-level structure of objectives and metrics that facilitates the design of specific experimentation objectives. This approach has been used and refined over several years of fleet experimentation (e.g., TRIDENT WARRIOR) as it was developed for Navy Network-Centric Warfare Command (NAVNETWARCOM). The approach we are using entails detailed documentation of objectives, metrics, and all aspects of the measurement process.

MDA Critical Tasks

- Direct Operational Intelligence Activities
- Process and Exploit Collected Operational Information
- Produce Operational Intelligence and Prepare Intelligence Products
- Disseminate and Integrate Operational Intelligence
- Evaluate Intelligence Activities in the JOA
- Collect and Share Operational Information
- Acquire and Communicate Operational Level Information and Status
- Assess the Operational Situation
- Develop a Shared Understanding of the Situation
- Prepare Plans and Orders
- Command Subordinate Operational Forces
- Coordinate and Integrate Joint/Multinational and Interagency Cooperation

Metrics are needed to assess the effects of technology insertion relative to the current state of capabilities for MDA. Currently, there are few if any published standards that define the effectiveness of current solutions in operations. Moreover, a sufficiently detailed scenario is needed to drive testing and must systematically address the variety of MDA data types (vessel, people, cargo, etc.), reporting products, node interactions, and time course of activity in a problem that involves discovery, analysis, and prosecution of VOIs. Particularly important challenges in MDA include ISR management, collection planning, decisions regarding opposed and unopposed boardings, and tracking neutrals. In addition, scenario designers need to consider events in which multiple vessels collaborate in a threat incident, either through cargo transfer between vessels or by synchronized tactical actions of two or more vessels.

Test Objectives Structure. MDA program objectives were obtained, however these do not include specific objectives for the various tests. Specific test objectives will be developed as part of the NPS assessment planning effort, derived from MDA program objectives. Test objectives are organized into the following six test areas: (1) supporting technology capabilities; (2) information processing capabilities; (3) operations performance status; (4) workflow status; (5) guidance quality; and (6) E-MIO operations capabilities. The objective categories for each test area are shown in Table 4.

Table 4. Test Areas and Objective Categories for MDA Program Objectives.

Test Area / Objective Category	Test Area / Objective Category
Supporting Technology Capabilities	**Information Processes Capabilities**
Monitoring & Collection	Monitoring & Collection
Processing/Fusion	Processing/Fusion
Analysis	Analysis
Dissemination	Dissemination
Archiving & Maintaining Repository	Archiving & Maintaining Repository
Operations Performance Status	**Workflow Status**
Plan Operations	Structure
Execution	Organization
Execution Monitoring	Group
Execution Assessment	Individual
Guidance Quality	**E-MIO Operations Capabilities**
TTP & SOP	Information Acquisition
CONOPS	Mission Planning
Command Guidance	Boarding Execution
Standing Orders	Execution Monitoring
	Information Collection
	Information Dissemination
	Information Assessment

The objective categories monitoring and collection, processing/fusion, etc., appear in two test areas. One set is for determining the capabilities of the various MDA information processes, the other is for determining the capabilities of the systems that support those processes. Specific objective types, their associated metrics, and objectives have been defined for each of the objective categories. The full set of objectives and metrics structure is currently being developed. E-MIO is a special test area, as E-MIO involves a specific operation, and the other areas are general and apply to the full range of MDA activities. Each test area includes several objective categories which correspond to the MDA objectives.

Metrics Structure. Metrics are based on: (1) attributes; (2) measures associated with each goal and attribute; and (3) any applicable standards/thresholds for the measures. The accepted MOP, MOE, MOU structure is used, with **Measures of Readiness** (MOR) added for acquisition purposes. MOR applies only to systems. **Measure of Effectiveness** (MOE) refers to the overall effectiveness of a system, people, or process to perform its *stated mission*. **Measures of Performance** (MOP) are direct measures of a specific *performance parameter* of people, process, or system. **Measures of Utility** (MOU) include the effectiveness of organizations, humans, processes, or systems for *supporting operational activities*, or for guidance in directing those activities. Measure of Readiness (MOR) is used to determine if the system is *ready for fielding*.

Table 5 contains the MOE, MOP, MOU attribute structure. For example, there are four attributes for measures of effectiveness (i.e., accessible, reliable, capable, and usable) and under each one are its component MOP attributes. There are also four attributes for MOU. MOP-level attributes for MOU are not shown; use of the MOP is appropriate, although most MOU determinations are made through surveys. Readiness is a combination of effectiveness, utility, whether there is a life-cycle plan, and whether trained personnel are in the pipeline for use of the system.

Table 5. MOE, MOP, MOU Attribute Structure for MDA Assessment.

Effective				
Accessible	**Reliable**	**Capable**	**Usable**	**MOE**
Capacity	Robust	Sufficient	Clear	**MOP**
Available	Persistent	Flexible	Trusted	"
Compatible	Secure	Accurate	Manageable	"
Extensive	Assured	Timely	Relevant	"
Efficient		Reach	Compliant	"
		Automatic	Deployable	"
Military Utility				
Improved	**Needed**	**Applicable**	**Wanted**	**MOU**
Ready				
Effective	**Utility**	**Life-Cycle**	**Personnel**	**MOR**
System Readiness is a roll up of the component readiness measures (MOR)				

Task / Attribute / Measure Relationships. Attributes and measures have meaning only when associated with an activity or task. Figure 5 depicts the various types of task, attribute, and measure associations encountered in military operations assessments. It is not sufficient to test system performance in isolation; it is also necessary to test the processes that systems serve, and

the humans and organizations that execute the processes. The relationships shown in Figure 5 illustrate the types of assessments that are needed.

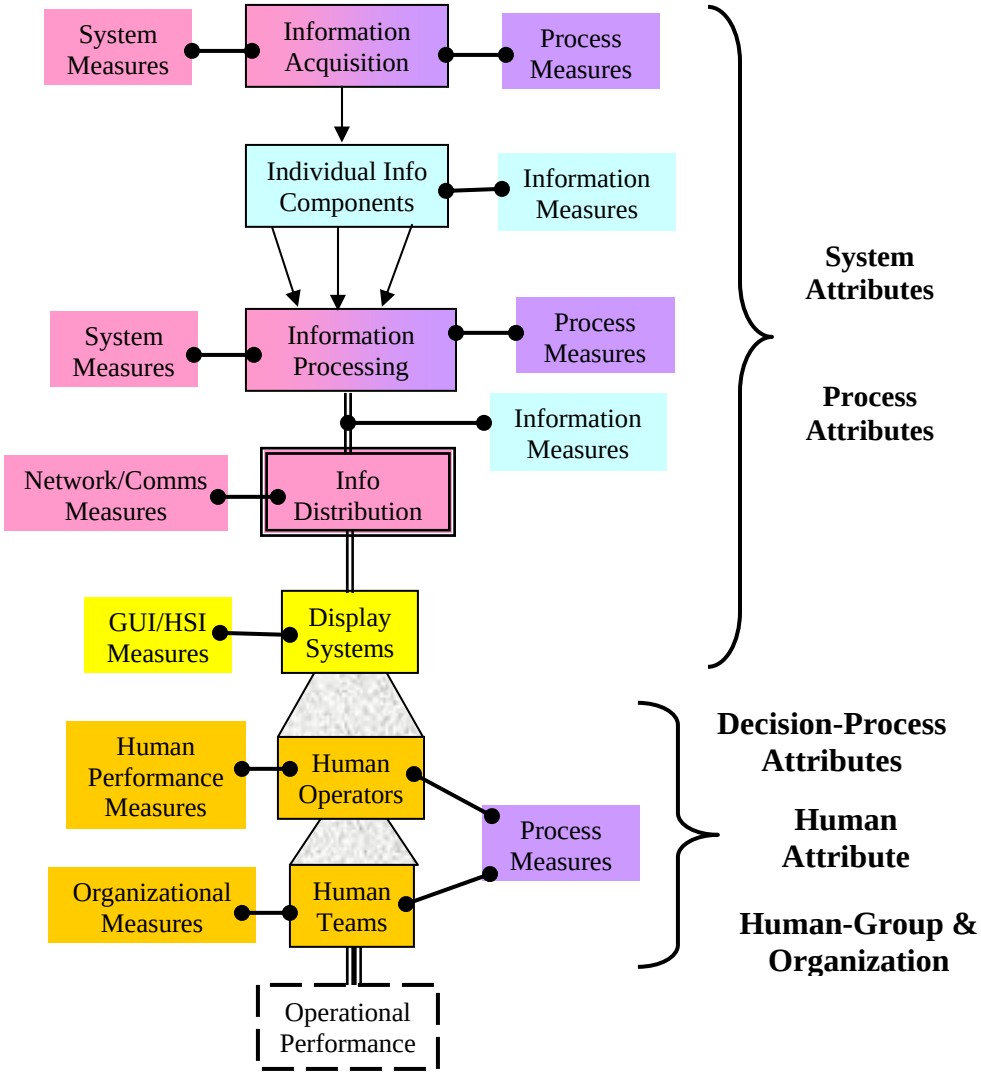

Figure 5. Attribute and Measure Types and Relationships to Systems and Activities.

RECOMMENDATIONS

We make approximately twenty recommendations based on these analyses. (For a more detailed reporting on this effort and the complete list of recommendations see, Freeman, Gallup, MacKinnon & Hutchins, 2008.) These recommendations concern training, provisioning, evaluation, management of technology enabled processes, and other issues. We recommend that the Navy build upon this work in the following ways:

- Conduct technology assessments that focus on human factors issues: trainability, usability, utility, and the fit between technology, organizational structure, and processes.

- Extend the current 'as-is' analysis to define MDA 'to-be' procedures that (1) conform to the MHQ w/ MOC and ONI process architectures and (2) are customized to the needs of specific users.
- Develop instruments and techniques for monitoring, measuring, and managing workflow at critical junctures in the MDA process.
- Implement a program to define a rapid, tailorable technology training program and measure its effectiveness. Adapt both the training and technology accordingly.

Recommendations from Qualitative Analysis

(1) Pay particular attention to planning and socializing the plan to train and maintain support for Spiral 1 technologies. This may allay concerns in COMPACFLT, NAVCENT, and elsewhere that the technology delivery is not paying sufficient attention to the human factor.

(2) Training for Spiral 1 technology users and maintainers should be rapid, demonstrably effective, and customized to local missions and procedures. This will address concerns that technology won't support local missions and processes for staffs with high turnover.

(3) Given the potential that staff will use new MDA technologies infrequently in some organizations, they may forget how to use the technologies accurately and efficiently. Usability, training, and technical support will be particularly important predictors of success in these organizations. These should be a focus of assessment.

(4) Technology providers should continue to brief user communities concerning the maturity and delivery schedules for technologies. This may help users to prepare for the specific capability they will receive.

(5) The accreditation process must be carefully managed across the Spiral 1 technologies. Lessons learned should be used to accelerate that process.

Assessing the Effect of Spiral 1 Technologies

PEW participants offered ideas for assessing the effects of Spiral 1 technologies on tasks, though there were few specific measures suggested and no performance standards. These strategies for assessing the fit of technologies to tasks fell into three categories, which should be a focus of future experiments and evaluations: affects on (1) access to information (that was previously inaccessible by the performing entity); (2) speed of decision making; and (3) accuracy of decision making.

Future Work

NPS will proceed with its planned assessment activities and the majority of the assessment events will occur in Spring/Summer 2008. This includes collecting and refining objectives, as well as defining each objective's goals, guiding questions, system requirements, measures to be recorded, and data collection plan. The assessment plan for each objective will be placed into a retrievable data base: FIRE (ForceNet Innovation Research Enterprise) (Schacher, 2007).

REFERENCES

Department of the Navy. (2007). Navy Maritime Domain Awareness Concept. Chief of Naval Operations: Washington, DC.

Freeman, J., Gallup, S.P., MacKinnon, D., & Hutchins, S. (2008). Maritime Domain Awareness Workflow Model Status Report. Naval Postgraduate School Technical Report, NPS-IS-08-002, Monterey, CA. 1 March 2008.

Freeman, J., Heacox, N., & MacKinnon, D. (2008). Maritime Domain Awareness (MDA) Process Engineering Workshop. Report produced by the Naval Postgraduate School, Monterey, CA. 18 January 2008.

Schacher, G. (2007). FIRE Experiment Planning and Reporting Structure. Naval Postgraduate School Technical Report, NPS-IS-07-002, Monterey, CA. 1 July 2007.

Schacher, G. & Freeman, J. (2008). MDA Program Test Structure and FIRE Implementation. Naval Postgraduate School Technical Report. NPS-IS-08-001, 1 March 2008.

Stubbs, B. & Truver, S. C. (2000). America's Coast Guard: Safeguarding U.S. Maritime Safety and Security in the 21st Century. Center for Security Strategies and Operations, Anteon Corporation: Arlington, VA.

White House. (1998). A National Security for a New Century. Washington, DC: GPO, October 1998.

Related Documents

a) The National Strategy for Maritime Security, dated September 2005
b) National Plan to Achieve Maritime Domain Awareness, dated October 2005
c) Maritime Domain Awareness Prototype Capability Acquisition Strategy v1.1, dated 17 August 2007
d) Maritime Domain Awareness Scoping Document v2, Oct 2007
e) Maritime Domain Awareness Test and Evaluation Plan v1.0, 1 Oct 2007
f) Maritime Domain Awareness Initial Capabilities Document (ICD), TBD

The following documents have been used as sources for developing the objectives for this effort:

- Campaign Plan for Navy Maritime Domain Awareness Prototypes, 21 Aug 2007
- MDA Spiral 1 Overarching T & E Plan, 1 Oct 2007
- Scoping Document for Navy Maritime Domain Awareness, Version 2.0, 11 April 2008.
- Fleet MDA CONOPS, 13 Mar 2007