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Facilitating Decision Making, Re-use and Collaboration: A Knowledge Management Approach to Acquisition Program Self-awareness

02 June 2009

by

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Abstract

Decades of reform have been largely ineffective at improving the efficiency of the Department of Defense (DoD) Acquisition System. Such inefficiency is, in part, due to complex processes and stovepipe activities that result in duplication of effort, lack of re-use and limited collaboration on related development efforts. This research applies Knowledge Management (KM) concepts and methodologies to the DoD acquisition enterprise to increase “Program Self-awareness” (Gallup & MacKinnon, 2008, p. 2). This research supports the implementation of reform initiatives such as Capability Portfolio Management and Open Systems Architecture, which share the common objectives of reducing duplication of effort and promoting collaboration and re-use of components. The DoD Maritime Domain Awareness (MDA) Program will be used as a test case to apply KM tools to identify duplication and/or gaps in the features of select MDA technologies. This paper may also provide the foundation for future development of the Program Self-awareness concept and KM tools to support decision-making and to improve the effectiveness of the DoD Acquisition System.

Keywords: Defense Acquisition System, Knowledge Management (KM), Open Architecture (OA), Capability Portfolio Management (CPM), Business Intelligence (BI), Maritime Domain Awareness (MDA), Data Mining, Text Mining, Data Visualization

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I. Introduction

A. Background

The Department of Defense (DoD) fiscal year 2009 budget for Research, Development, Test and Evaluation (RDT&E) and procurement exceeds $180 billion (Gates, 2009, p. 37). With such huge budget outlays and the increasing pressures of shrinking discretionary budgets in a fragile economy, the DoD Acquisition System is the subject of intense scrutiny from government oversight activities, industry, and the general public. This scrutiny has been amplified by highly publicized acquisition program failures, continued cost and schedule overruns, and lengthy development cycles.

The DoD acquisition has endured an environment of seemingly perpetual reform to arrest this chronically poor performance, resulting in complex acquisition process models, increased executive oversight, and incremental policy changes. Continued reform is certain since Defense Secretary Gates repeatedly expresses frustration with the acquisition process. He cites examples that reflect the need for change: a need to conduct the recent acquisitions of the Mine Resistant Ambush Protected vehicles (MRAP) and Intelligence Surveillance Reconnaissance capabilities outside normal acquisition processes. Secretary Gates has also called for a change in the mindset of those in the acquisition community to accept 75% solutions, vice the 99% solutions often overreached by typical acquisition programs (pp. 37-38).

The effectiveness of these reforms is not yet evidenced in the overall performance of the DoD Acquisition System. Independent- and government-chartered studies and reports have repeatedly highlighted the need for improved systems engineering and business processes to incorporate best practices from the commercial sector. In the Government Accounting Office (GAO) FY08 review of select DoD Acquisition Programs, the GAO found that total acquisition costs increased 26% and development costs increased by 40% from first estimates, with program schedule delays averaging 21 months. The GAO also noted the "continuing absence of knowledge-based acquisition processes steeped in disciplined systems engineering practices—aimed at analyzing requirements to determine their reasonableness before a program starts—contributed significantly to this" (GAO, 2008, March, p. 5).

The DoD embraced several recommendations from these critical reports and moved to adopt several commercial best practices and process initiatives. Two such policy changes relevant to this research are the adoption of Capability Portfolio Management (CPM) and Open Architecture (OA) approaches, discussed at length in Chapter II. CPM and OA are relatively early in their implementation and address different levels of the acquisition process, but they reflect the overarching DoD goals of improving decision-making regarding systems-of-systems (SoS) acquisitions to avoid duplication, identify gaps, and decrease costs and development times.

The tools and processes used by acquisition decision-makers to implement CPM and OA policies are not well defined. A fundamental requirement of both CPM and OA approaches is that acquisition managers develop an awareness of related efforts and activities across an enterprise and/or community of interest (COI) to support decision-making regarding duplication of effort, capability gaps, re-use and collaboration opportunities. It is the premise of this paper that development of Program Self-awareness is fundamental to the success of the CPM/OA reform initiatives. This paper applies commercial and government best practices to develop Program Self-awareness through Knowledge Management (KM) methods and tools.

The DoD Maritime Domain Awareness (MDA) Program will be used as a test case for application of KM decision support tools, providing relational views of program elements and attributes—termed "features"—to support informed program decision-making. This thesis asserts that application of KM tools will improve Program Self-awareness and support better decision-making, which is required to realize the full potential of CPM and OA initiatives.

B. Problem Statement and Research Question

The DoD Acquisition System is comprised of numerous stakeholders and organizations that navigate procurement processes in an uncertain environment in order to deliver useful military capability to the warfighter at the best possible value to the government. Acquisition reforms have been largely ineffective at improving the efficiency of the system due, in part, to stovepipe activities that often result in duplication of effort, lack of re-use and collaboration on related development efforts. It is the goal of this thesis to demonstrate the Program Self-awareness concept through application of KM tools to the DoD MDA Program to answer the following research question.

- How can Knowledge Management methodologies and decision support tools be used to improve Program Self-awareness and decision-making that will enable collaboration and re-use in complex DoD acquisition programs?

C. Methodology

The Stanford University Center for Integrated Facility Engineering (CIFE) "Horseshoe" methodology (Figure 1) was used to guide this research (Ho, 2007, p. 2). This research will explore the problem of duplication, lack of re-use, and collaboration in the DoD Acquisition and following the intuition that increased Program Self-awareness—enabled by KM decision support tools—will improve acquisition process efficiencies in these areas. The research will be grounded in Systems Theory and the Congruence Model to develop an understanding of the DoD Acquisition System and to identify root causes of the stated problem. The research will then apply KM tools to the DoD MDA Program as a test case and evaluate the potential benefit of these prototype KM tools to program decision-makers. This work will provide the foundation for future research on the Program Self-awareness concept and development of KM tools with the goal of improving decision-making and enabling re-use and collaboration in the DoD acquisition programs.

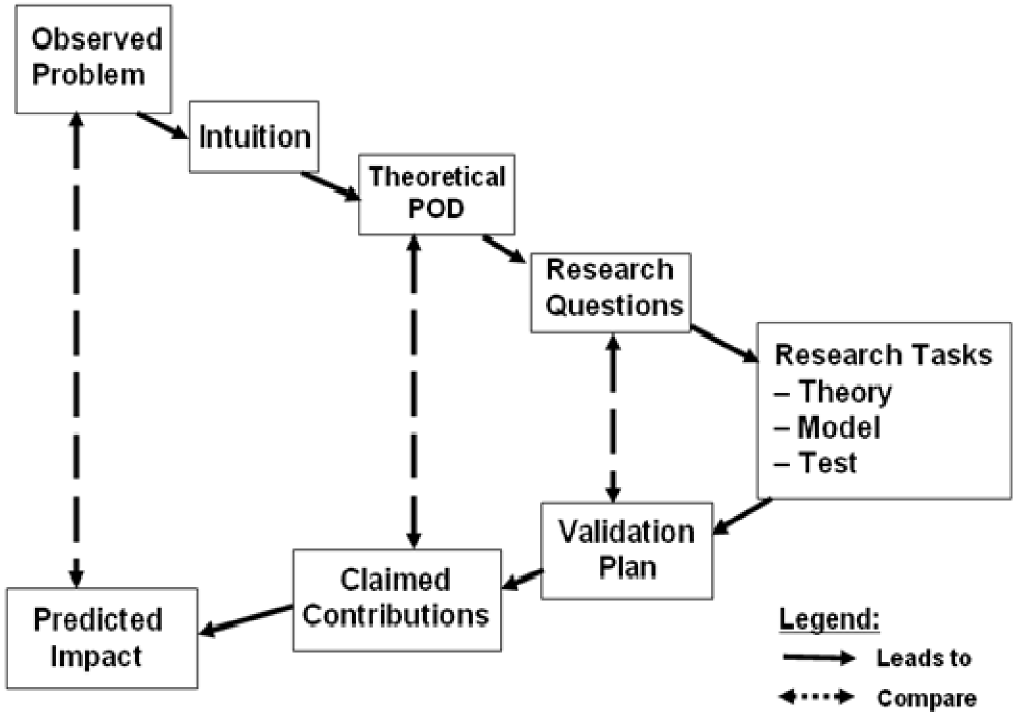

Figure 1. CIFE Research Methodology
(Ho, 2007, p. 2)

D. Scope

This thesis will develop the foundation of the Program Self-awareness concept to support improved decision-making, collaboration, and re-use in the DoD Acquisition. It will apply Systems Theory and Knowledge Management principles and tools developed during the academic and technology review, grounding the Program Self-awareness concept in mature academic concepts and methodologies.

The implementation impact of this research on other organizational components within the DoD Acquisition System (structure, processes, people) are not addressed in depth in this research. Further research will be required to study organizational congruence and cultural issues in order to realize the full benefits of the Program Self-awareness concept.

E. Organization of Thesis

Chapter II will build the academic and technology foundation for the Program Self-awareness concept through a review of Systems Theory and the Congruence Model, the field of Knowledge Management, and trends in the DoD Acquisition environment that lend themselves to application of KM tools. Chapter III will introduce the concept of Program Self-awareness and apply the Congruence Model to describe the DoD Acquisition System. Chapter IV will apply KM tools and methodologies to the DoD MDA Program to identify feature clusters of select MDA technologies to demonstrate the potential for improved Program Self-awareness. Chapter V will provide conclusions and recommendations for future research.

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II. Literature and Technology Review

A. Systems Theory and Organizations

This research explores the potential for change in the DoD Acquisition System through application of KM tools, resulting in improved Program Self-awareness. This section reviews Systems Theory and the Congruence Model to provide a framework to understand the complexity of the DoD Acquisition System described in later parts of this research.

1. The Leavitt Diamond

Organizational change has been discussed in academic work for the past century. In an effort to improve organizational efficiency—through process improvements, structural changes, and new technology—both commercial and government sectors have been avid consumers of newly developed approaches designed to resolve performance issues and challenges in these areas. In order to provide a theoretical foundation for this field of study, organizational theorists applied Systems Theory to model organizational dynamics and affects of change. Developed in the 19th century, Systems Theory was adapted to explore the "similarities in naturally occurring systems and human organizations. In very basic terms, both take input from their surrounding environment, subject it to an internal transformation process, and produce some kind of output" (Mercer Delta, 1998, p. 2). Feedback is then generated to influence the input element of the system, as depicted in Figure 2.

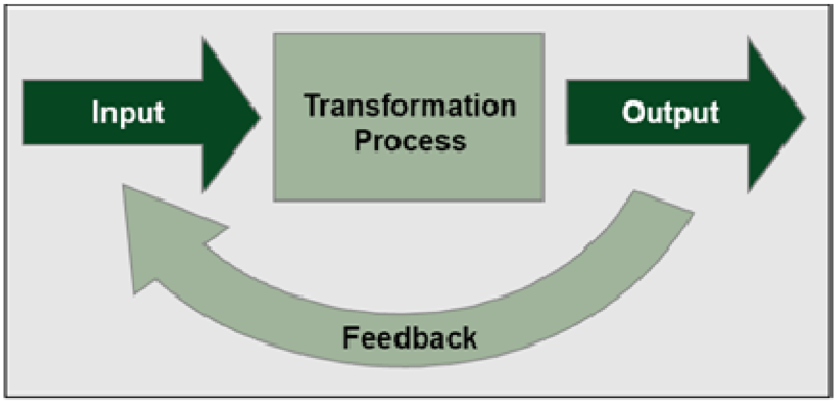

Figure 2. The Basic Systems Model
(Mercer Delta, 1998, p. 3)

One of the most prominent "systems thinkers" to apply systems theory to organizations was Dr. Harold Leavitt. According to Leavitt, "one can view industrial organizations as complex systems in which at least four interacting variables loom especially large; task variables, structural variables, technology variables, and human variables" (Leavitt, 1965, p. 1144). Leavitt defined these primary organizational variables as follows:

- Task: refers to industrial organizations—the production of goods and services, including the large numbers of different, but operationally meaningful, subtasks that may exist in complex organizations.
- Actors: refers chiefly to people, but with the qualification that acts executed by people at some time or place need not remain exclusively in the human domain.
- Technology (Information and Control): refers to direct problem-solving inventions like work-measurement techniques or drill presses.
- Structure: refers to systems of communication, systems of authority, and systems of work. (Leavitt, 1965, p. 1144)

Leavitt further suggested that these variables are highly interdependent and that a change to one will effect corresponding change(s) in one or more of the other variables. The resulting interdependency is perhaps the most significant concept of Leavitt's work in this area since it provides a holistic approach to understanding and problem-solving in an organization. The interdependency proved that continuous efforts to improve system output efficiency through consideration of just one variable are incomplete and often unsuccessful in achieving the desired effects due to unintended effects on the static variable(s). Leavitt provides such an example:

> The introduction of new technological tools—computers, for example—may cause changes in structure (e.g., in the communication system or decision map of the organization), changes in actors (their numbers, skills, attitudes, and activities), and changes in performance or even definition of task, since some tasks may now become feasible for the first time, and others become unnecessary. (Leavitt, 1965, p. 1145)

Leavitt also concluded that organizations must be considered because they share attributes of an open system by existing and being influenced by a dynamic environment that can dramatically influence system variables. Figure 3 captures the Leavitt Diamond with the environmental consideration to provide the holistic view of a complex organization that provides the foundation for this research (Leavitt, 1978, p. 286).

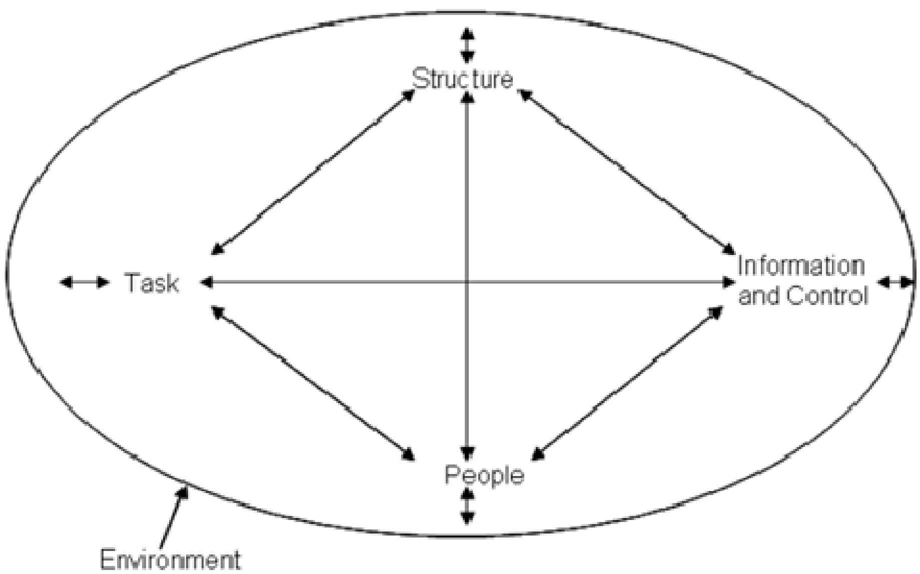

Figure 3. Leavitt Diamond
(Carroll & Sundland, 2008, p. 25)

2. Congruence Model

The work of Leavitt and other “systems thinkers” provided the foundation for subsequent organizational models and diagnostic tools. One such application is the Congruence Model, which builds upon Leavitt’s work to provide a methodology for understanding complex organizations, their environment, and the importance of “fit” among variables (termed “components” in the Congruence Model). Figure 4 provides the key organizational components of the Congruence Model. Another notable difference between the two models is that the Leavitt variable of Technology (Information and Control) is blended into the Process and Informal and Formal Organization components of the Congruence Model. The Congruence Model further refines the variable definitions, with the objective of developing a deeper understanding of the variable elements and attributes—thereby supporting a more detailed understanding of the organization. Despite these differences, the fundamental approach of the Leavitt Diamond and Congruence Model remains the same: complex human organizations are comprised of interdependent components that operate in a dynamic environment.

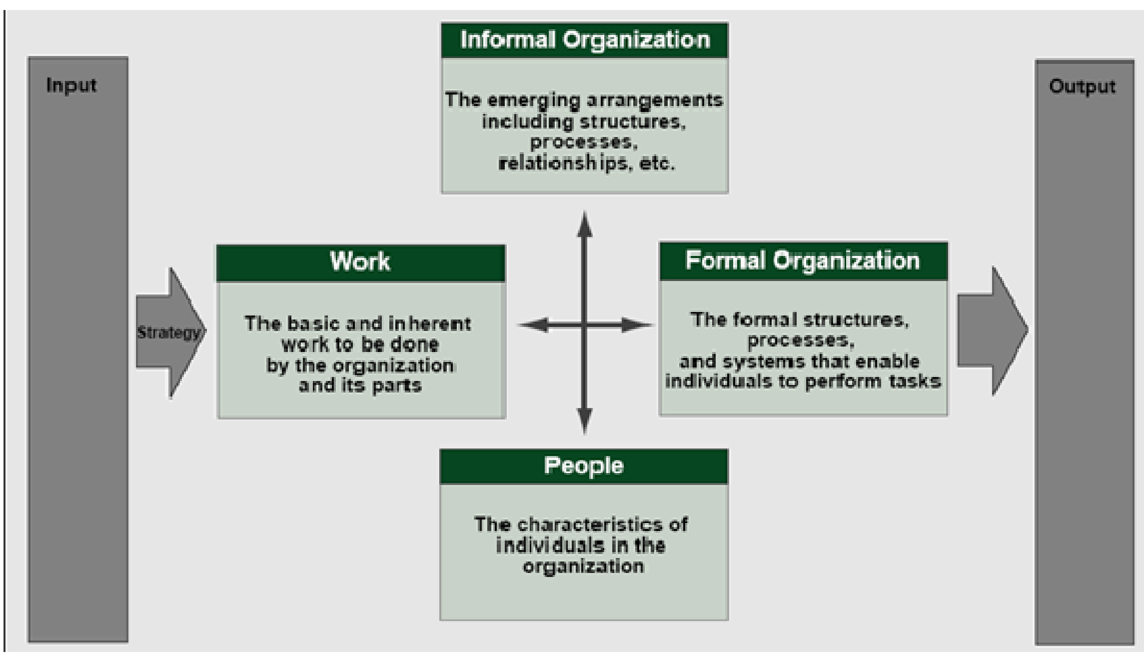

Figure 4. Key Organizational Components
(Mercer Delta, 1998, p. 8)

The Congruence Model suggests this deeper understanding of the entire system can be used to determine "fit" among the components. The concept of "fit" addresses the alignment or congruence of the system variables, which can then be used to address overall system performance issues in the holistic manner suggested by Leavitt. The Congruence Model suggests organizations must perform this comprehensive self-analysis prior to considering major changes to systems variables and/or to addressing changes in the environment. The analysis must result in an understanding of the current and/or anticipated state of "fit" among system components while recognizing that improved congruence will improve overall system performance. Put another way, the model suggests "the interaction between each set of organizational components is more important than the components themselves […]. [T]he degree to which the strategy, work, people, formal organizations, and operating environment are tightly aligned will determine the organization's ability to compete and succeed" (Mercer Delta, 1998, p. 10). Figure 5 depicts the major elements of the Congruence Model.

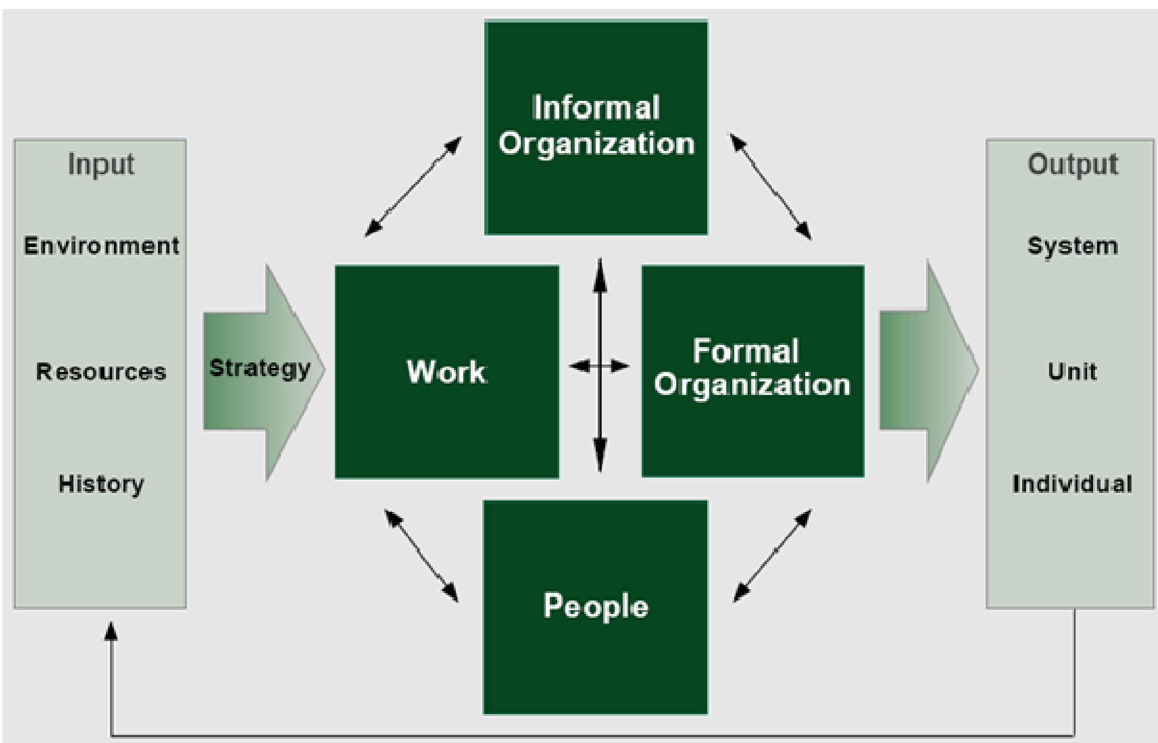

Figure 5. The Congruence Model
(Mercer Delta, 1998, p. 14)

This research focuses on the potential benefit of KM tools to improve “fit” among acquisition system components as a means to achieve improved system output efficiency through implementation of policy objectives such as CPM and OA. The Leavitt Diamond and Congruence Model are useful in this context because they stress the interdependency among variables/components. It is not the purpose or intent of this research to analyze each variable/component in great detail or to suggest corresponding changes in the people, organizations, or processes. Instead, this research suggests that application of KM tools may form a sort of “glue” to improve the fit among components. Subsequent change(s) to other variables (i.e., structure and process) will likely be necessary due to implementation of these technologies. The improved fit among system components will improve overall system performance and efficiency through increased Program Self-awareness. The increase in Program Self-awareness will facilitate improved decision-making, increased collaboration, object re-use, and reduced development timelines.

B. Knowledge Management

The Information Age continues to shape the organizational environment and affect all system components of the Congruence Model. The fundamental power of personal computing, global networking, and collaborative technologies is essential to many organizational processes, enabling increased speed, availability, and volume of data to support decision-making. These technology changes challenge organizational norms and force organizations to perform self-analysis to assess the impact to the “fit” among organizational components (Mercer Delta, 1998, p. 15).

The hazards of automating a bad process or applying technology to outdated organizational structures are common pitfalls in the Information Age. Several organizations, including Xerox, recognized these hazards and applied the Congruence Model to conduct sweeping organizational change. Xerox leveraged technology to achieve improved fit among components in response to a changing environment, resulting in a competitive edge in the integrated document management marketplace (Mercer Delta, 1998, p. 10).

The challenges posed to organizations in the Information Age are many. One such challenge is turning massive amounts of data into pertinent knowledge and leveraging the potential of the network-enabled “informal organizations” to improve decision-making. The study of the dynamics and potential of technology, process, and structure to improve organizational knowledge and decision-making has fueled both academic study and technology research and development under the umbrella term of KM. The formal definitions of KM vary among theorists and field practitioners, but they generally address the common goal of improving how organizations transform data into knowledge that supports decision-making. This research focuses on how KM methodologies and tools can be applied to organizations to improve process, structure, and decision-making. Some relevant definitions of KM include:

> [K]nowledge management is an attitude, not a specific application—a commitment to taking full advantage of all the information at an organization’s disposal and delivering it to the appropriate constituencies to facilitate decision-making at every possible level. (McKellar, 2009. p. 1)

> Knowledge Management definitions span organizational behavioral science, collaboration, content management, and other technologies […]. Knowledge and content management technologies are used to search, organize, and extract value from all of these information sources and are the focus of significant research and development. These technologies include text mining, clustering, taxonomy building, classification, information extraction, and summarization. (Codey, 2002, p. 698)

The application of KM principles to the DoD acquisition was the subject of a research report by military fellows at the Defense Systems Management College (DSMC) in January 2000 titled *Program Management 2000: Know the Way—How Knowledge Management Can Improve DoD Acquisition* (Cho, Hans & Landay, 2000). Figure 6 describes the DSMC researchers’ concept of development of knowledge from data.

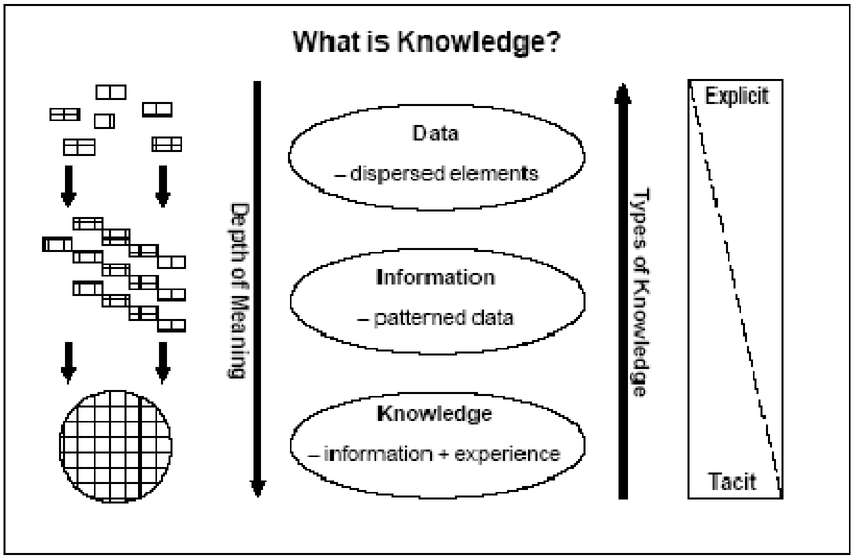

Figure 6. Types of Knowledge
(Cho et al., 2000, p. 2-4)

The DSMC researchers draw the following conclusions relevant to this research:

- The commercial sector is successfully adopting KM strategies to achieve competitive advantage.
- The implementation of KM technologies in an organization must consider impacts on its people, processes, and structure to be successful.
- KM initiatives require culture change and must have the full support of the leadership to be successful.
- Mangers who effectively used their company's knowledge were able to overcome knowledge-based barriers and institutional stovepipes to improve collaboration and customer relationships, as described in Figure 7.

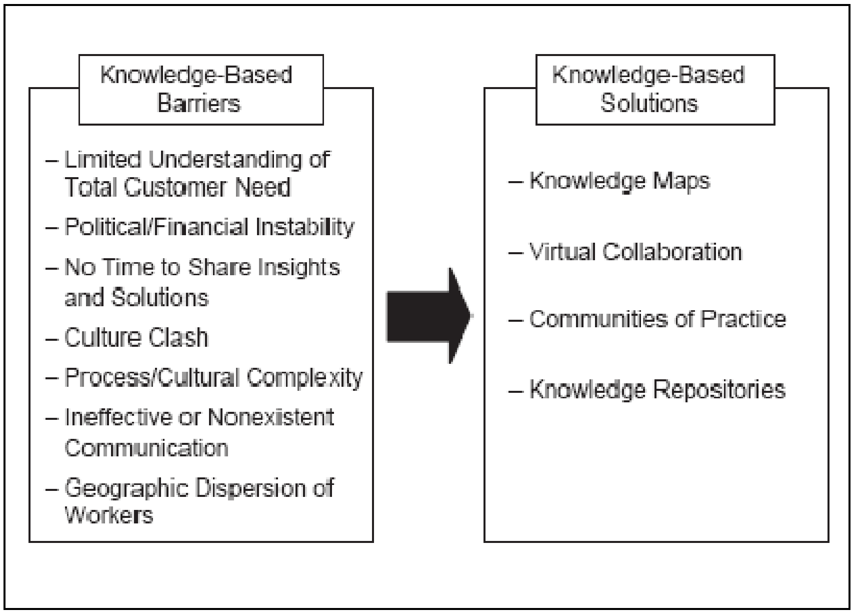

Figure 7. Knowledge-based Barriers and Solutions
(Cho et al., 2000, p. 2-7)

- KM is a source of organizational and economic value.
- Communities of Practice or Interest (COP/COI) are forums of networked people with similar interests and issues that gather to address problems, provide solutions, share ideas, and build communication links. COI development provides the foundation for KM implementation.
- KM implementation should be an incremental process built on small successes. Figure 8 depicts the KM Framework as a continuum to capture this point.

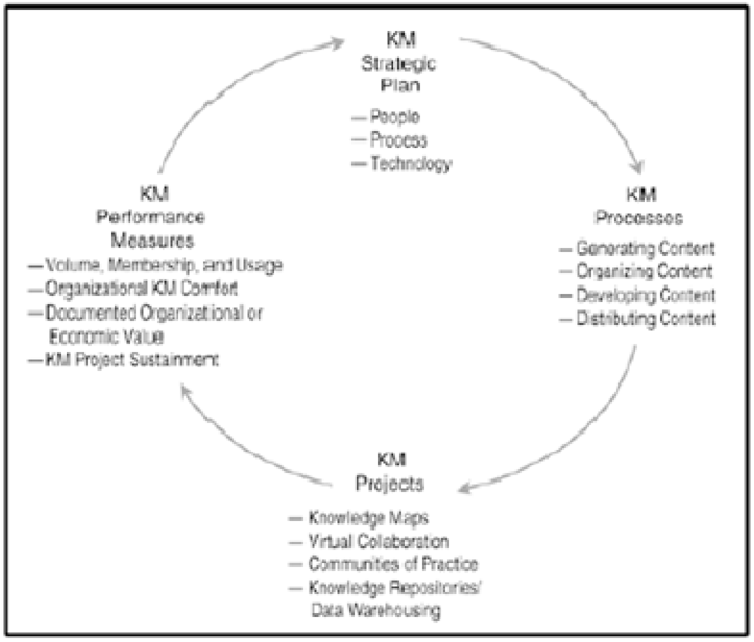

Figure 8. KM Framework
(Cho et al., 2000, p. 2-7).

Cho et al. (2000) make a compelling case for adopting KM concepts, tools and strategy in the DoD Acquisition System. This research will apply KM tools to specific acquisition problems that may lead to the "small success" that Cho et al. suggest is vital to foster widespread KM adoption in the DoD acquisition.

C. Business Intelligence (BI)

The KM field has a close cousin in the emerging field of Business Intelligence (BI). BI captures a powerful set of concepts and tools that are being employed with great success across a range of organizations in the commercial and government sectors. BI can be defined as "an umbrella term that includes architectures, tools, databases, applications and methodologies […] to help decision makers get valuable insights upon which they can base more informed and better decisions […]. The Process of BI is based on the transformation of data to information, then to decisions, and finally to actions" (Turban, Shardra, Aronson & King, 2008, p. 9). Figure 9 describes the many tools and methodologies that comprise the BI field.

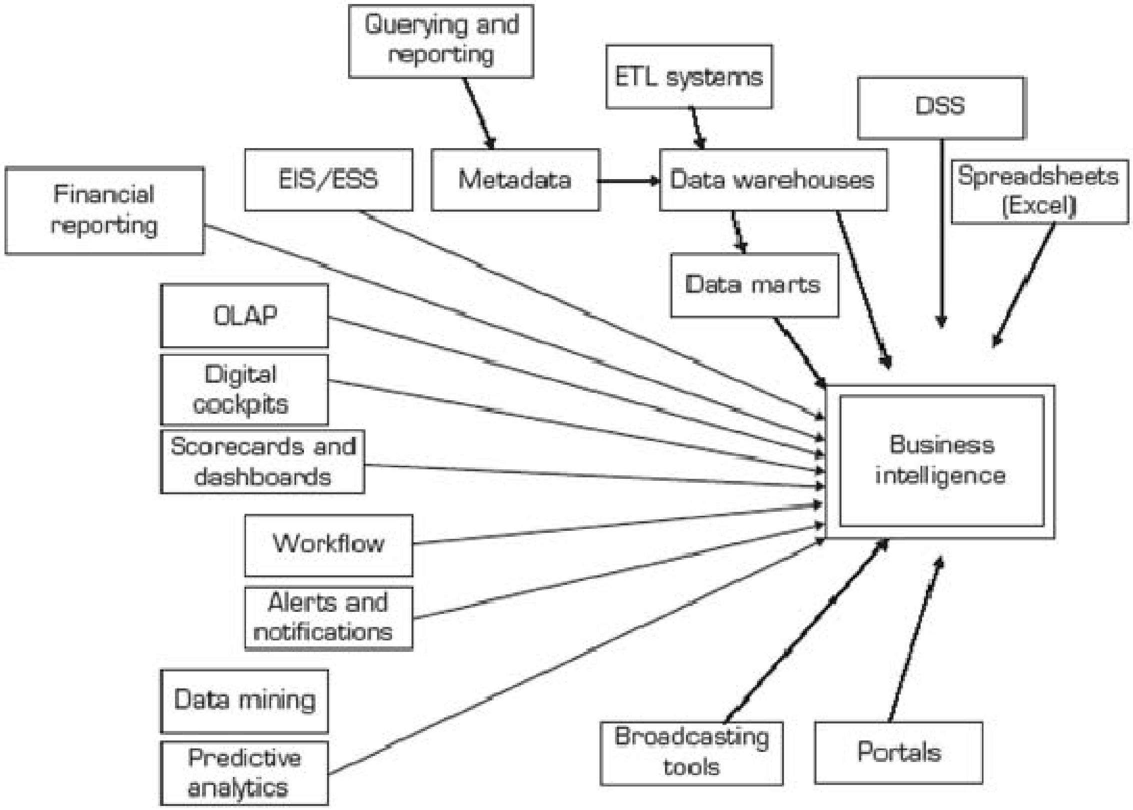

Figure 9. Evolution of BI
(Turban et al., 2008, p. 10)

BI draws upon the power of computing and networking to provide decision-makers the right information at the right time in an environment that increasingly produces massive amounts of often uncorrelated data. The following summary data from a survey of more than 500 companies that employed BI highlights the potential benefits relevant to the DoD acquisition:

- Time savings (61%),
- Single version of truth (59%),
- Improved strategies and plans (57%),
- Improved tactical decisions (56%),
- More efficient processes (55%), and
- Cost savings (37%). (Turban et al., 2008, p. 15)

D. KM and BI Tools

KM and BI share tools and methodologies that transform data into information and knowledge, respectively. The tools relevant to this research are detailed below.

1. Data and Text Mining

The DoD acquisition programs generate massive amounts of documentation during all phases of the development process, including text documents, spreadsheets, structured relational databases, etc. The amount of data and text contained in these documents is staggering but has the potential for applying data and text mining techniques to derive useful information from seemingly unrelated data.

Data mining is a "class of information analysis based on databases that looks for hidden patterns in a collection of data, which can be used to predict future behavior. Data mining software does not just change the presentation, but actually discovers previously unknown relationships among the data" (Turban et al., 2008, p. 13).

Text mining is "the application of data mining to non-structured or less structured text files, which entails the generation of meaningful numeric indices from the unstructured text and then processing those indices using various data mining algorithms" (Turban et al., 2008, p. 224).

This research applies certain data and text mining techniques to the DoD MDA Program in an effort to demonstrate the potential for increased Program Self-awareness to support improved programmatic decision-making.

2. Data Warehouses and Data Marts

Data mining techniques require that a set of data be defined such that the various data mining algorithms can be applied and subsequent analysis be performed. This set of data is termed a data warehouse or data mart. A data warehouse is a "physical repository where relational data are specifically organized to provide enterprise-wide, cleansed data in a standardized format" (Turban et al., 2008, p. 223). A data mart can be considered a subset of a data warehouse, which can be used to support a functional area, department, or community of interest (p. 222). These terms will be used interchangeably for the purposes of this research.

The development of data warehouses into the structured form required to support data mining is not a trivial process. The data warehouse needs to be developed to support the functional area and include fundamental characteristics: subject oriented, integrated, time-variant, and nonvolatile. The data warehouse may also be developed to include the following capabilities: web-based, relational/multi-dimensional, client/server, and metadata (data about data) inclusion (Turban et al., 2008, pp. 39-40).

Text mining, on the other hand, is focused on developing new meanings and relationships from unstructured data in the form of documents (e.g., memos, e-mails, instructions, policies, etc.) to support decision-making. The set of documents required to support text mining varies in type and structure, providing more flexibility in formulation compared to data warehouse development. The additional benefit of text mining is the amount of information available in a form ready for processing, which includes upwards of 80% of the data a typical organization collects. Text mining algorithms are also complex and typically involve the following steps:

1. Eliminate commonly used words (the, and, other);
2. Replace words with their stems or roots (e.g., eliminate plurals, and various conjugations and declarations);
3. Consider synonyms or phrases (e.g., student and pupil may be grouped);
4. Calculate the weight of the remaining terms (based on frequency of occurrence in a document or set of documents). (Turban et al., 2008, pp. 159-160)

3. Analytics and Visualization

The development of data described above supports its transformation to information and knowledge through the process of analytics and visualization. Analytics includes a broad range of capabilities and sub-elements described in Figure 10 and can be defined as a “category of applications and techniques for gathering, storing, analyzing, and providing access to data to help enterprise users make better business and strategic decisions” (Turban et al., 2008, p. 86). This research will apply several analytical applications, including data mining, text mining and visualization techniques to discover relationships among program “features” to support decision-making regarding duplication of effort, gaps, re-use, and collaboration opportunities in the DoD MDA program. For the purposes of this research, a feature is a marketable behavior or property of a system ideally documented in a design—such as the power window feature on modern automobiles.

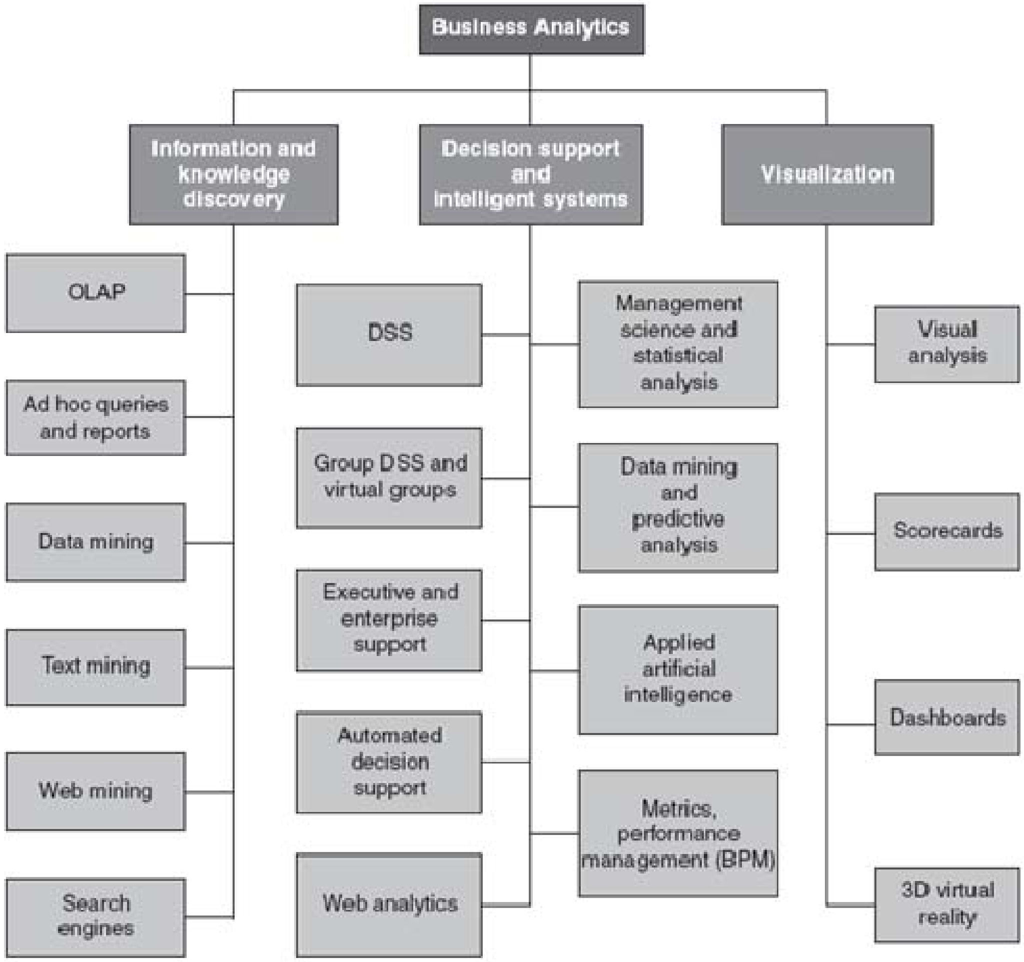

Figure 10. Categories of Business Analytics
(Turban et al., 2008, p. 88)

E. Collaboration

This research has repeatedly identified the importance of collaboration to support KM implementation. The DSMC study heavily emphasized the link between KM success and the organization's culture of information sharing and collaboration. DSMC researchers also concluded that a typical DoD acquisition program performs very little collaboration across different programs other than informal networks of functional area associates formed at the same physical location. When development teams were asked how often they go outside their program organization to seek knowledge about problems, the most frequent response was "rarely, if ever." The researchers found it is not that the teams do not recognize the potential power of collaboration, but they just "don't know who else is working on similar issues or don't see any connection between their project and another one in a different area" (Cho et al., 2000, p. 1-4). This finding is not surprising given the size of the DoD acquisition enterprise, the lack of enterprise collaboration and KM tools, and stovepipe organizational structures that do not support a culture of information sharing.

Despite these organizational and cultural challenges, the proliferation of networking technologies has penetrated the DoD acquisition environment. Several collaboration and knowledge-sharing initiatives have emerged in the past decade that may represent the early stages of a move towards greater collaboration in the DoD acquisition:

- **FORCEnet Innovation & Research Enterprise (FIRE)**

  Developed by the Naval Postgraduate School (NPS), FIRE is an enterprise information system designed to support Navy and Joint Experimentation. FIRE employs the latest web collaboration technologies to provide information archiving, document sharing, e-mail, and web conferencing capabilities to geographically dispersed experimentation teams supporting a wide range of RDT&E activities.

- **DoD Techipedia**

  Developed by the Defense Technical Information Center (DTIC), DoD Techipedia is a scientific and technical wiki designed to increase communication and collaboration among the DoD scientists, engineers, program managers and operational warfighters. This tool will enable the DoD personnel to collaborate on technological solutions, reduce costs, add capability and avoid duplication. DoD Techipedia will aid in the rapid development of technology and the discovery of innovative solutions to meet critical capability needs and gaps (DTIC, 2009).

- **Software Hardware Asset Reuse Enterprise (SHARE) Repository**

  Developed by the Navy Program Executive Office of Integrated Warfare Systems (PEO-IWS) and Naval Surface Warfare Center (NSWC), the SHARE Repository serves as a library of ship combat system software and related assets for use by eligible contractors (both prime contractors and subcontractors) for developing or suggesting improvements to Navy Surface Warfare Systems. SHARE fosters enterprise collaboration to support asset re-use and Navy OA principles. (Johnson & Blais, 2008, p. 1)

- **AT&L (Acquisition, Technology & Logistics) Knowledge Sharing System (AKSS)**

  Developed by the Defense Acquisition University (DAU), AKSS provides acquisition information for all the DoD service components and across all functional disciplines. AKSS serves as the central point of access for all AT&L resources and information and to communicate acquisition reform. As the primary reference tool for the Defense AT&L workforce, it provides a means to link together information and reference assets from various disciplines into an integrated, but decentralized, information source. (DAU, 2009)

In recognition of the imperative and potential power of collaboration to support the complex DoD Acquisition System, KM and acquisition experts at the NPS (Thomas, Hocevar & Jansen, 2006) studied collaboration in the most complex DoD and Interagency acquisitions to develop a "collaborative capacity" assessment tool. Figure 11 depicts the Collaborative Capacity Model developed by the NPS researchers. The notion that collective Self-awareness is integral to the success of solving a common problem can be derived from this model. It can also be inferred from the model that collaboration is the glue used to bond stovepiped organizations together to solve a common problem.

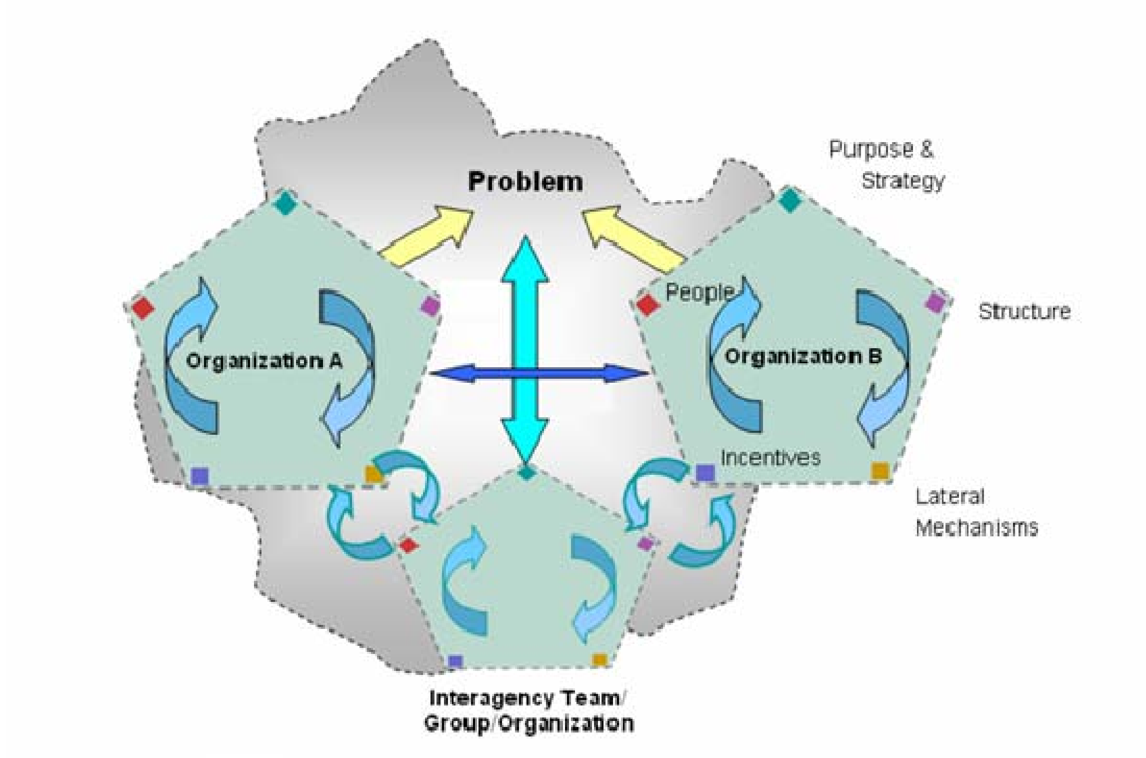

Figure 11. Collaborative Capacity Model
(Thomas et al., 2006, p. 7)

The NPS findings reinforce the work of the DMSC fellows and highlights recent policy emphasis on collaboration to support implementation of best business practices. The NPS research also suggests that collaboration in complex interagency acquisition programs is a function of the success and barrier factors described in Table 1.

Table 1. Factors Affecting Inter-organizational Collaboration (Thomas et al., 2006, p. 2)

Organization design component	*"Success" factors that contribute to collaborative capacity*	*"Barriers" that inhibit collaborative capacity*
Purpose & strategy	- "Felt need" to collaborate - Common goal or recognized interdependence - Adaptable to interests of other organizations	- Divergent goals - Focus on local organization over cross-agency (e.g., regional) concerns - Lack of goal clarity - Not adaptable to interests of other organizations
Structure	- Formalized coordination committee or liaison roles - Sufficient authority of participants	- Impeding rules or policies - Inadequate authority of participants - Inadequate resources - Lack of accountability - Lack of formal roles or procedures for managing collaboration
Lateral mechanisms	- Social capital (i.e., interpersonal networks) - Effective communication and information exchange - Technical interoperability	- Lack of familiarity with other organizations - Inadequate communication and information sharing (distrust)
Incentives	- Collaboration as a prerequisite for funding or resources - Leadership support and commitment - Absence of competitive rivalries - Acknowledged benefits of collaboration (e.g., shared resources)	- Competition for resources - Territoriality - Organization-level distrust - Lack of mutual respect - Apathy
People	- Appreciation of others' perspectives - Competencies for collaboration - Trust - Commitment and motivation	- Lack of competency - Arrogance, hostility, animosity

F. The DoD Acquisition Initiatives

Two of the DoD acquisition policy changes relevant to this research are the adoption of Open Architecture (OA) approaches and Capability Portfolio Management (CPM). Both OA and CPM are relatively young in their implementation and address different levels of the acquisition process, but they share the common goal of improving the DoD decision-making regarding systems-of-systems (SoS) acquisitions to avoid duplication, reduce costs, and decrease development times.

1. Open Architecture

The emphasis on open systems architecture (OA) has increased over the past decade, with OA now being recognized as an integral part of the DoD systems engineering and acquisition processes. OA is not a new concept; it draws from engineering design principles that have shaped mature industries for many decades. The modern automobile is an example of OA design principles, as it supports integration of thousands of its components through what can be viewed as an SoS design. This OA design allows most components to be built by numerous manufacturers to a standard interface specification, such as tires built by numerous manufacturers that can fit onto the wheel of a wide range of vehicles while providing different levels of performance. The OA approach is very attractive in the context of the DoD acquisition, as it offers potential for decreased development timelines and reduced costs through re-use of components in system-of-systems acquisitions. OA designs also support quick upgrades and modifications, removing the requirement to redesign other components or entire systems. The application of OA to the design of software-intensive systems has been the focus of early OA initiatives, including the Navy PEO-IWS Software Hardware Asset Reuse Enterprise (SHARE) Repository mentioned above (Johnson & Blais, 2008, p. 1).

The Navy PEO-IWS has provided the most visible leadership in developing OA principles, concepts, and tools for the DoD acquisition community. The Navy has also adopted policies that mandate application of OA design in all SoS acquisitions and that define OA and core principles as the following: “Naval Open Architecture is the confluence of business and technical practices yielding modular, interoperable systems that adhere to open standards with published interfaces” (Shannon, 2007, p. 2).

Naval OA principles include:

- Building modular designs and disclosing data to permit evolutionary designs, technology insertion, competitive innovation, and alternative competitive approaches from multiple qualified sources.
- Building interoperable, joint warfighting applications and ensuring secure information exchange using common services (e.g., common time reference), common warfighting applications (e.g., track manager) and information assurance as intrinsic design elements.
- Identifying or developing reusable application software selected through open competition of “best of breed” candidates, reviewed by subject-matter expert peers and based on data-driven analysis and experimentation to meet operational requirements. (Brummett & Finney, 2008, p. 20)
- Encourage competition and collaboration through the development of alternative solutions and sources. (Shannon, 2007, p. 2).

The increased emphasis on OA has resulted in several initiatives to establish common technical and architectural standards that will promote increased re-use and interoperability for OA systems, including the SHARE repository. These efforts are critical to the success of the DoD OA implementation and require continued development of common vocabularies and collaboration tools. The availability of such data will facilitate users’ and PMs’ discovery of related efforts and potential re-use opportunities. The imperative of collaboration in the Naval OA implementation is detailed in Figure 12, taken from a 2007 PEO-IWS presentation.

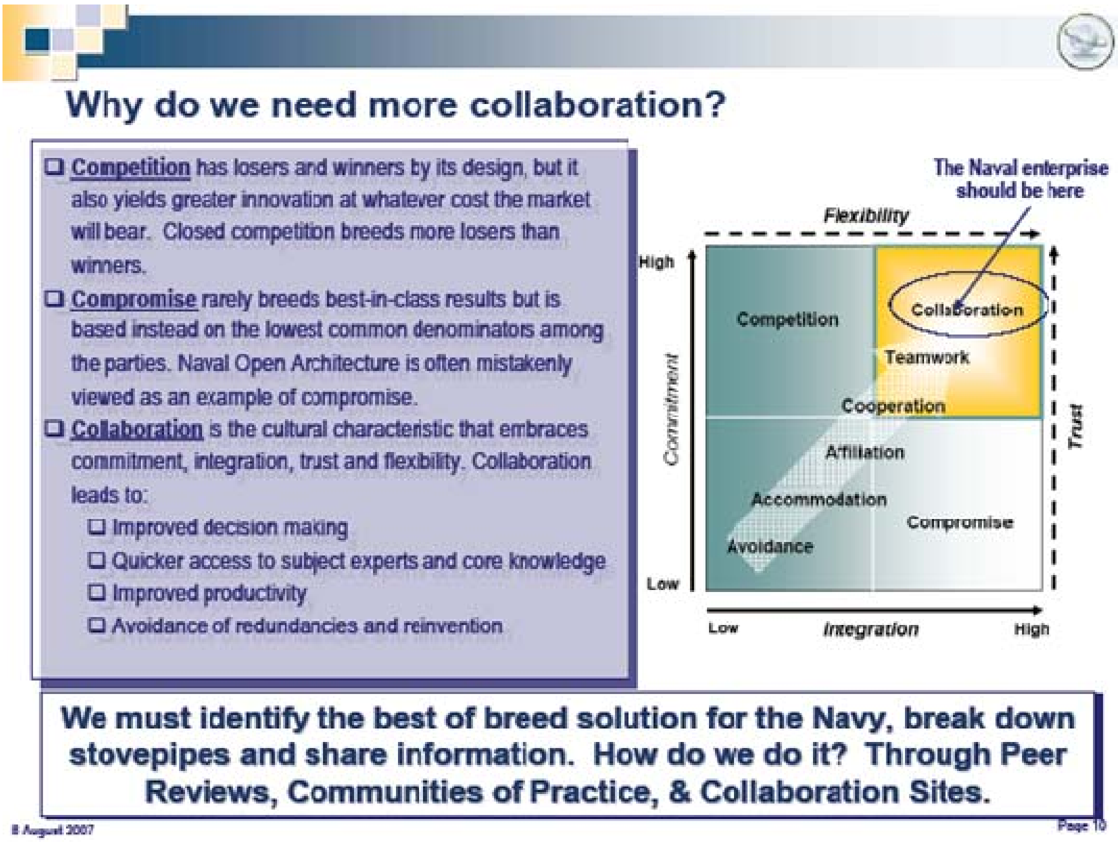

Figure 12. Naval Open Architecture Collaboration
(Shannon, 2007, p. 10)

Another important aspect of OA implementation is developing supporting information architectures with a common vocabulary. If the vocabulary is common, it can describe similar system features to enable acquisition program managers to correlate program attributes across the range of supporting the DoD RDT&E and acquisition programs and activities. The current process used by Program Managers and Systems Engineers to develop awareness of related RDT&E efforts to identify potential re-use and collaboration opportunities is not well defined and dramatically limits the potential advantages of OA acquisitions.

A fundamental requirement of OA is that acquisition managers develop an awareness of related efforts and activities across an enterprise and/or community of interest to support decision-making regarding duplication of effort, capability gaps, re-use and collaboration opportunities. Development of Program Self-awareness is fundamental to the success of OA policy initiatives.

2. Capability Portfolio Management (CPM)

In 2006, the Deputy Secretary of Defense released a memorandum to introduce the Capability Portfolio Management (CPM) approach to the DoD Acquisition. The intent of exploring the CPM approach was to

> manage groups of like capabilities across the (DoD) enterprise to improve interoperability, minimize capability redundancies and gaps, and maximize capabilities effectiveness. Joint capability portfolios will allow the Department to shift to an output-focused model that enables progress to be measured from strategy to outcomes. Delivering needed capabilities to the joint warfighter more rapidly and efficiently is the ultimate criterion for the success of this effort. (England, 2006, p.1)

The initial implementation of CPM included the establishment of four capability area test cases (i.e., Joint Command and Control, Joint Net Centric Operations, Battlespace Awareness, Joint Logistics) to evaluate the CPM approach with the long-term goal of achieving broader implementation in the 2009-2013 timeframe. CPM goals, objectives, and guidance emphasized the importance of system-of-systems engineering approaches and “data transparency”:

> test case managers—in conjunction with existing data management stewards and the Institutional Reform and Governance effort—should work together to establish an approach (business rules, data structure changes, knowledge management tools) that will strengthen the linkage of authoritative information to capabilities without compromising information flexibility. (England, 2006, Attachment A, p. 4)

CPM implementation was further directed across the DoD acquisition enterprise in 2008 and linked to all nine Tier 1 Joint Capability Areas (JCA). The new policy detailed CPM integration and alignment with the existing DoD acquisition structures and processes to achieve widespread implementation (England, 2008, p.1). The definition of CPM was refined to “the process of integrating, synchronizing, and coordinating Department of Defense capabilities needs with current and planned

DOTMLPF investments within a capability portfolio to better inform decision making and optimize defense resources" (England, 2008, Glossary, p. 8).

The CPM approach is relevant to this research because it is grounded in improving acquisition decision-making, reducing duplication of effort and identifying capability gaps. The emphasis on development supporting data structures, KM tools, and implied expectation of expanded collaboration provide a clear link between the DoD policy and this research. KM tools directly support CPM decision-making at multiple levels of acquisition—as will be demonstrated with the DoD MDA Program—to identify relationships among a portfolio of system features.

III. Program Self-awareness

A. Program Self-awareness

This research defines Program Self-awareness as the collective and integrated understanding of program attributes (i.e., system technology features, R&D activities, etc.) and their surrounding environment by program decision-makers (i.e., program managers, system engineers, sponsors). Program Self-awareness is fundamental to reform initiatives such as OA and CPM because it enables decision-makers to recognize relationships among program attributes and seize collaboration and re-use opportunities to support cost-effective acquisitions.

Achieving Program Self-awareness in complex acquisition programs such as the DoD MDA program described in Chapter IV is a lofty goal considering the myriad stakeholders, processes, people, activities, and organizational structures involved. This research will highlight the potential of KM tools to provide an incremental improvement in Program Self-awareness. Figure 13 represents what Program Self-awareness embodies in the MDA COI.

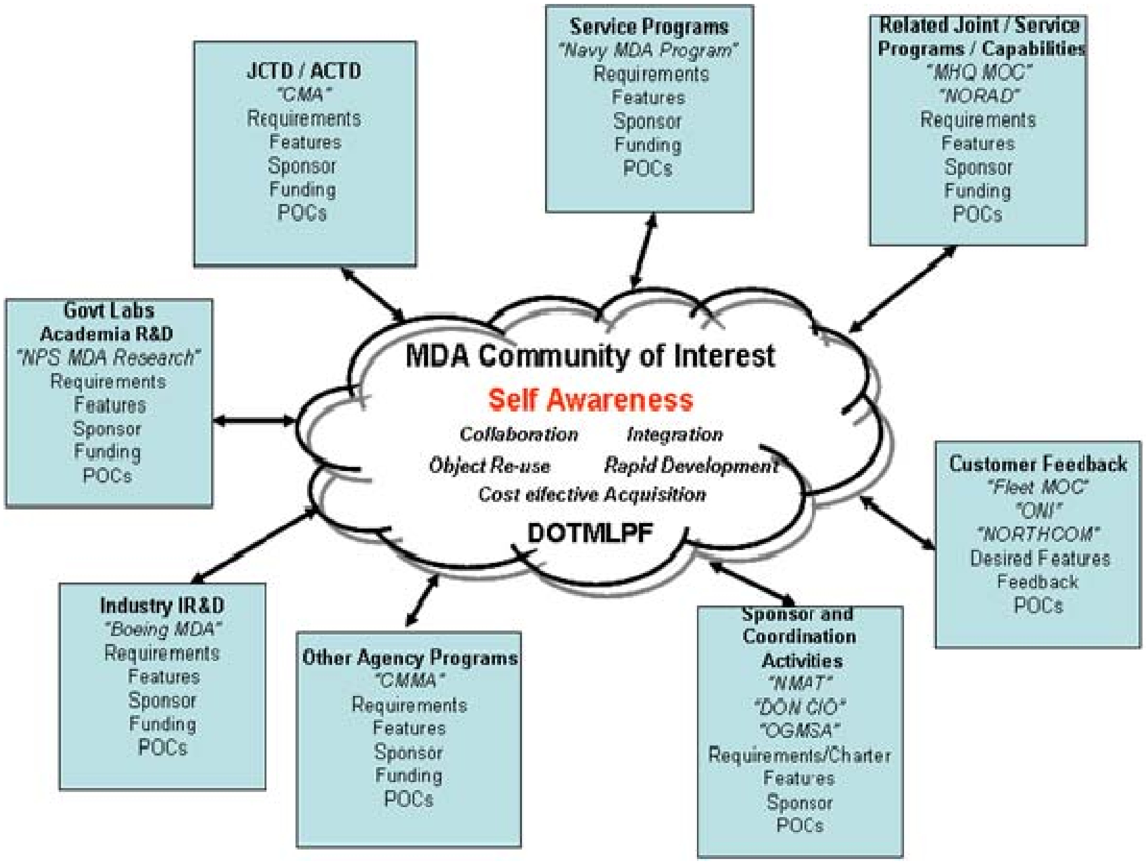

Figure 13. MDA Program Self-awareness
(From Gallup & MacKinnon, 2008)

This research suggests that the DoD acquisition decision-makers could benefit from applying KM tools—such as data and text mining, in structured and unstructured program data sources hosted in a COI data mart—to discover relationships among program elements (i.e., requirements, system features, activities). These previously uncorrelated relationships could lead to increased collaboration within and across programs and to improved COI Program Self-awareness and integration of acquisition system components. The Program Self-awareness KM methodology applied in this research to the DoD MDA COI is depicted in Figure 14.

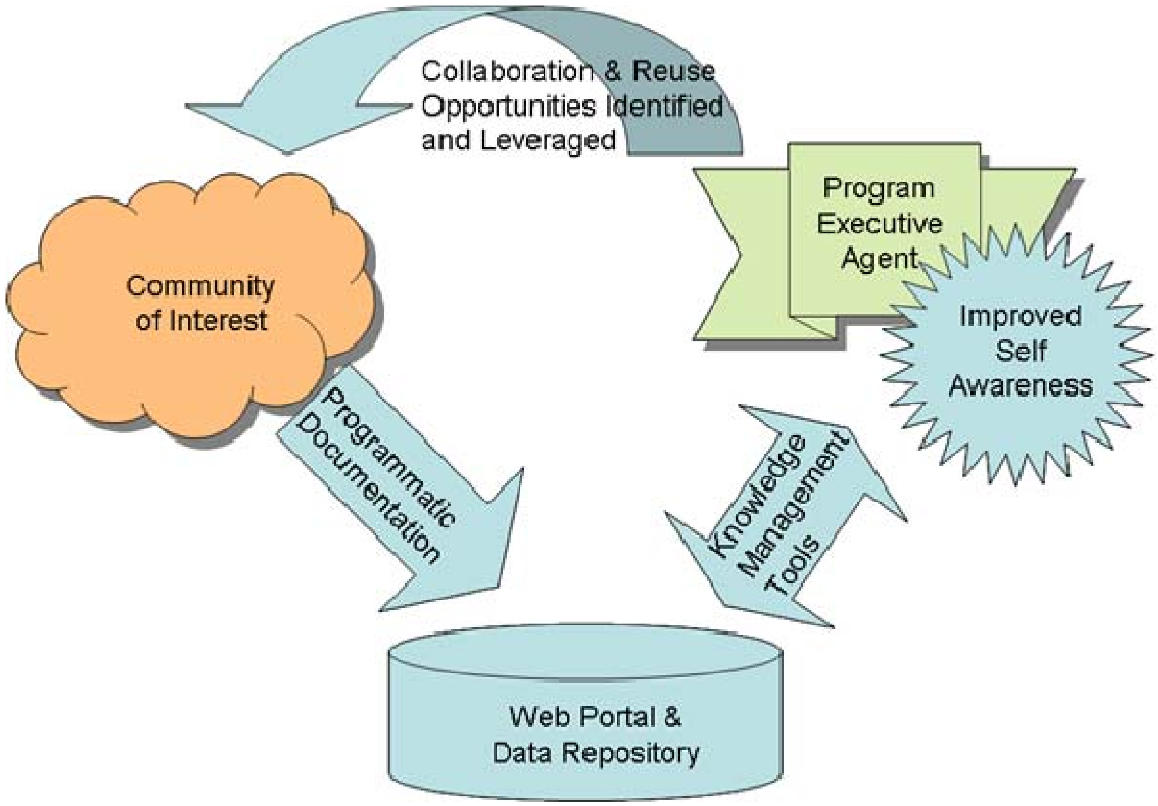

Figure 14. Program Self-awareness KM Process

B. The DoD Acquisition System

The DoD Acquisition System is inherently complex due to the processes, people (stakeholders), and informal/formal organizations that exist to develop, procure, and sustain military capability. This research does not seek to examine the DoD Acquisition System in great detail to identify major processes, organization, or technology problems that contribute to inefficiencies. Therefore, it is beyond the scope of this research to provide a detailed explanation of the DoD Acquisition System and surrounding environment. It is useful, however, to describe the major components of the DoD Acquisition System to demonstrate the potential benefits of technology—namely KM tools and collaboration—to improve the fit among system components.

The primary processes that comprise the DoD Acquisition organization and work elements are the Joint Capabilities Integration and Development System, Defense Acquisition System, and the Planning, Programming, Budgeting Execution process. A detailed explanation of each of the DoD Acquisition Decision Support System elements is provided at the Defense Acquisition Guidebook website (https://akss.dau.mil/dag/) to compliment the overview provided below (DoD, 2006, pp. 1-2).

- Joint Capabilities Integration and Development System (JCIDS): The systematic method established by the Joint Chiefs of Staff for assessing gaps in military joint warfighting capabilities and recommending solutions to resolve these gaps. (pp. 1-2)

JCIDS is designed to be event-driven to address emerging joint warfighting requirements and priorities derived from Combatant Commander (COCOM) operational needs. JCIDS is also designed to stimulate Science and Technology (S&T) and RDT&E in industry, government, and academia.

- Defense Acquisition System (DAS): The management process by which the Department acquires weapon systems and automated information systems. Although the system is based on centralized policies and principles, it allows for decentralized and streamlined execution of acquisition activities. (2006, pp. 1-2)

The DAS is managed by civil and military government acquisition officials who comprise Program Executive Offices (PEO) and Program Management (PM) Staffs and Integrated Product Teams (IPTs). The DAS is designed to be event-driven, especially in the system development phase, but is greatly influenced by the calendar-driven nature of the PPBE funding process.

- Planning, Programming, Budgeting and Execution (PPBE) Process: The Department's strategic planning, program development, and resource Determination process. The PPBE process is used to craft plans and programs that satisfy the demands of the National Security Strategy within resource constraints. (pp. 1-2)

The PPBE process is calendar-driven to meet FY budget cycle timelines mandated by law and is largely controlled by the legislative and executive branches (pp. 1-2).

These three systems, as illustrated in Figure 15, are designed to provide an integrated approach to strategic planning, identification of needs for military capabilities, systems acquisition, and program and budget development (DoD, 2006, pp. 1-2).

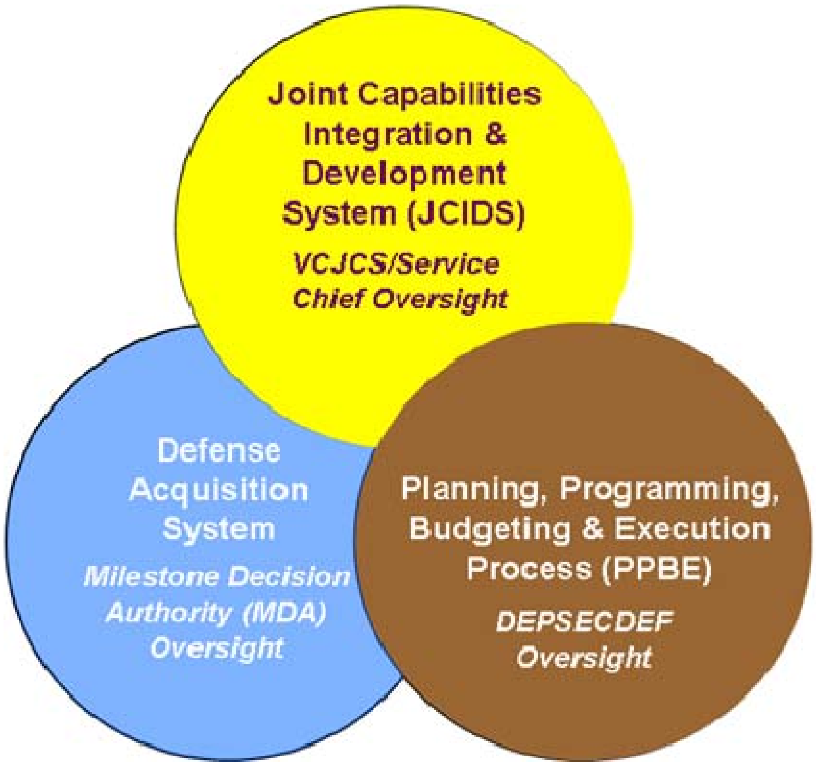

Figure 15. Acquisition Decision Support Systems
(DoD, 2006, p. 2)

The decision support systems described above are supported by a complex array of processes and organizations in government, academia, and industry. An explanation of these supporting processes and organizations is quite extensive and is available through the DoD acquisition workforce training material developed by the Defense Acquisition University and hosted on the AT&L Knowledge Sharing System (AKSS) website (https://akss.dau.mil/default.asp). For the purpose of this research, the subordinate processes and organizations of the decision support systems highlight another level of complexity in the DoD Acquisition System.

In terms of system congruence, the fit among these major system processes and numerous supporting organizations has been the subject of a series of GAO reports. The GAO has been critical of the effectiveness of these systems in performing the core functions of identifying joint warfighting requirements, controlling and forecasting costs and schedules, and reducing duplication in the portfolio of existing and planned systems. The GAO suggests that the DoD "lacks an effective, integrated approach to balance its weapon system investments with available resources" and that capability needs are still largely determined by the individual services and programs that lack joint perspectives, resulting in duplicative and stovepiped solutions (GAO, 2008, September, pp. 2-3).

Secretary Gates has been openly critical of the effectiveness of the acquisition system in these areas, noting that while "operations had become better integrated across the services, budget and procurement decisions were still largely separate, and sometimes duplicative" (Shalal-Esa, 2009, January 27, p. 1). In a recent speech at the Marine War College, Secretary Gates asked the following questions regarding future acquisition reform: "How do you move toward more effective management of our systems? How do you move from joint operations to greater joint procurement?" (McMichael, 2009, April 13, p. 1).

Given these documented system inefficiencies and the observed lack of collaboration across acquisition programs discussed in Chapter II, this research suggests that poor fit among the major components of the DoD Acquisition System is one root cause of system inefficiencies that lead to duplication of effort and limited re-use of components. The consequences of these inefficiencies and lack of Program Self-awareness are increased acquisition costs, delayed and lengthy development schedules, and reduced capability available to the warfighter.

This research suggests that the DoD acquisition decision-makers could benefit from application of KM tools such as data and text mining to structured and unstructured data sources hosted in a COI data mart to discover relationships among program elements (i.e., requirements, system features, activities). These previously uncorrelated relationships could lead to increased collaboration across programs, improved COI Program Self-awareness and integration of acquisition system components. Figure 16 applies the Congruence Model to the DoD Acquisition System to highlight the system complexity, area of poor fit among components, and area of opportunity for application of KM tools, collaboration and increased Program Self-awareness.

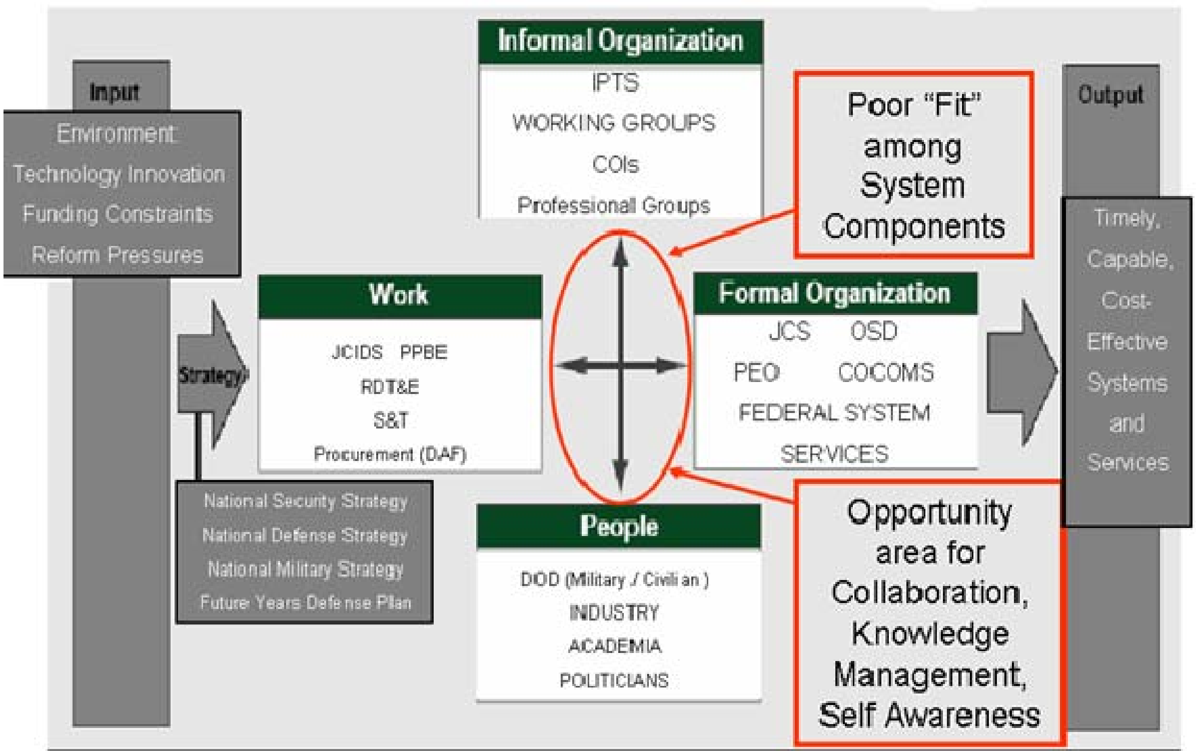

Figure 16. The Congruence Model Applied to the DoD Acquisition System
(Mercer Delta, 1998, p. 14)

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IV. An Application of Program Self-awareness

A. MDA Program Overview

This thesis will use the Maritime Domain Awareness Program as a test case to qualitatively analyze the utility of KM tools to improve Program Self-awareness. MDA, though having its roots in traditional operational intelligence, emphasizes understanding the maritime environment in all its facets. There has been a litany of directives, instructions, and strategies written to define and structure this effort. The following is an overview of the program genesis.

National Security Presidential Directive 41 (NSPD-41) and *Homeland Security Presidential Directive 13* (HSPD-13), signed in December 2004, define the Maritime Domain as “all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances” (POTUS, 2004). NSPD-41 laid the foundation for MDA by setting the following goal: “Maximizing awareness of security issues in the Maritime Domain in order to support U.S. forces and improve United States Government actions in response to identified threats” (POTUS, 2004). NSPD-41/HSPD-13 also establishes a Maritime Security Policy Coordinating Committee (MSPCC) to oversee the development of a National Strategy for Maritime Security and eight supporting implementation plans (POTUS, 2004, pp. 2-3).

The National Plan to Achieve MDA, signed in October 2005, identifies the many threats that face the US within the maritime domain. The *National Plan* aims to persistently monitor, collect, fuse, analyze and disseminate, and maintain data on vessels and craft, cargo, crews and passengers, and other identified areas of interest. These tasks form the basis for an “effective understanding of anything associated with the Maritime Domain that could impact the security, safety, economy, or environment of the United States and [for] identifying threats as early and as distant from our shores as possible” (MSPCC, 2005, pp. 1).

The Secretary of the Navy (SECNAV) directed in a May 2007 memorandum that a prototype MDA capability be fielded by August 2008. This document also appointed the Deputy Chief of Naval Operations for Communication Networks (N6) and Deputy Under Secretary of the Navy (DUSN) as co-chairs of a Cross Functional Team (CFT) to oversee prototype development. The Assistant Secretary of the Navy for Research, Development, & Acquisition (ASN RDA) appointed Space and Naval Warfare Center's (SPAWAR) Program Executive Office for Command, Control, Communications, Computers and Intelligence (PEO C4I) as the Acquisition Lead for delivery of the Navy MDA Prototype. The memorandum directed the fielding of an enduring operational MDA capability. This initial capability, called Spiral-1, would provide a technical capability to the US Central Command (CENTCOM) and US Pacific Command (PACOM) Areas of Responsibilities (AORs), interagency partners, and select friendly and allied nations. Spiral-1, at its core, would create a multilayer, multi-domain network that would combine many data streams into a common operational picture (COP) accessible by US Government and foreign or Coalition partners. Subsequent spirals would expand on the capabilities and functionalities of Spiral-1 (SECNAV, 2007).

DoD Directive 2005.02E, signed August 27, 2009, designated SECNAV as the DoD Executive Agent (EA) for MDA. Under this directive, SECNAV is given authority over the following:

- Oversee execution of MDA initiatives within the Department of Defense and coordinate on MDA policy with the Under Secretary of Defense for Policy USD(P).
- Ensure continuous, global, and sustainable support for the DoD MDA implementation, coordinated with the DoD Components.
- In coordination with the Office of the Secretary of Defense Principal Staff Assistant (OSD PSA) and Under Secretary of Defense for Intelligence USD (I), develop and distribute goals, objectives, and desired effects for MDA as they pertain to the DoD missions.
- Identify and update MDA requirements and resources for the effective performance of the DoD missions, coordinating closely with the USD(I)

> for relevant intelligence and security matters and with the Chairman of the Joint Chiefs of Staff to direct the consolidation of Combatant Commander requirements and to coordinate the DoD maritime-related intelligence, surveillance, and reconnaissance initiatives and resources (England, 2008, August 27).

SECNAV Instruction 3052.1, signed January 2009, assigns responsibilities and establishes the authorities and governance structure for development and implementation of comprehensive, integrated MDA activities for the Department of the Navy (DON) (SECNAV, 2009).

On March 18, 2009, the Chief of Naval Operations released a NAVADMIN message announcing the role and objectives of the Navy MDA Office. The Navy MDA Office will report directly to the Deputy Chief of Naval Operations for Operations, Plans, and Strategy (N3/N5). This is a change from the former N6 MDA responsibility. The Office's objectives include:

- Ensuring that the right Navy stakeholders are engaged in MDA development and that the Navy presents a single, cogent MDA perspective to interagency, international and industry partners.
- Ensuring that MDA capability and training requirements are identified and integrated into Navy programming and budgeting processes.
- Ensuring Navy MDA efforts and investments are synchronized with the US Coast Guard, the Joint Force and other partners.

The Navy MDA Office responsibilities include:

- Providing the CNO an annual assessment of investment, engagement, and developmental efforts.
- Coordinating with US Fleet Forces Command (USFF) to establish MDA priorities and capability requirements.
- Developing roadmaps to align and synchronize Navy MDA activities—including architecture, acquisition, science, and technology. (CNO, 2009)

Through the short history of the MDA program, a top-down strategy has developed. A perceived need for a fielded baseline capability outweighed the development of an MDA technical architecture into which such component capabilities would fit, and no set of detailed core requirements were written to guide its development. There was no clear direction on how acquisition organizations should cooperate during the development process to ensure efforts were synchronized and emphasized interoperability.

Myriad organizations within the Global Maritime Community of Interest (GMCOI) developed systems to provide this baseline MDA capability. The Defense Advanced Research Project Agency's (DARPA) Information Processing Techniques Office (IPTO) developed Predictive Analysis for Naval Deployment Activities (PANDA), which has subsequently been cancelled. The US Naval Research Laboratory (NRL) Information Technology Research Group directs the development of Comprehensive Maritime Awareness (CMA) Joint Capabilities Technology Demonstration (JCTD) and its component application Track Assessment and ANomaly DEtection – Maritime (TAANDEM).

The MDA Program is indicative of complex SoS acquisition efforts being undertaken by the DoD. The MDA program includes additional complexity due to the extensive international and interagency involvement. The program exhibits the complexities shown in the Collaborative Capacity Model shown in Figure 3. Figure 17 gives the reader a sense of the complexity of the MDA development enterprise, the numerous stakeholders, and the shear complexity of MDA information-sharing relationships.

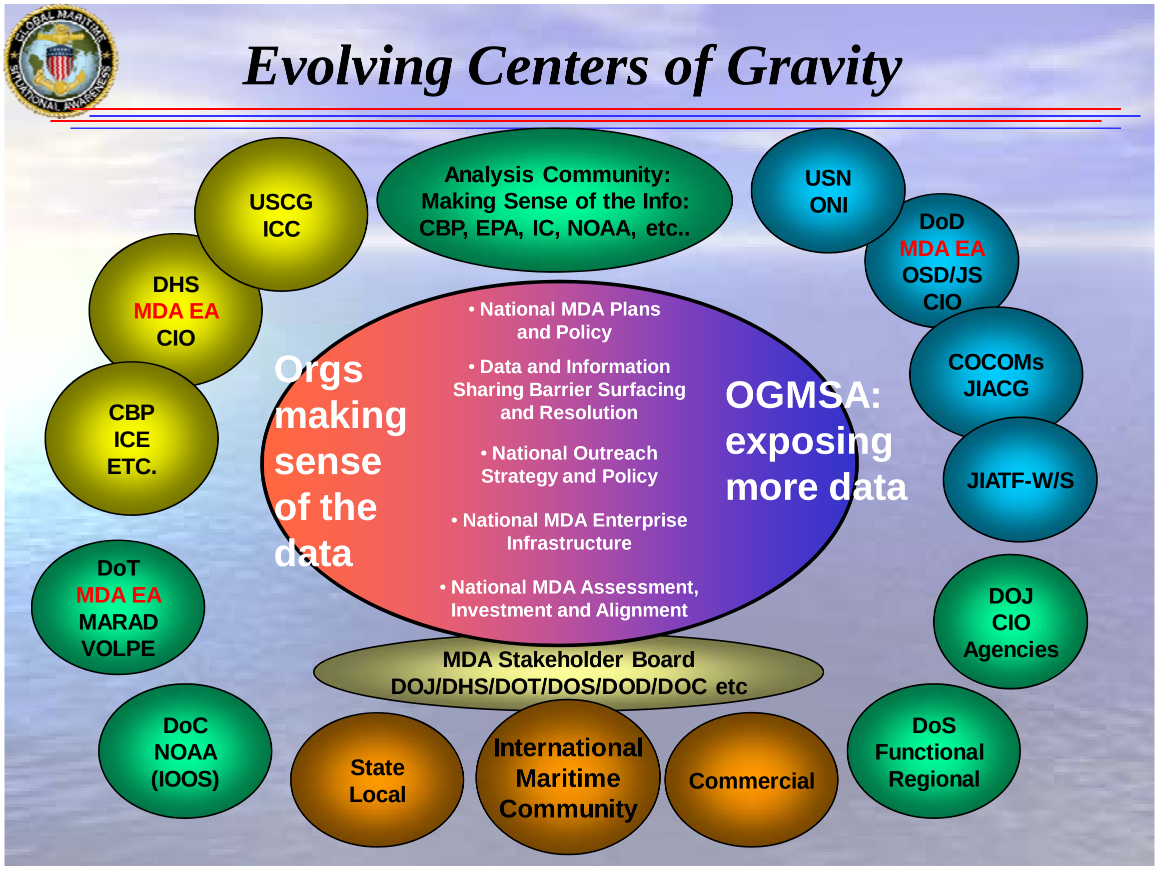

Figure 17. Evolving MDA Centers of Gravity
(Metcalf, 2008)

It is the goal of this research to examine how the numerous MDA stakeholders might reduce duplicative research and development efforts, encourage re-use of MDA system components and features, and facilitate better collaboration. It will also demonstrate how KM tools might help the MDA program develop better Self-awareness of the complex MDA acquisitions environment.

B. MDA Program Self-awareness

MDA technologies were designed to provide the operator with tools or features that monitor, collect, fuse, analyze and disseminate, and maintain data on vessels and craft, cargo, crews and passengers, and other identified areas of interest. In order for decision-makers to have more visibility into what systems were being developed by the various MDA stakeholders, they need a high level of

Program Self-awareness. Heightened Self-awareness may lead to feature re-use through increased collaboration on feature development, selection of the best-among-like features, and promotion of feature interoperability.

This thesis proposes a notional KM methodology to support improved Program Self-awareness and decision-making (Figure 18). This research demonstrates how one might go about deriving features from existing program documentation and databases. More importantly, this research will demonstrate how Self-awareness can be improved through visualizations of the relationships between features of select MDA technologies.

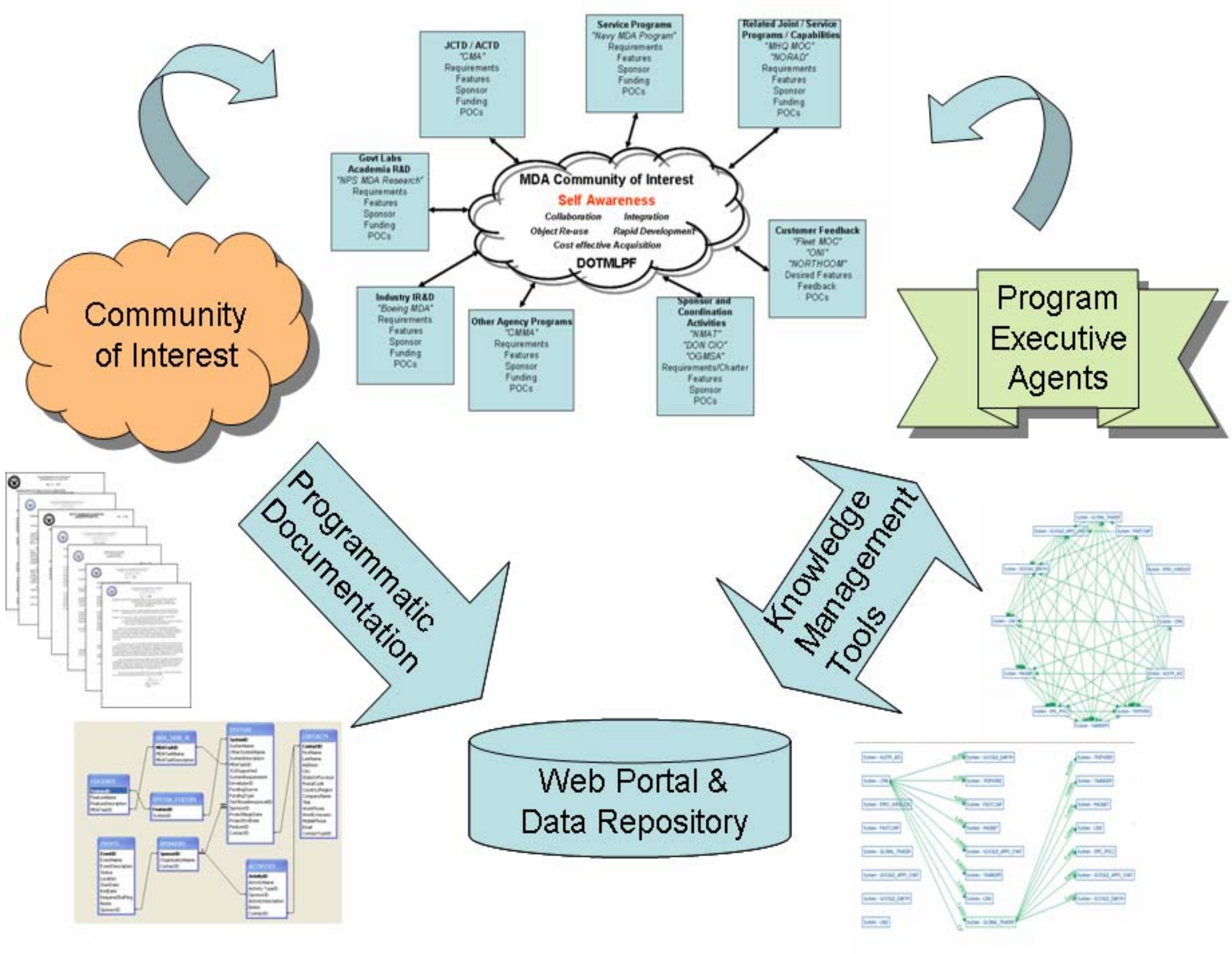

Figure 18. KM Methodology to Support Improved MDA Program Self-awareness

C. Unstructured Text Mining Methodology

The authors used the process depicted in Figure 19 to conduct an analysis of an MDA data set. This process begins with the development of business and data understanding. The authors gained business and data understanding by individual research, conference attendance, e-mail and phone discussions, and site visits to MDA Program activities. The authors leveraged the NPS KM expertise to conduct this modeling and evaluation. The authors served as the program “experts.” The pairing of KM and program expertise enabled the authors to understand the data context and the technical aspects of KM processes applied in the research. The authors followed the process in Figure 19 to the evaluation step.

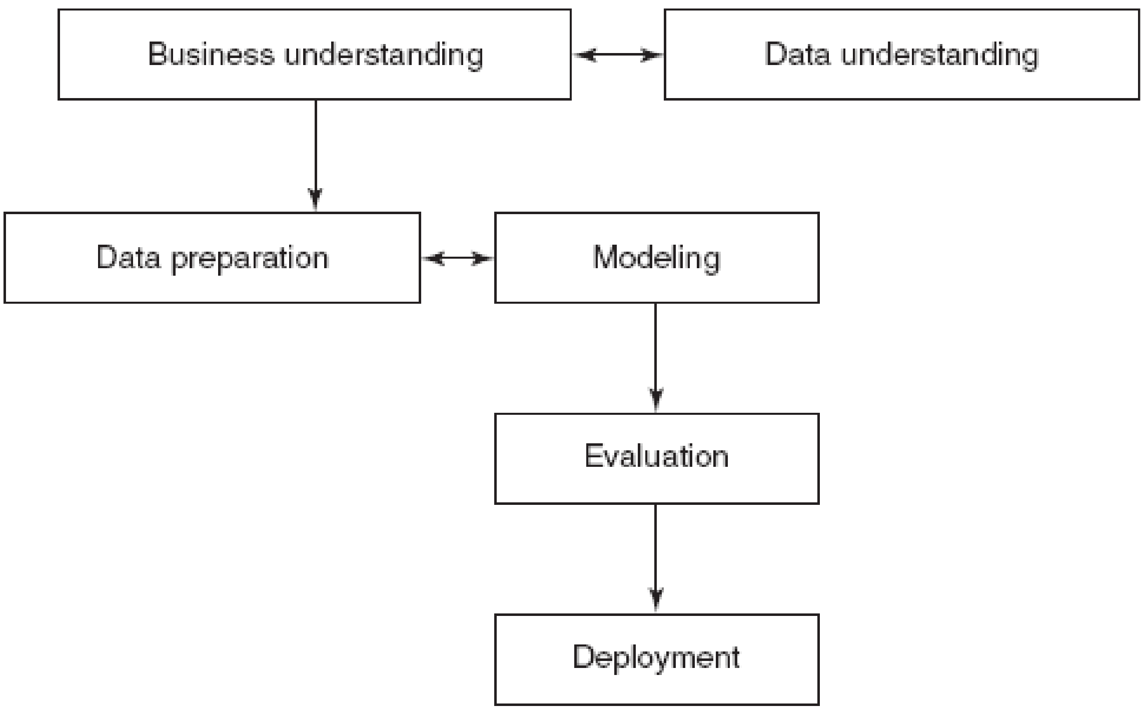

Figure 19. Data-mining Process
(Turban et al., 2008, p. 156)

This research develops and examines a representative data mart of unstructured data (program documents) gathered from members of the GMCOI involved in MDA systems development and acquisition. This task was especially challenging in that there is not a consolidated repository for MDA-related programmatic documentation. The data set that the authors were able to collect to support this research was not comprehensive but represents a small subset of MDA-related documents available to the GMCOI.

Data collection was conducted via several methods. Access was granted to the PANDA development SOURCE FORGE collaboration website by the PANDA program manager at DARPA. PANDA documents were downloaded into the data mart from this site as well as gathered directly from contacts involved in its development. CMA documentation was gathered during a data-collection visit to SPAWAR PEO-C4I 1-3 in April 2009 and directly from the CMA program manager at NRL. TAANDEM documents were gathered in the same manner.

The documents in the data mart included Microsoft PowerPoint (.ppt), Microsoft Word (.doc), Adobe Acrobat (.pdf), e-mails, .html files, and plain text files (.txt). They were grouped into five folders (Figure 20). Three of the folders contained systems-related documents including TAANDEM, PANDA, and CMA. Another folder contained MDA programmatic documents. The final folder contained MDA-related reports from the NPS Distributed Information Systems Experimentation (DISE) research group. The data was subsequently prepared for application of the mining algorithms. Some scanned documents were converted with Adobe Acrobat image recognition software back into text. A comprehensive list of documents used in this analysis can be found in the Appendix.

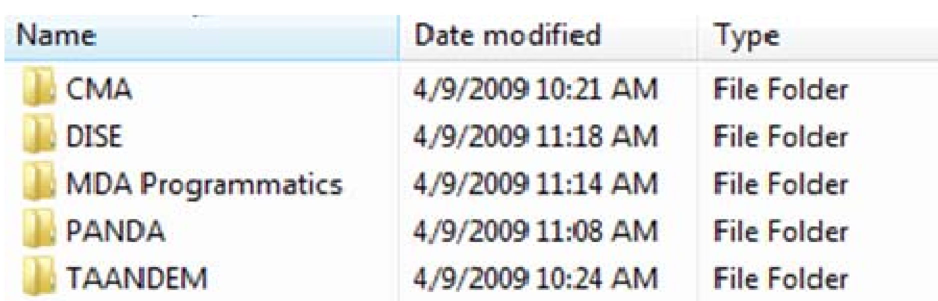

Figure 20. MDA Data Mart

A data and text mining toolset called Collaborative Learning Agent (CLA), developed by Quantum Intelligence, Inc., was used to extract related terms from the data sets. CLA's association algorithm was used against all 5 folders of the MDA Data Mart. The tool divides plain text into sentences, grouping words from period to period. The tool eliminates commonly used words from the documents (i.e., a, the, and, other). The tool then connects terms into pairs based on their use and proximity in the documents. The result is a list of word pairs for each data set. Contacts and information related to Quantum Intelligence knowledge management tools can be found at the Quantum Intelligence, Inc. website (http://quantumii.com/).

These lists were manually cleansed for feature-related terms. The feature-related terms were chosen based on the authors' understanding of the MDA program. Words such as common names and other terms unrelated to features were eliminated from the word pair lists. The clean word pair lists were then formatted for import into select visualization toolsets. Alone, these word pair lists are probably of little use in enhancing Program Self-awareness. It is only through the visualization of these feature terms that real relationships become apparent to the program decision-maker.

After removing non-feature-related terms from the lists, the authors ran a script to pair individual terms with the data mart folder it was associated with. This allowed the visualization tools to attribute each term to the system or program documentation set that it came from. Figure 20 is an excerpt from the formatted CMA word pair lists.

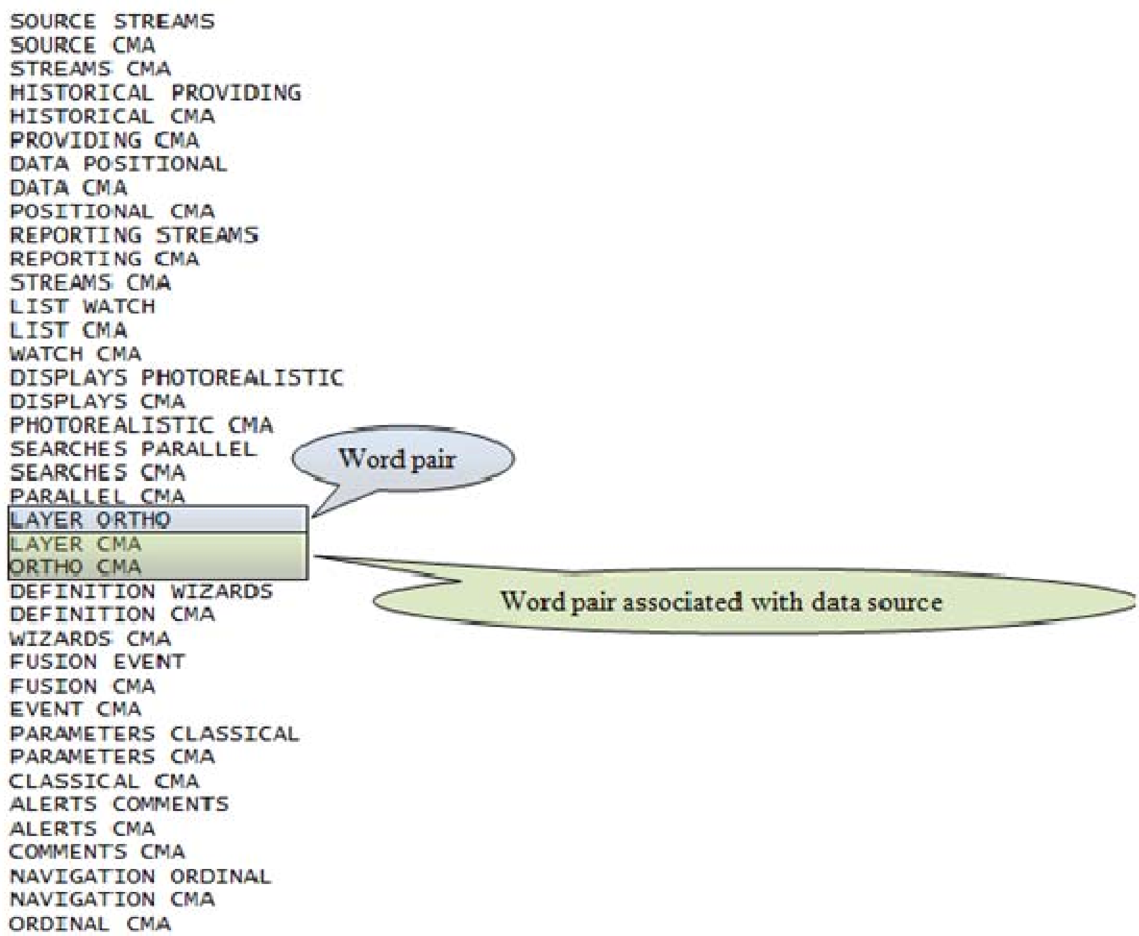

Figure 21. Excerpt from CMA Word Pair List

The word pairs from CMA, TAANDEM, PANDA, and MDA programmatic data sets were then utilized in the visualization portion of this research. After viewing the terms extracted, the authors judged that the word lists created from the DISE reports would not be as compelling to decision-makers as the other data sets. This led them to use some other KM techniques on structured data from the DISE FIRE database described in Chapter II.

D. Structured Data Mining Methodology

Similar KM methodologies can be used on structured data held in databases. Many organizations use queries, reports and other means to exploit known relationships between data within a database. KM techniques can be used to identify previously unknown relationships between that data. To demonstrate some of these capabilities, the authors utilized MDA objective data from the TRIDENT WARRIOR 2008 (TW08) Experiment housed in the FIRE database. TW08 personnel collected data on a number of MDA toolsets used in the experiment. The objectives and results for each tool set where recorded in FIRE. This represented to the authors a snapshot of MDA capability from the summer of 2008.

The CLA association algorithm used with the unstructured data was run against the TW08 data set. Word pairs were extracted from the data set and then grouped by the software based on frequency of use within the data set. The authors compared the lists and chose the list that they most associated with feature information. After the feature-related list was chosen, a CLA search algorithm was used to find which MDA toolsets from TW08 were associated with each feature cluster. Next, these results were formatted for visualization.

E. Visualization Methodology

1. Unstructured Data Visualization

Through the use of visualization tools, such as network analysis tools, relationships between the mined data become useful to a decision-maker. The first visualization tool utilized in this research was AutoMap, developed by Carnegie Mellon University's Center for Computational Analysis of Social and Organizational Systems (CASOS) (Carley & Diesner, 2005). Although AutoMap can be used to conduct text-mining, it was utilized only for its visualization capabilities. More detail on the AutoMap program can be found at the CASOS website (http://www.casos.cs.cmu.edu/projects/automap/).

The first step in this visualization methodology was to import the word pair lists into AutoMap's Network Visualizer. This resulted in a display showing the terms and their relationship to other terms in the imported network. The Organizational Risk Analysis Network Visualizer toolset connects terms that are associated in the word pair lists. For example, if the word pairs (Social Network) and (Network

Analysis) appear in the imported list, AutoMap will form the relationship (Social Network Analysis). These word nodes are then connected by a series of links to form clusters.

After creating the visualization, it can be enhanced by grouping these relationships with the Newman Grouping tool. This tool displays each node and connector in a relationship by color. The color clusters represent the degree to which the groupings show community structure. These clusters are based on the statistical properties of networks (Carley & Diesner, 2005). An example of this visualization can be seen in Figure 22, which depicts some of the Newman Groupings within the PANDA data set.

The reproduction of the visualization products in this document is very difficult due to resolution limits and the inability to manipulate the data visualization through the software tools (pan, zoom, etc.). The graphics included do, however, provide a fair representation of the products this tool can generate.

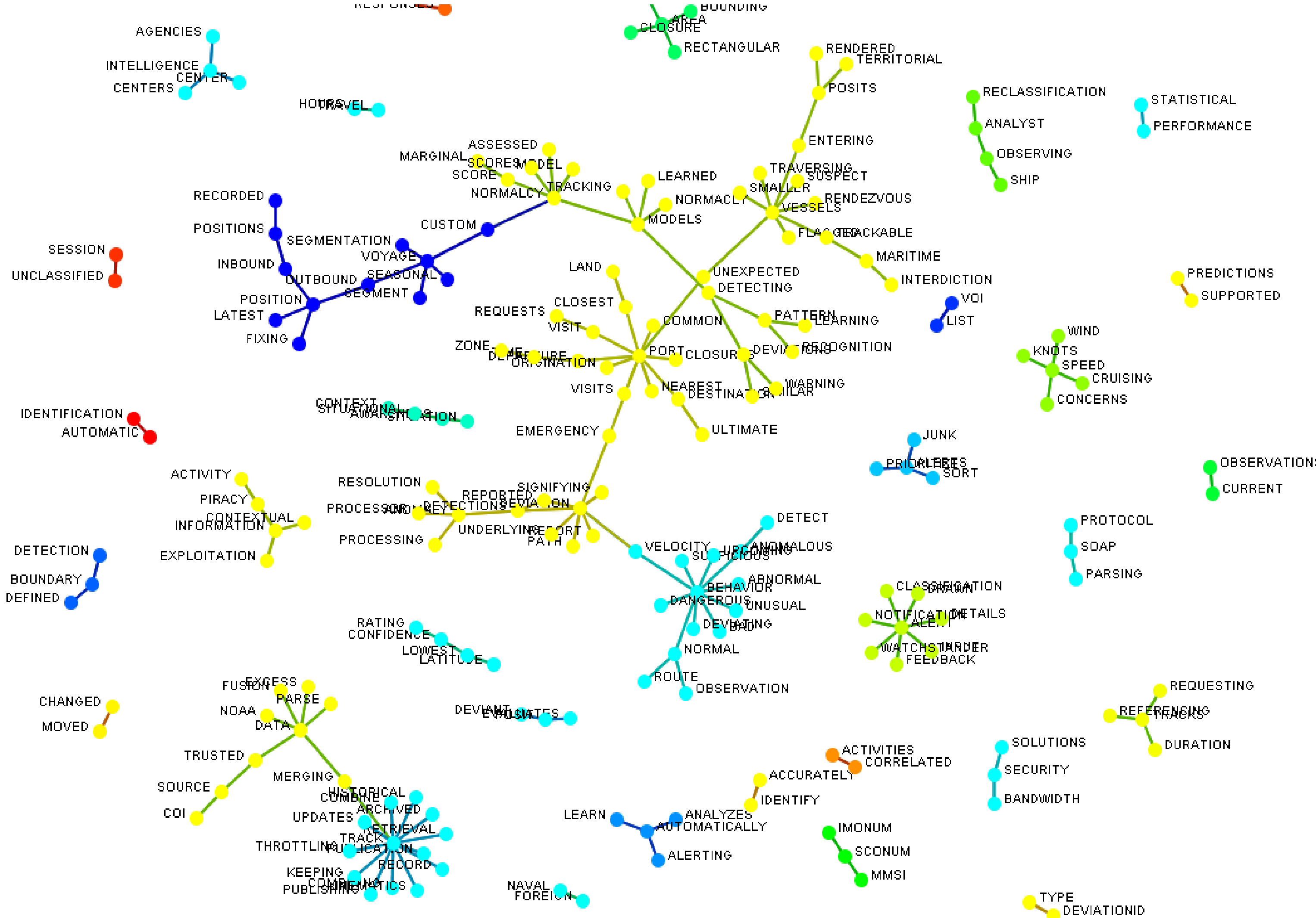

Figure 22. Feature Clusters from PANDA Data Set Displayed in AutoMap

On the surface, Figure 23 is a complex series of links and nodes, which may not be useful to the casual observer. However, these clusters represent MDA feature concepts that have been extracted from programmatic documentation. As a program decision-maker, it would be interesting to know what features and capabilities have been proposed to improve awareness in the maritime domain. This visualization organizes the feature concepts laid out in hundreds of pages of unstructured documents. Even through a complex visualization, an observer with some knowledge of the MDA Program would recognize that some of the relationships point to specific capabilities or features desired by the GMCOI. Extracting key terms from existing documentation and displaying their relationships provides insight into how the GMCOI is using the terms and where there might be redundant terms and need for de-confliction and standardization.

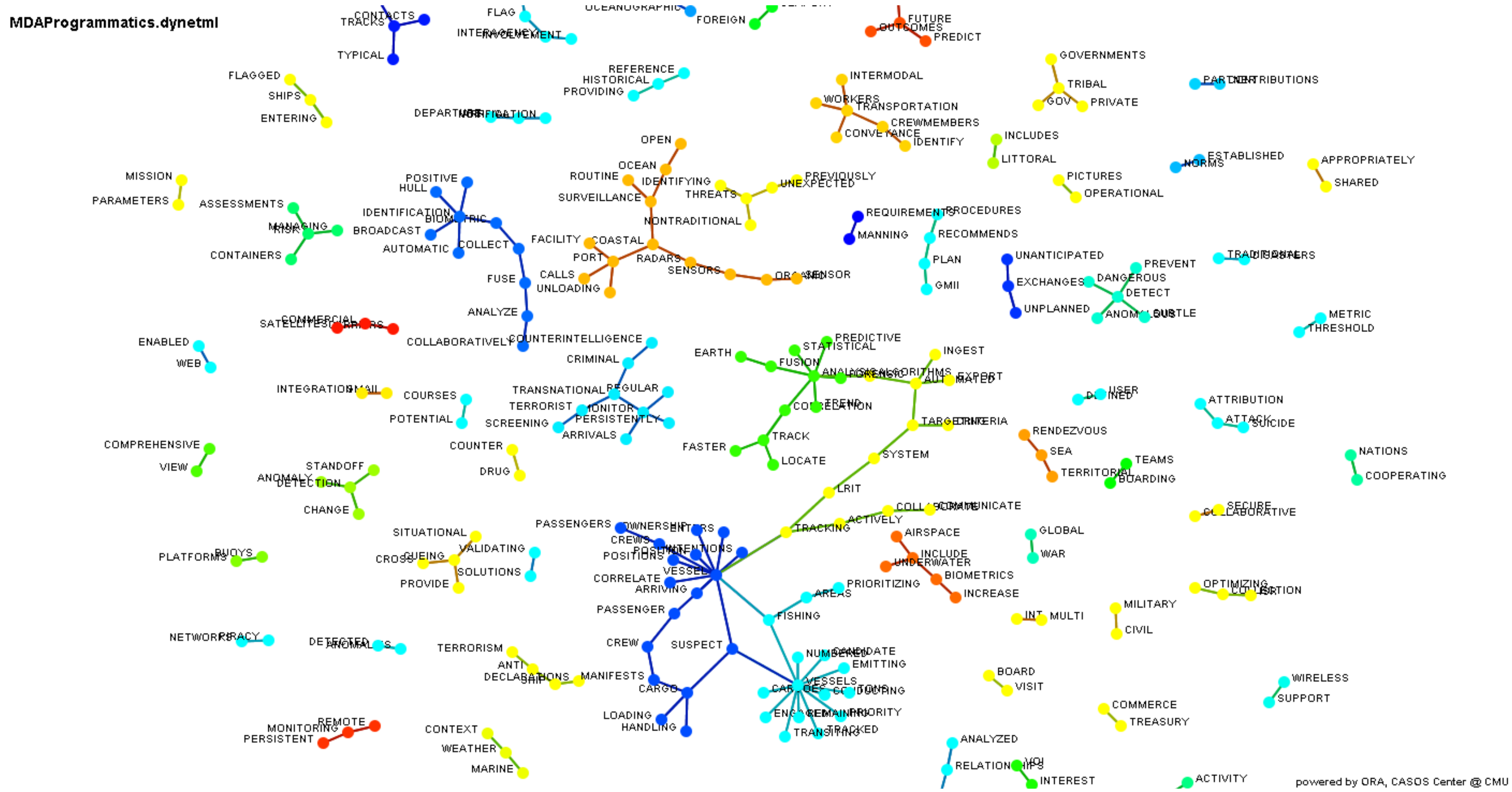

Figure 23. Feature Clusters from MDA Programmatic Data Set Displayed in AutoMap

Figure 24 displays a network map that connects all the terms with their pairs and with the CMA system. This visualization will give the viewer a sense of what feature clusters the CMA system data contains and how they are related. This visualization shows the feature clusters of a single system.

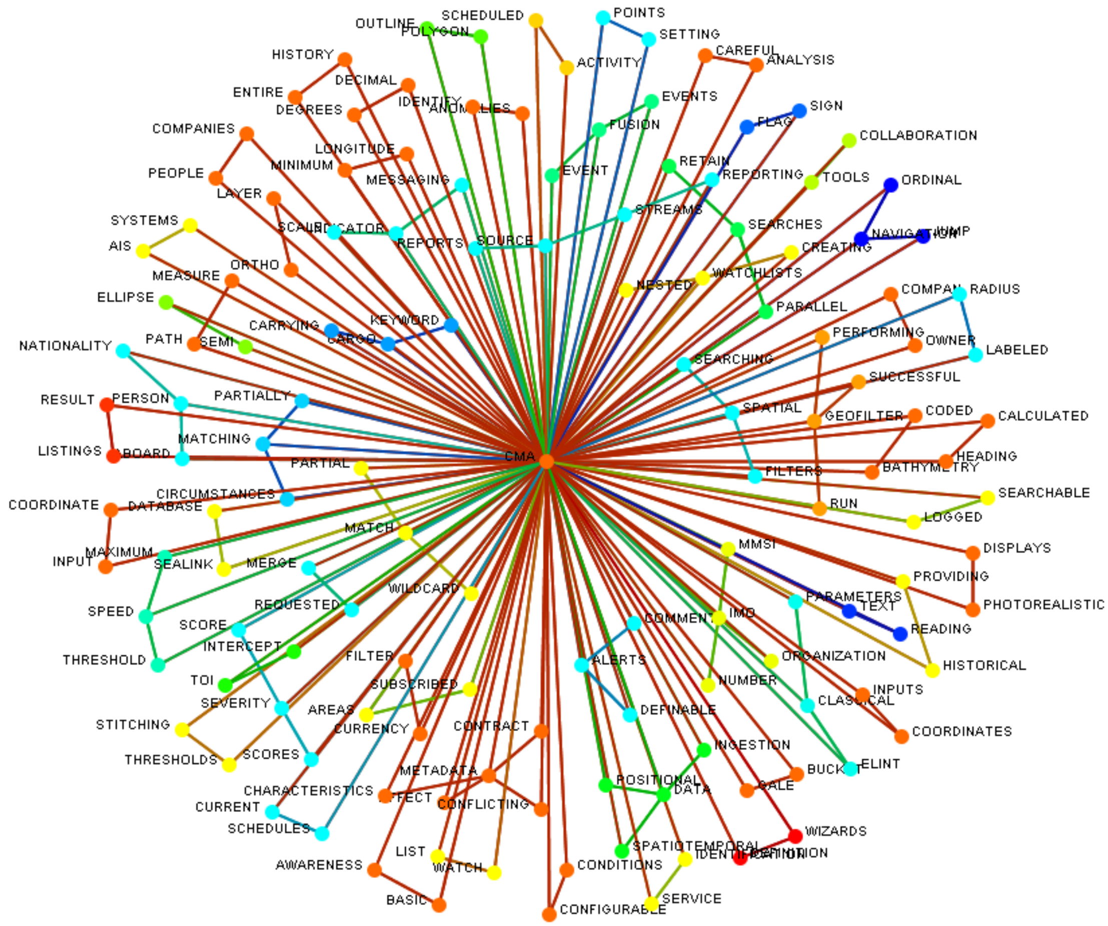

Figure 24. Feature Clusters from CMA Data Set Displayed with Central Node in AutoMap

Decision-makers may also want to know how the feature systems of two or more clusters compare. The following three visualizations (Figures 25, 26 and 27) were the result of concatenating two sets of word pairs. These visualizations show the relationships within and between two systems. On the outside edges of the networks is a large grouping of like-colored terms whose links radiate to the center node. These terms are only connected to a single system. The links in the center, between the two groupings, share terminology with both systems. This is indicated by links crossing between the two circular concentrations.

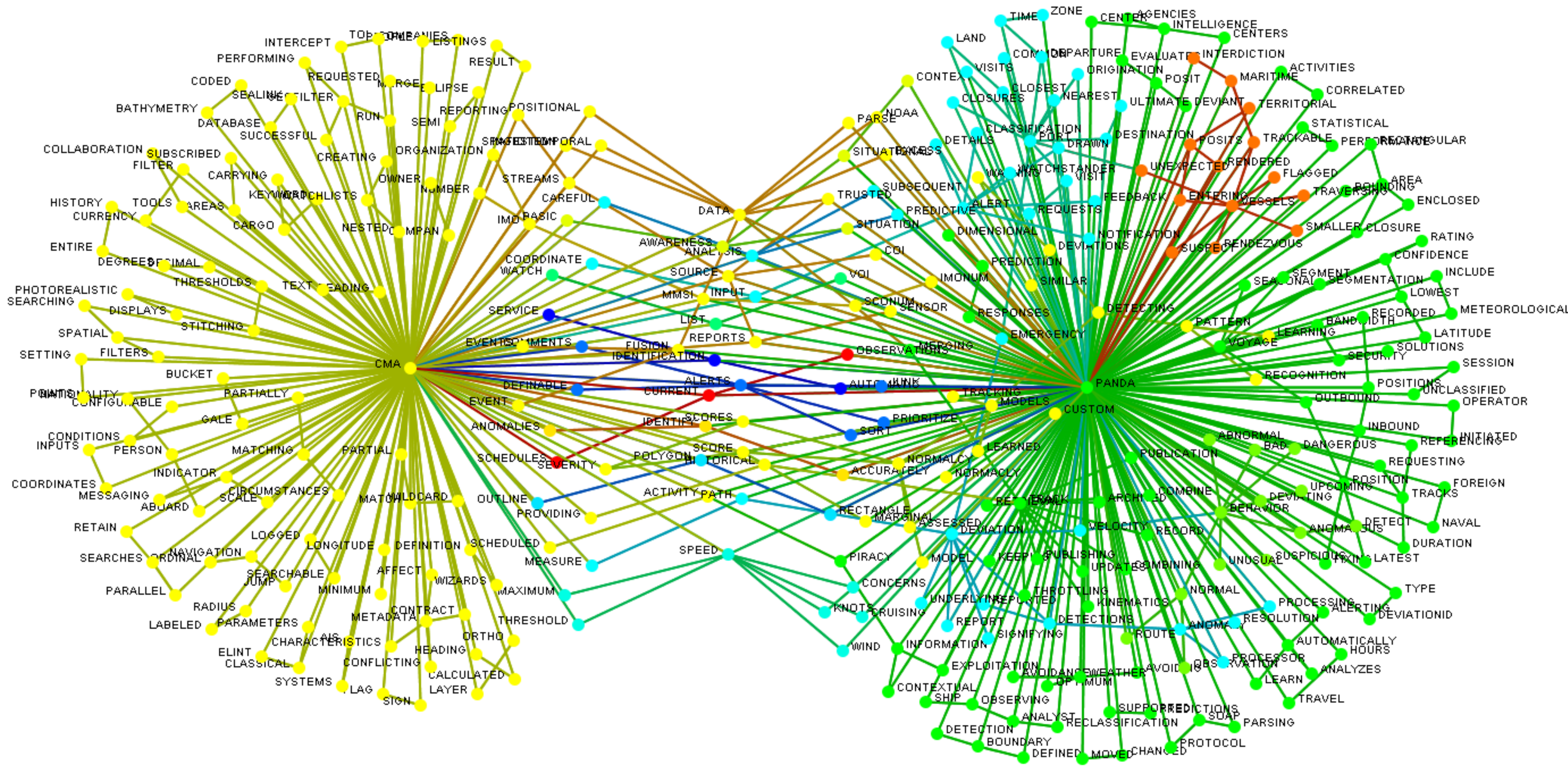

Figure 25. PANDA and CMA Shared-feature Clusters Visualization

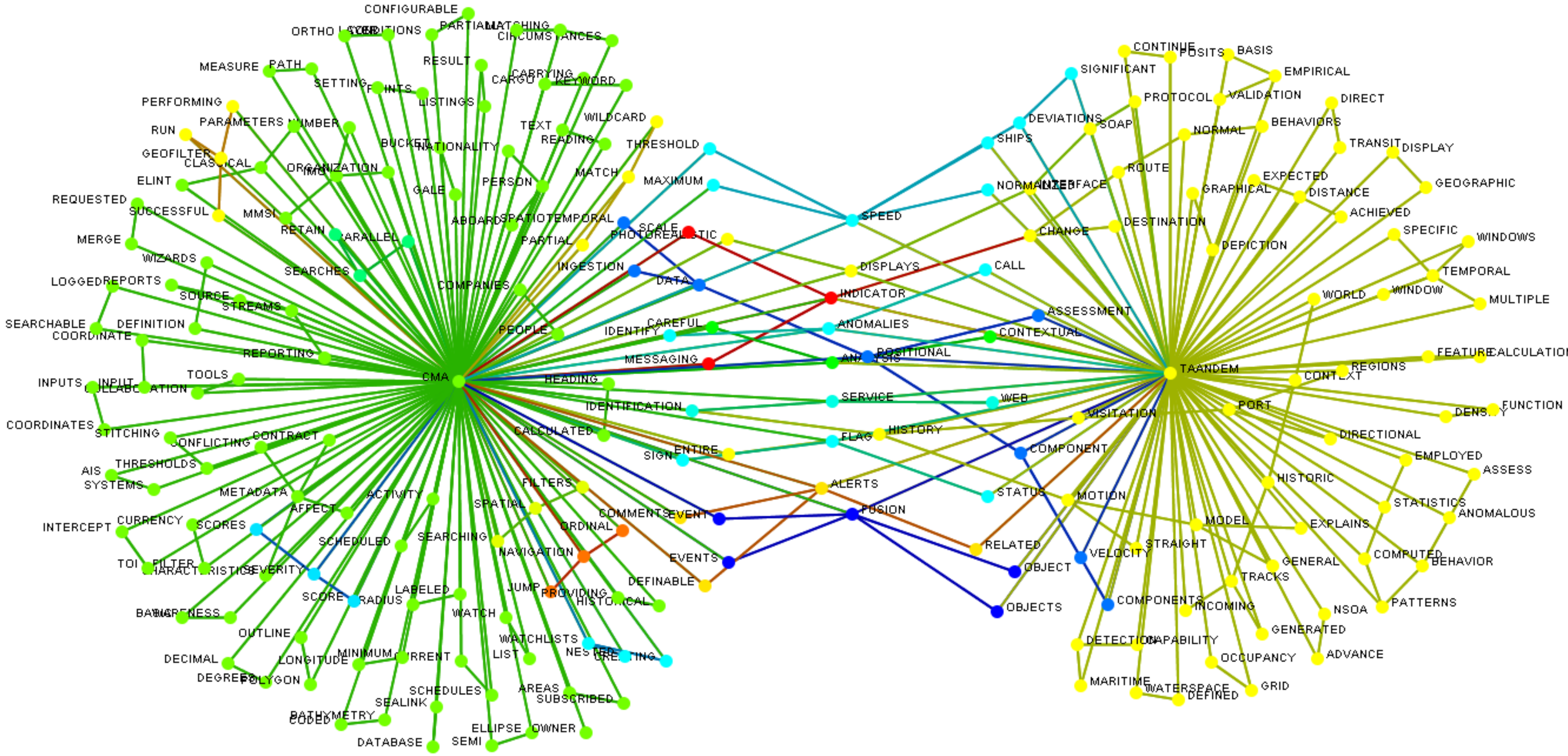

Figure 26. AutoMap Visualization of CMA and TAANDEM Shared-feature Clusters

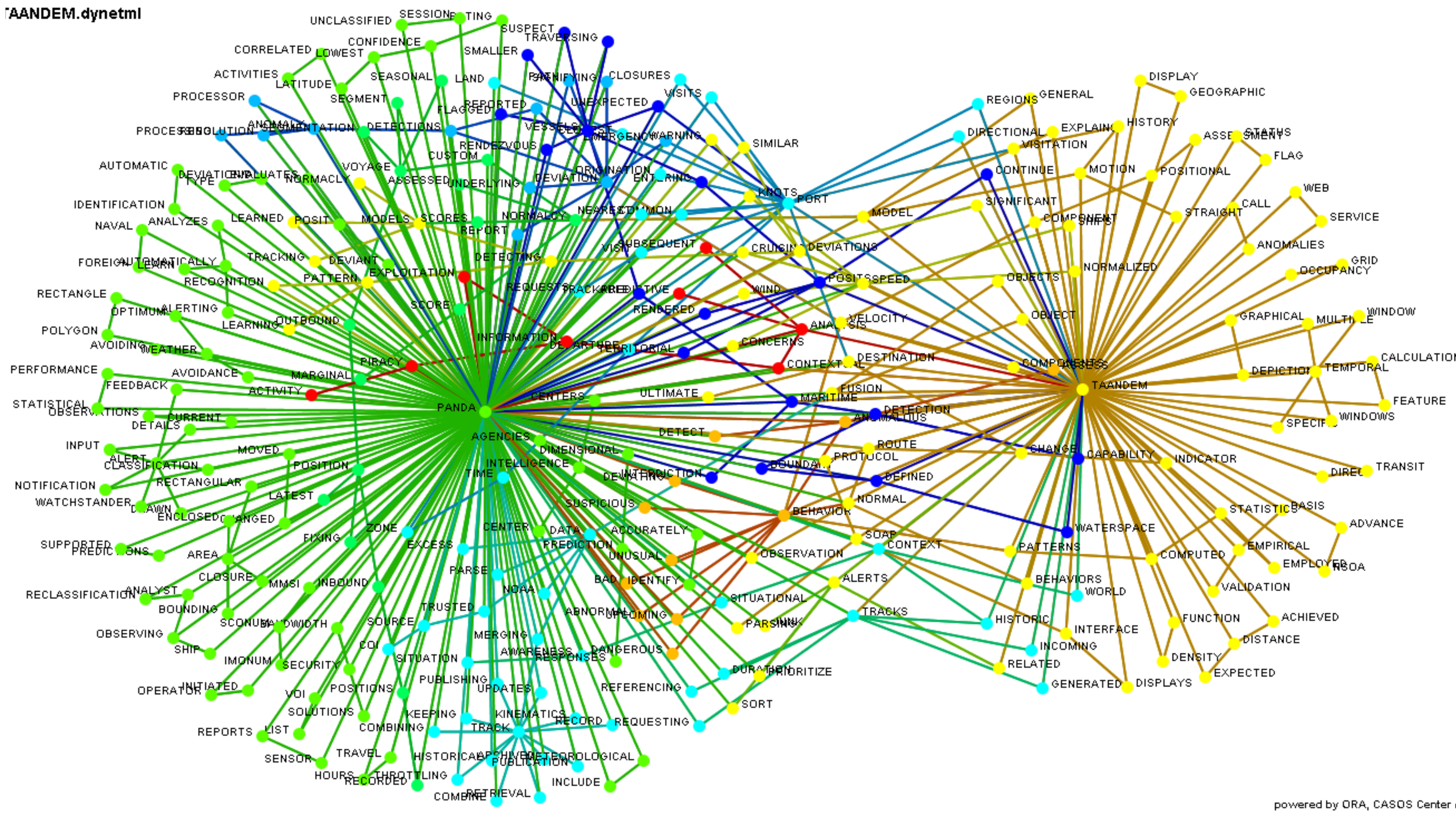

Figure 27. PANDA and TAANDEM Shared-feature Cluster Visualization

Additionally, if a user were to concatenate three lists, he or she could visualize the relationships among features of all three systems (Figure 28). There is also a three-dimensional capability in the AutoMap visualization toolset that displays the three-way groupings much more clearly. These visualizations reproduce poorly in document form and were, therefore, omitted from this text.

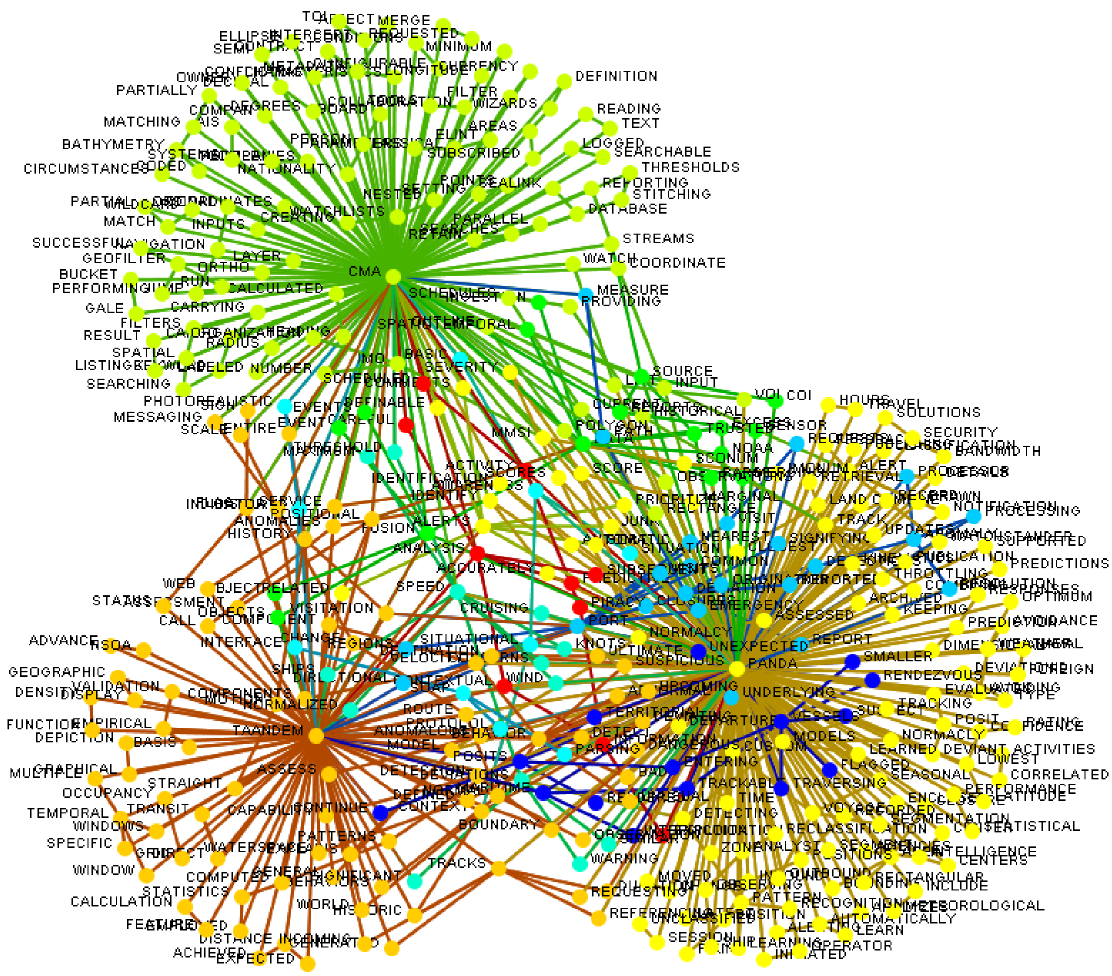

Figure 28. CMA, PANDA, and TAANDEM Shared-feature Cluster Visualization

Deeper analysis of the feature clusters shared between systems can highlight similarities and differences among the systems. An examination of the shared hubs between systems may give an indication of these relationships. Hubs are nodes with multiple links extending from them. Figure 29 is a closer view of the PANDA and

TAANDEM feature clusters. There are several shared hubs between PANDA and TAANDEM, including:

- port,
- vessels,
- posits,
- deviation, and
- anomaly.

Take the "port" hub, for example. TAANDEM connects "port" with the terms "regions" and "directional." PANDA connects "port" with "common," "origination," and "nearest." Another example is the "vessel" hub. TAANDEM connects "vessel" with "trackable." PANDA connects "vessel" with "small," "suspect," "rendezvous," "traversing," and "flagged." The two systems are both linked to common hubs but display different relationships with them. This type of analysis might be used to help differentiate between similar features in two different systems.

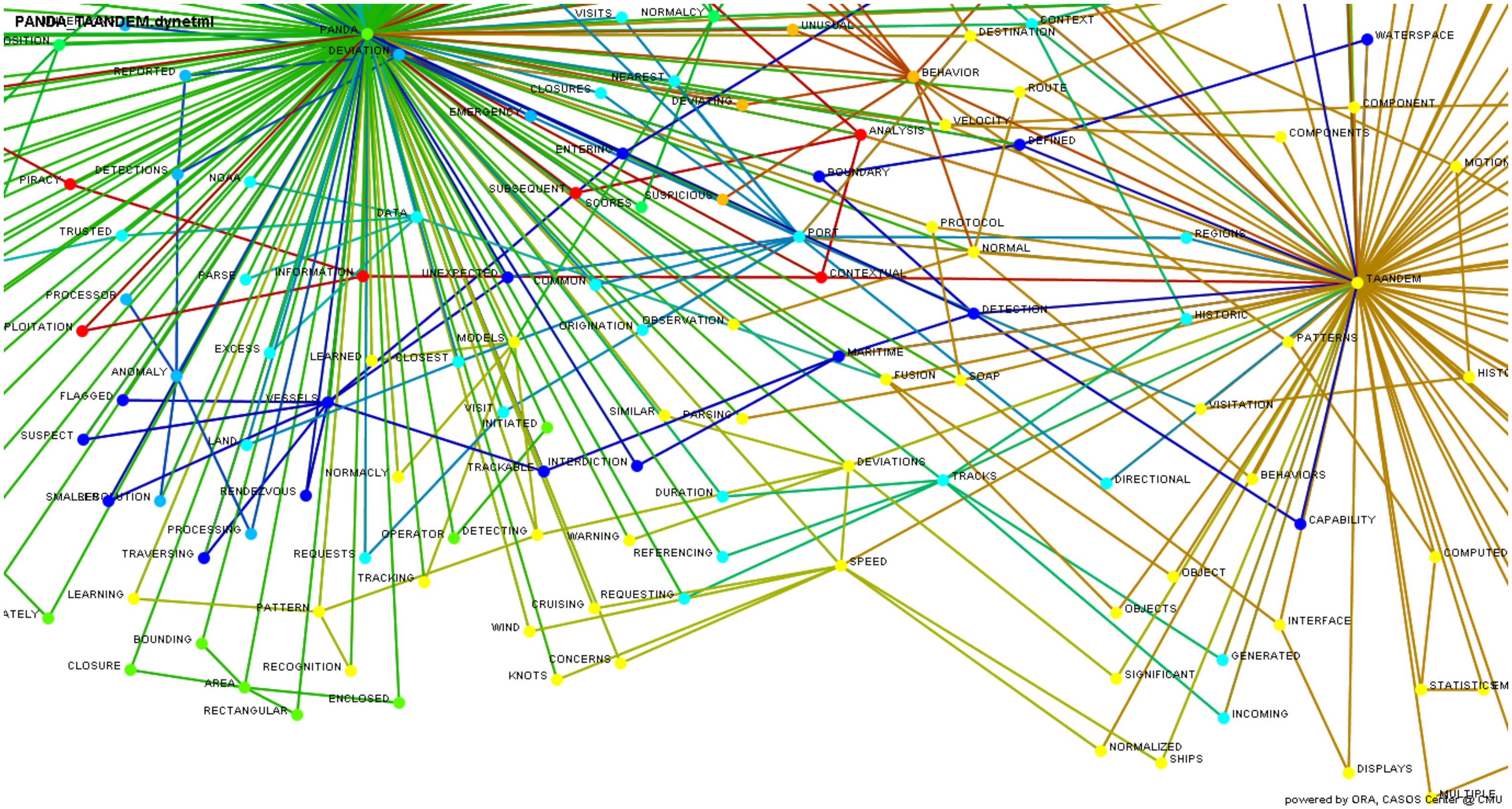

Figure 29. PANDA and TAANDEM Shared-feature Clusters

Another way to visualize which feature terms are shared between systems is to remove the center node of one system as shown in Figures 30, 31 and 32. This shows one system in its entirety and shows its connections to feature terms from the other toolset. This visualization makes it clearer within AutoMap what features are related and not related between the systems.

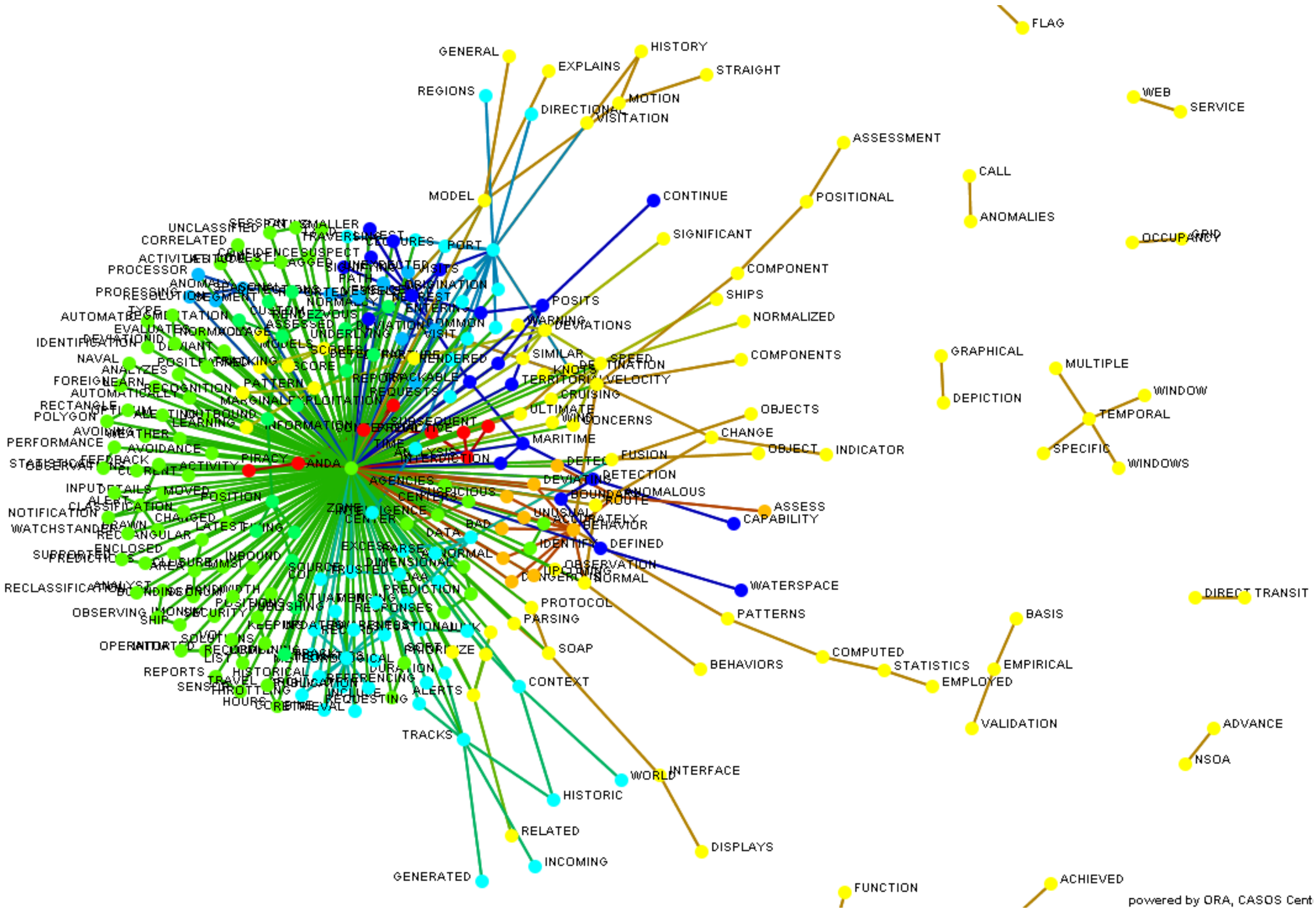

Figure 30. AutoMap Visualization of PANDA and TAANDEM Feature Clusters with TAANDEM Node Removed

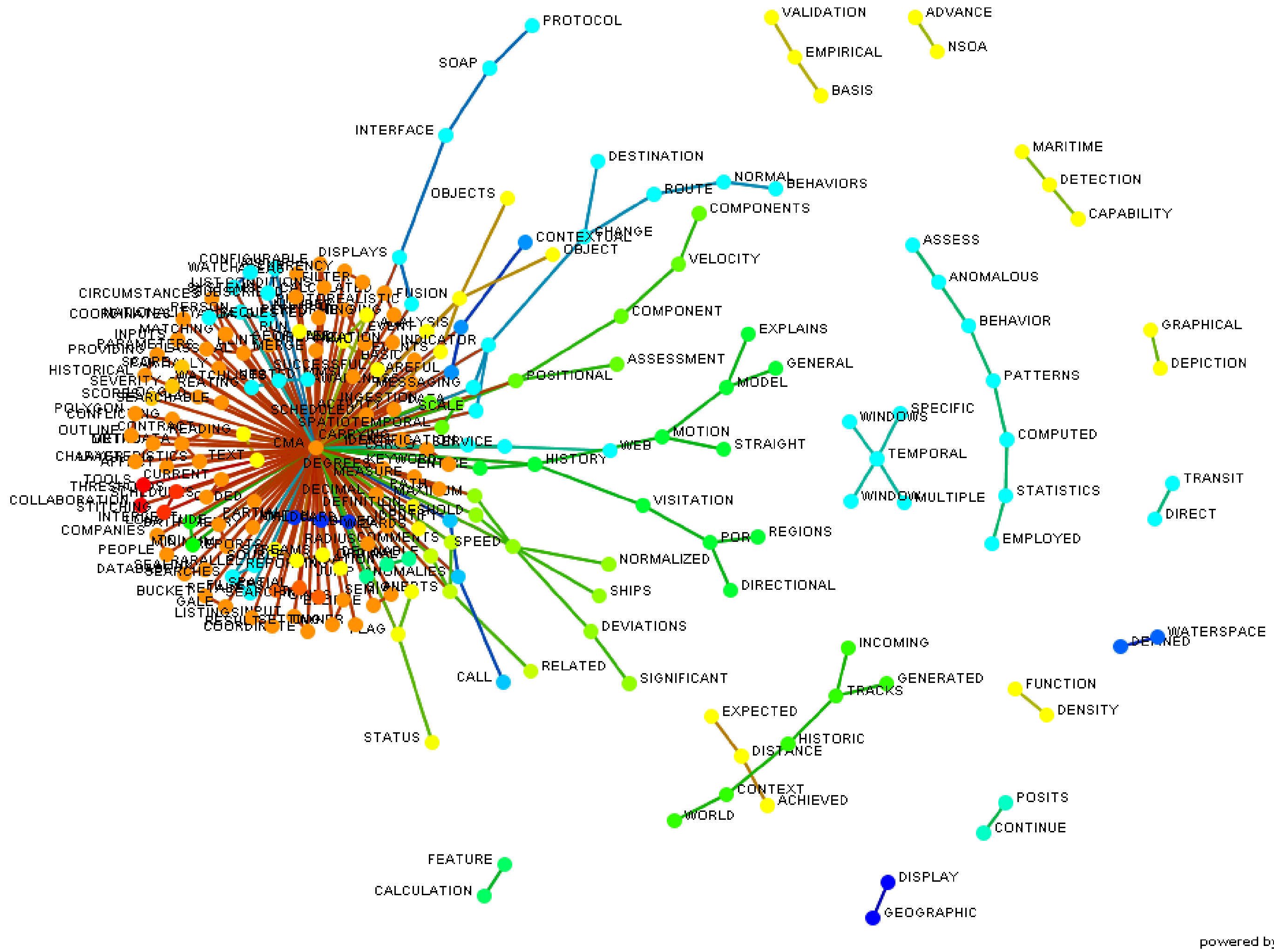

Figure 31. AutoMap Visualization of CMA and TAANDEM Feature Clusters with TAANDEM Node Removed

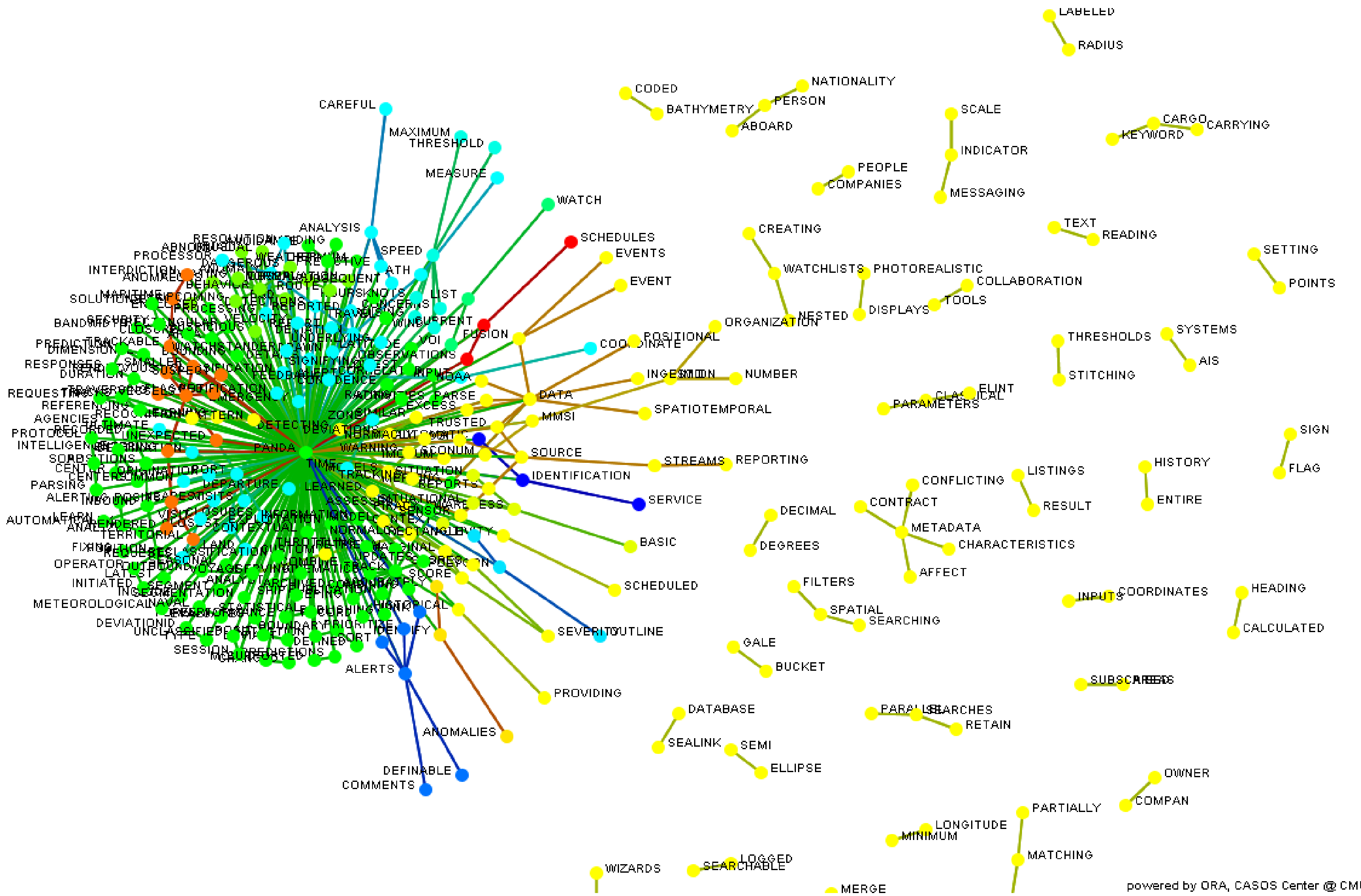

Figure 32. AutoMap Visualization of PANDA and CMA Feature Clusters with CMA Node Removed

AutoMap Network Visualizer is a powerful tool for observing the relationships between system-related feature terms. The display, however, is very complex, and the complexity grows with the number of nodes displayed. There are other tools that can display these relationships and that may have more utility for the program decision- maker.

Microsoft Excel was also used to create visualizations of the relationships discovered through AutoMap. Feature clusters from AutoMap were exported, formatted, and imported to Excel. The clusters were sorted and displayed in radar graphs to answer questions about data relationships.

The authors were interested in knowing where gaps existed in MDA capabilities given the three systems being studied. The data was sorted for feature clusters that only appear in the MDA programmatic data. Additionally, the authors were interested in what features were unique to a single system. The data was sorted for feature clusters that were unique to each system. Figure 33 displays MDA feature clusters that were not associated with any of the three systems in red. It also displays feature clusters that were unique to a single system, represented by the color in the graph legend. For readability, some of the feature clusters have been shortened. This type of graph could serve as a gap analysis for MDA-related features. This representation would be useful for program decision-makers who want to know what MDA capabilities are not addressed by existing systems in the MDA Program.

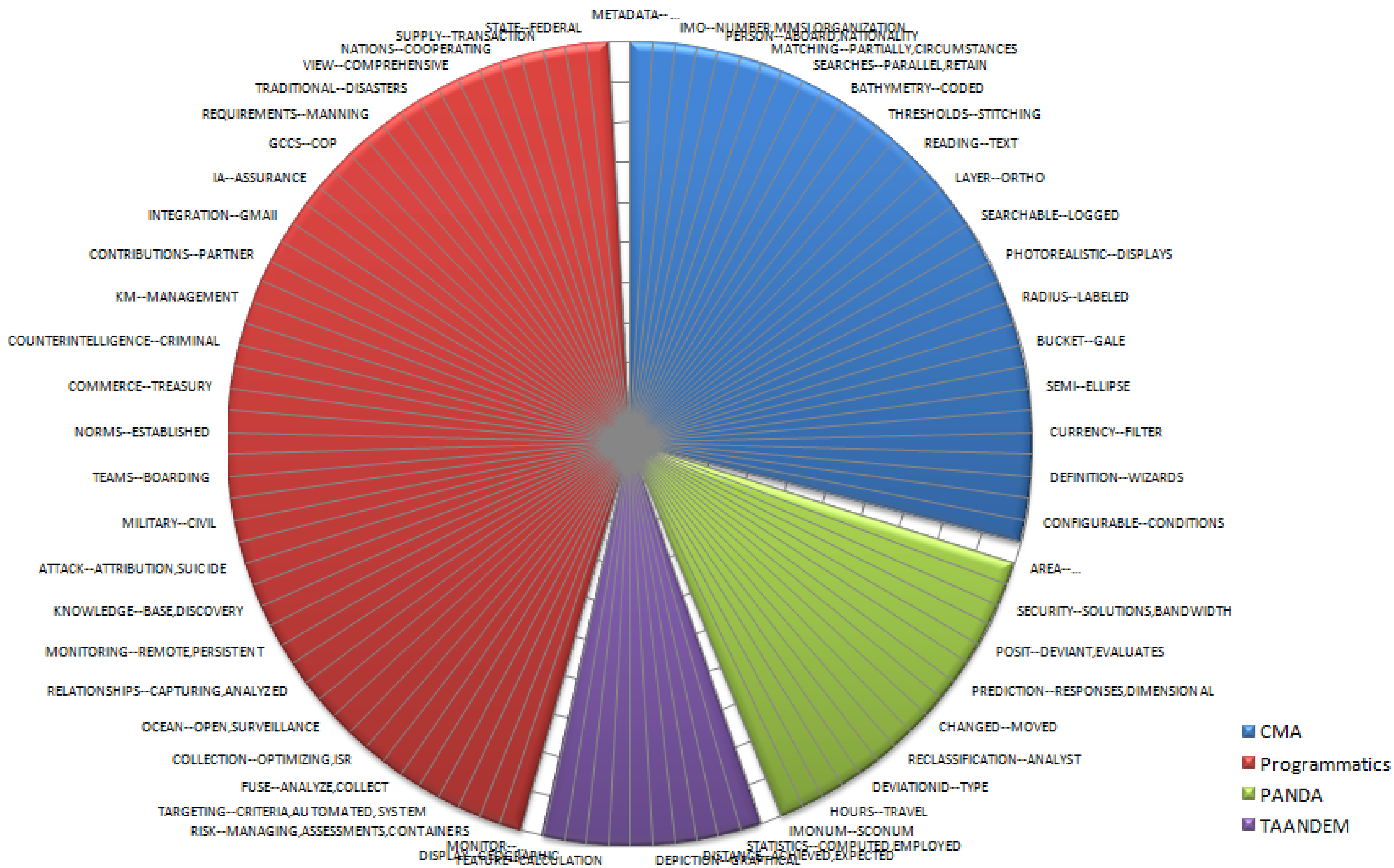

Figure 33. Radar Graph Showing Gaps in MDA Feature Coverage and Features Unique to a Single System

The authors were interested in what feature clusters were shared by systems. In order to visualize this, the authors sorted the clusters by the number of systems with which they were associated. Figure 34 displays a subset of feature clusters related to one, two or three systems represented by the radials and rings of the graph. Once again, the clusters are shortened for readability. The utility of this graph in its static format is limited, but the underlying data exists to determine which systems are associated with which capability.

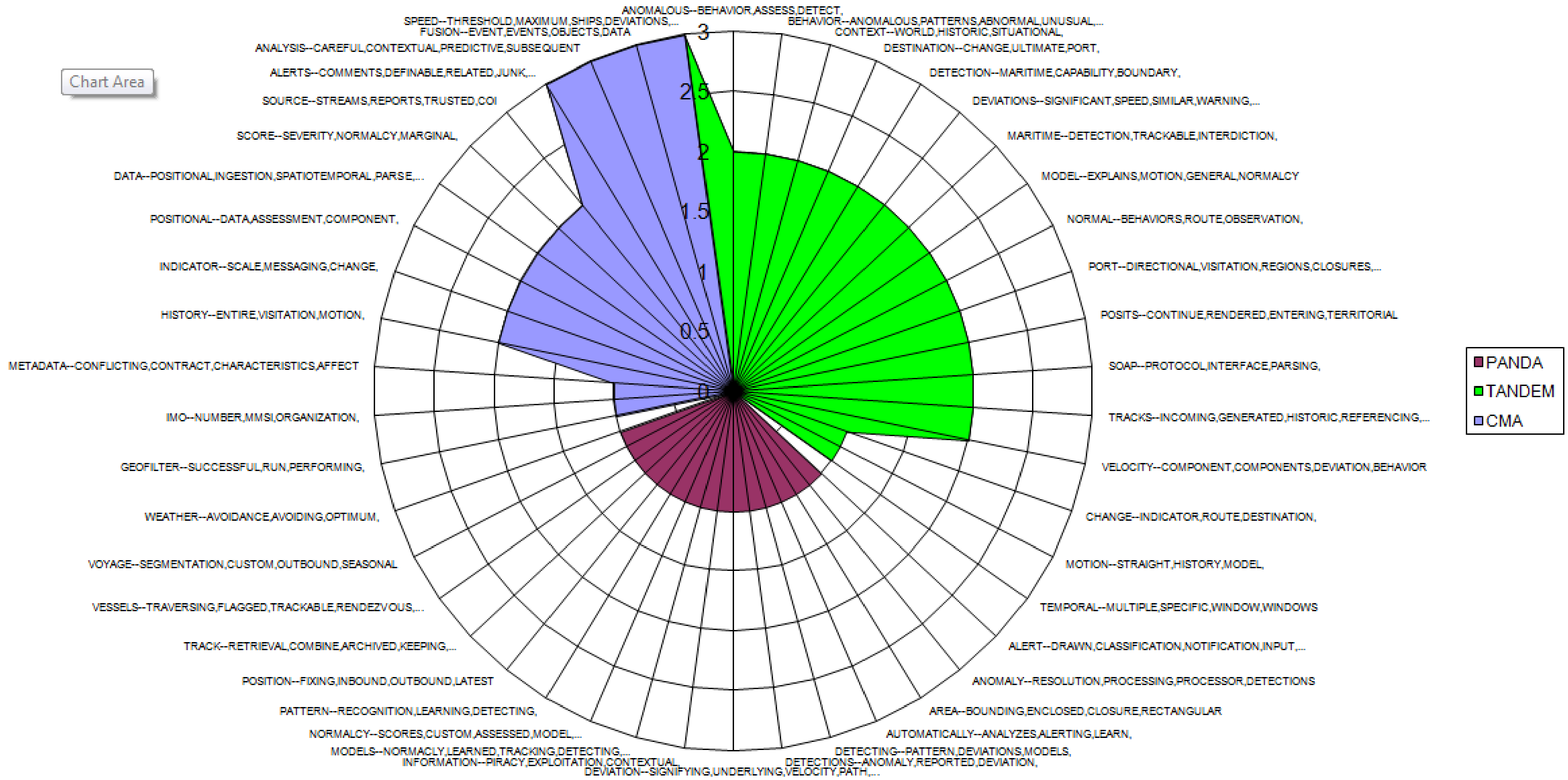

Figure 34. Radar Graph Indicating Feature Clusters Shared by One, Two, or Three Systems

2. Structured Data Visualization

After the results from the TW08 were formatted, they were imported into Tree Vizualizer. Tree Visualizer is freeware available from the Softpedia website (http://mac.softpedia.com/get/ Utilities/Tree-Visualizer.shtml). The program displays interactive visualization of large data structures organized in a tree. With this tool, the user is able to visualize a data structure quickly in its entirety. It also provides the ability to quickly drill down to points of interest in a data structure.

Tree Visualizer was used to associate the feature clusters extracted from the TW08 MDA objectives data set with the MDA tools used in the experiment. Figure 35 displays a hyperbolic tree view of the data. The MDA objectives data set is represented by the center node labeled MDA2. The gray nodes surrounding the center node are feature clusters, and the blue nodes on the outside are MDA tools used in the experiment.

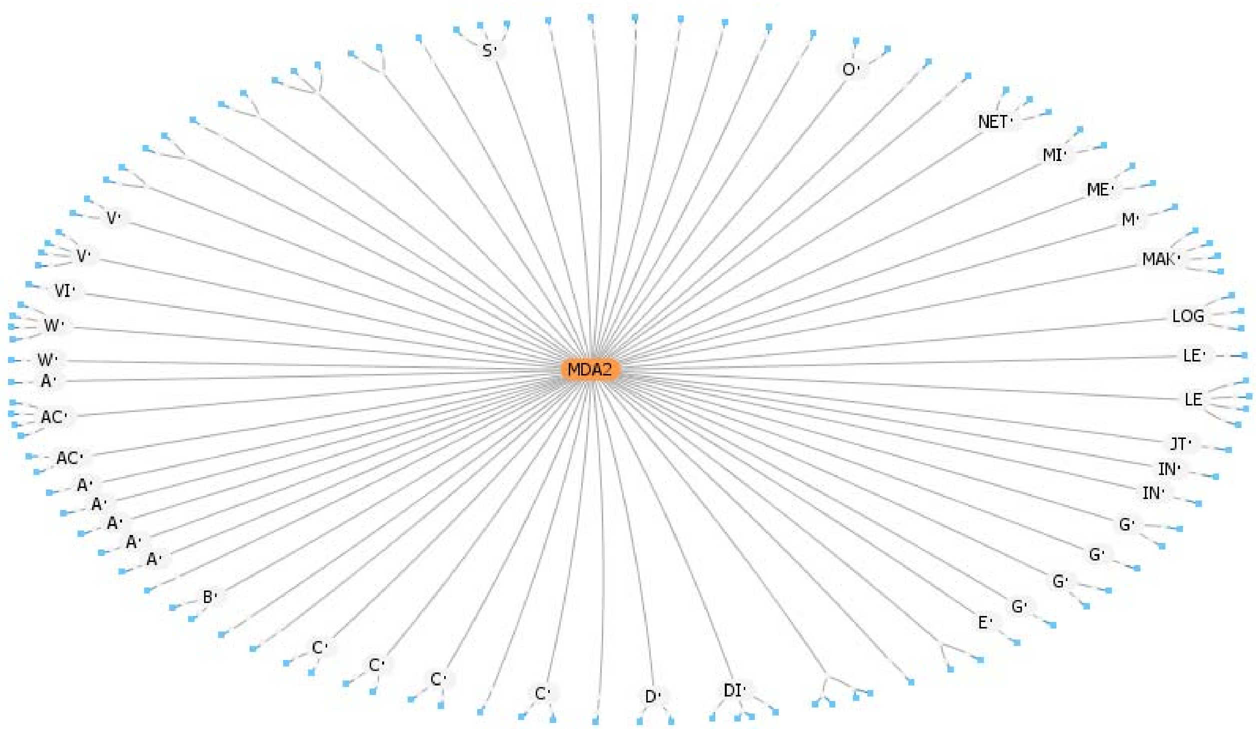

Figure 35. Hyperbolic Tree Visualization of TW08 Objective Data

In Figure 36, the view is drilled down to a specific feature cluster. In this case, “Distributed” has been clustered with “Planners,” “Partners,” and “Networks.” Each of these relationships is also associated back to the specific tool used in TW08. In this case, feature terms from this cluster were associated with 4 systems used in TW08, including Google Earth, MIDAS, Global Trader, and CMA.

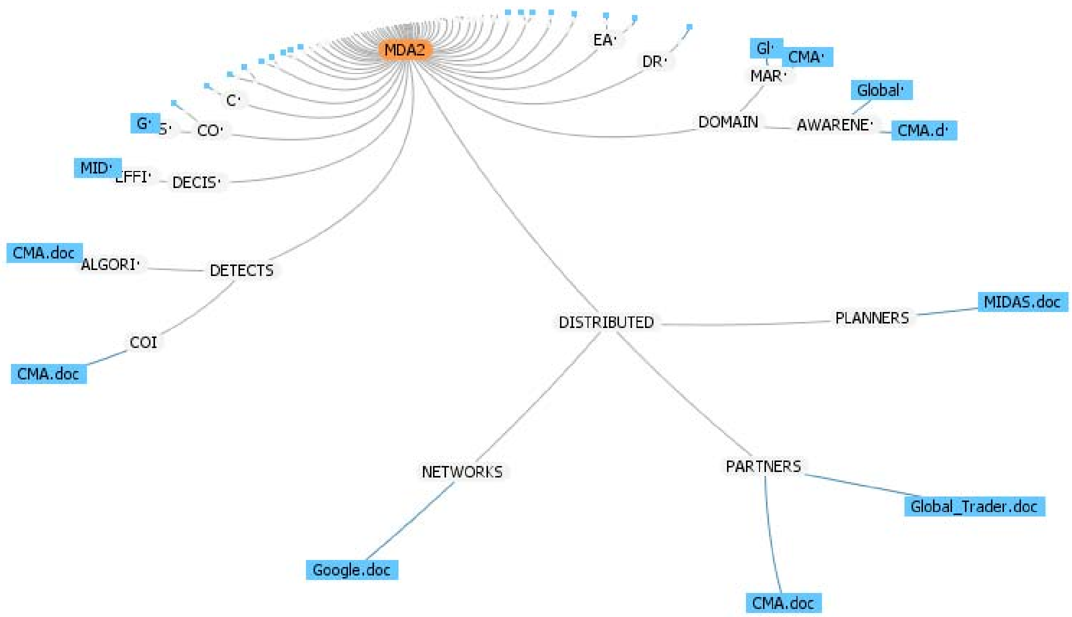

Figure 36. Hyperbolic Tree Graph of Feature Cluster from TW08 Objective Data Set

Another visualization that was useful in displaying this data was the icicle tree graph. In Figure 37, the same nodes are laid out in a chart. A user can click on a specific term, in this case “Distributed,” and see the feature cluster as well as the tools associated with the cluster.

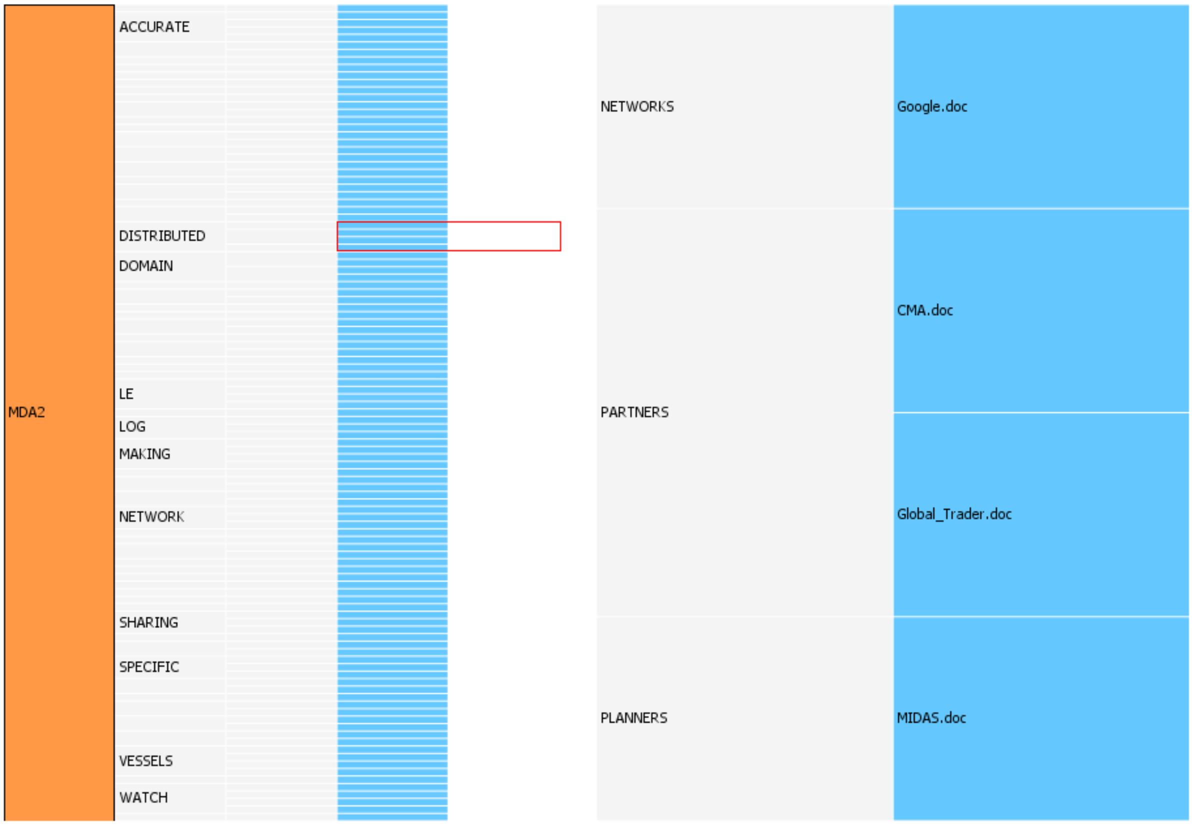

Figure 37. Icicle Tree Graph Representing a Feature Cluster from TW08

The visualizations in this chapter represent data that were interesting to the authors and show potential utility for program decision-makers. Other visualizations could be produced depending on the needs of the decision-maker and/or program. These visualizations are powerful tools that can be used to improve Program Self-awareness by displaying relationships among system features within and across programs that would otherwise be very difficult or impossible to recognize.

V. Conclusions and Recommendations

A. Conclusions

This research has explored the problem of duplication, lack of re-use and collaboration in the DoD acquisition and has followed the intuition that increased Program Self-awareness, enabled by KM tools and collaboration, will improve acquisition process efficiencies in these areas. The CIFE research methodology depicted in Figure 38 was used to guide the research, as summarized in Table 2.

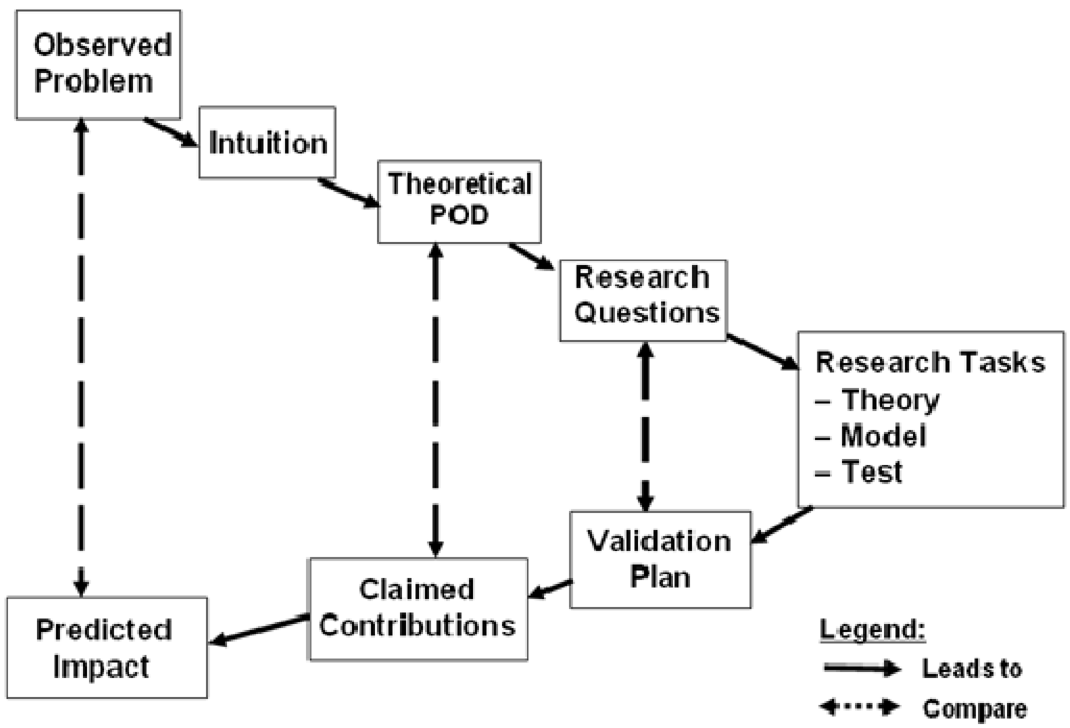

Figure 38. CIFE Research Methodology
(Ho, 2007, p. 2)

Table 2. Thesis-applied CIFE Research Methodology (Ho, 2007, p. 2)

Observed Problem and Intuition	*Theoretical POD / Gap*	*Research Question*	*Data Source*
Duplication of effort, limited re-use and collaboration in DoD Acquisition Programs due to lack of Program Self Awareness	Systems Theory and Congruence Model – a model to understand the acquisition environment and Program Self Awareness	How can Knowledge Management methods and tools be used to improve Program Self Awareness, collaboration and re-use in complex acquisition programs?	Case study of Navy MDA Program -Develop MDA Data Mart from structured and unstructured program data sources
Improved DOD Acquisition Program efficiency and effectiveness	Better understanding of DoD Acquisition System knowledge environment and potential for improved Program Self Awareness enabled through KM tools	- Collaboration complex and not efficient - Lack of Program Self Awareness due to complexity and culture - KM tools can be applied to improve MDA Program Self Awareness and decision making	- Mine Data Mart to derive system "feature" data and develop visualization tools to show relationships among system attributes - Identify duplication and opportunities for collaboration, re-use and efficiency
Predicted Impact	*Contribution*	*Findings*	*Data Analysis*

This research finds that KM tools such as data and text mining algorithms, applied to a data mart of structured and unstructured programmatic documents, can unearth relationships among system features which would otherwise be extremely difficult or impossible to recognize. The visualization products generated by these KM tools could be used by program decision-makers to identify duplication of effort, capability gaps and opportunities for component re-use and collaboration within and across acquisition programs and RDT&E activities. This research also finds that these visualization products could be used by decision-makers to measure program progress towards requirements traceability and system best-of-breed analysis in the RDT&E phase of the acquisition process.

This research also concludes that the development of Program Self-awareness by program and portfolio decision-makers is fundamental to the successful implementation of OA and CPM reform initiatives. The KM tools and visualization products applied in this research have the potential to improve Program

Self-awareness by highlighting system commonalities and/or clusters of like-component features. The data cluster visualization results shown in Chapter IV may prove especially useful in identifying previously unknown relationships among programs and system features, which could lead to increased collaboration and re-use in OA and SoS acquisitions. The potential impact of improved Program Self-awareness could be improved resource-allocation decision-making, which could reduce acquisition costs and system development timelines.

The data and text mining models and tools applied in this research are extremely complex in design and require significant expertise to effectively employ—especially on a data mart of the scale that would exist in a large acquisition program or capability portfolio. This research leveraged KM expertise at the NPS and a variety of cutting-edge mining algorithms to perform an iterative process of understanding, cleansing and analyzing mining results from a relatively small data mart of structured and unstructured program data. This process is not trivial and requires a team of KM experts and program experts working together to produce useful results. These results are produced in the form of data visualizations that can then be used to support improved Program Self-awareness and decision-making. That said, current efforts to improve Program Self-awareness in acquisition programs (such as the DoD MDA Program) utilizing human analysis of uncorrelated spreadsheets, two-dimensional lists and unstructured documents are far more expensive and less effective at producing useful results to support decision-making.

This research also finds that the size and complexity of the DoD Acquisition System contributes significantly to the poor congruence or fit among system components, which leads to information stovepipes, duplication of effort, barriers to collaboration and re-use of components. Acquisition programs such as the DoD MDA Program exist at an even higher level of complexity due a requirement to integrate across service, agency and international acquisition enterprises. KM tools and collaboration can be employed to address symptoms of poor fit by providing a sort of glue or patch to improve Program Self-awareness but do not alleviate the need for significant reform of the DoD Acquisition System—including organizations, processes, and people—to address the root causes of system inefficiencies.

It is also important to note that this research does not suggest that the DoD acquisition decision-makers are making poor decisions or are not working extremely hard under great pressure to deliver capabilities desired by the warfighter in a timely manner. The authors recognize that the complexity of the DoD Acquisition System makes informed decision-making and Program Self-awareness extremely difficult given the myriad stakeholders, processes and organizations involved during all phases of system development. Figure 39 highlights the complexity of the acquisition decision-making environment to capture this point with a bit of humor.

Figure 39. The Acquisition Warrior |
(DAU, 2009)

This research finds the DoD MDA Program is representative of large SoS acquisition programs in that decision-makers desire increased Program Self-awareness in order to control acquisition activities and resources. Program Self-awareness is extremely difficult to achieve due, in part, to the system complexity and cultural issues addressed in Chapters II and III. The fact that available KM technology is not being applied to support program decision-makers was also apparent during this research. Decision-makers are left the overwhelming task of managing large programs and portfolios with fractured, incomplete and uncorrelated information on which to base decisions. The researchers found gathering programmatic information on the DoD MDA Program to populate the data mart was cumbersome despite the cooperation of many within the program. This experience exposed a need for a central data repository and/or web portal to host the latest and historical program information.

Collaboration technologies such as web portals are fundamental to many commercial development programs and have been credited with improving decision-making and efficiency in business applications—very similar problems to those facing the DoD acquisition decision-makers. The incremental employment of KM and collaboration technologies in an information-sharing culture could improve SoS acquisition decision-making by developing improved Program Self-awareness through discovery of relationships in massive amounts of previously uncorrelated data. As discussed in Chapters II and III, in applying these technologies, PMs must consider the resultant impact to organizations, people and processes. In addition, the application of such technologies will require leadership and transformation to promote a culture of information sharing and collaboration.

B. Recommendations and Future Research

Given the conclusions and findings above, it is important to note that the KM methods and tools applied in this research do not provide the “magic bullet” to eliminate inefficiency in the DoD Acquisition System. These tools hold great promise for improving the quality of information available to support decision-making but require a range of actions (including those described below) to preclude false starts and/or failed implementation.

The authors strongly recommend a continuation of the research of KM-enabled Program Self-awareness. This follow-on research could refine the visualization products applied in this research and explore other applications which would enable user-controlled drill-down to further expose information useful to decision-makers. This follow-on research could also develop measures of program performance by providing correlation and/or traceability of system features to requirements; such research could also expose the potential for these tools to facilitate definition of system features and common vocabularies based on semantic relationships generated during the KM processes.

It is the recommendation of the researchers that a program similar to the DoD MDA Program be selected as a test case to apply the KM methods and tools described in this research. The researchers believe this test case would generate useful results and provide an incremental success and learning curve to streamline subsequent application to other acquisition programs.

The DoD should invest in KM and collaboration technologies and move beyond the current acquisition information environment, which is comprised largely of information silos contained in e-mails chains, phone and video conferences, and other isolated data sources of program information. Acquisition programs and related COIs should develop web portals to serve as information repositories of the latest program information—such as requirements documents, development updates, and test and experimentation data. These program documents could feed the program data mart for application of the KM tools described in this research. The program portal could also host program-related blogs and information wikis to promote Program Self-awareness and collaboration within and across related programs and activities. These web portals can provide for controlled access but must not be overly restrictive or inaccessible if they are to accommodate unanticipated membership and participation across programs and/or related COIs.

This research has also highlighted recent frustration with the DoD Acquisition System at the highest levels of government. There is clearly an active search for sweeping reform solutions to address the DoD Acquisition System inefficiencies and their resultant poor outcomes. The authors recommend these reform efforts go beyond the historical approaches of adding layers of additional executive oversight and processes through program reviews and decisions gates. The researchers believe reform efforts should devote significant time, energy, and resources to develop KM and collaboration technologies such as those described in this research. These investments could improve Program Self-awareness and promote a culture of information sharing and collaboration in the DoD Acquisition System. As Secretary Gates and Undersecretary Young have recently pointed out, the DoD Acquisition System must do better at sharing information—much as the Services are achieving battlefield success through Joint and net-centric interoperability. Perhaps the reform efforts could include a vision towards "net-centric acquisition" and culture that leverages and applies the principles of net-centric warfare to the DoD Acquisition System.

This research has detailed the potential utility of KM tools and collaboration applied to the DoD Acquisition System. The impact of these technologies on other elements of the Defense Acquisition System has also been discussed, to include the need for a holistic system analysis towards achieving system congruence. This research concurs with the conclusions and recommendations of the DSMC researchers discussed in Chapter II, especially their call for incremental KM implementation approaches built on small successes, development of a supporting KM implementation strategy, and sustained executive leadership throughout implementation of the process described in Figure 8. This research further recommends the following KM implementation success factors from the commercial sector be considered in developing a KM implementation strategy for the DoD Acquisition System (Weir, 2002):

- The project must fit with corporate strategy and business objectives.

- There must be complete buy-in to the project by executives, managers, and users.
- It is important to manage user expectations about the completed project.
- The data warehouse must be built incrementally.
- The PM must build in adaptability.
- The project must be managed by both IT and business professionals.
- The PM must develop a business/supplier relationship.
- Users of KM programs should only load data that have been cleansed and are of a quality understood by the organization.
- PMs should not overlook training requirements.

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Appendix. MDA Data MART Documents

A. DISE-Related Documents

(Note: Though the DISE folder is mentioned in this text, no data from this folder was actually used for this research.)

B. CMA-Related Documents

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- Navy Contract Writing Guide
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- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

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- Budgeting for Capabilities Based Planning
- Capital Budgeting for DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-tem Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC Aegis Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to Aegis and SSDS
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