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Towards Real-Time Program Awareness via Lexical Link Analysis

28 October 2010

by

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Abstract

DoD acquisition is an extremely complex system, comprised of myriad stakeholders, processes, people, activities, and organizational structures. We believe that the application of a data-driven automation system—namely, Lexical Link Analysis (LLA)—can facilitate acquisition researchers' data sense-making dilemma and help reveal important connections (concepts) and patterns derived from dynamic, voluminous, and on-going data collection. In this past year, we have demonstrated the LLA method to discover valid associations among disparate, unstructured data sets that would have otherwise required lengthy and expensive man-hours to achieve. We analyzed how Trident Warrior 10 technology capabilities link to classified Navy Urgent Need Statements (UNSs). We validated lexical links against the links identified by human experts in the context of realistic, large-scale data sets. We demonstrated using the LLA methods to discover statistically significant correlations. We discovered that the current congressional budget justification practice for Research, Development, Test and Evaluation (RDT&E) tends to allocate resources to avoid overlapping efforts and to fund new and unique projects. We also discovered that the Program Elements (PEs) that match the warfighters' requirements obtain more overall attention and less budget reduction compared to the ones without matches. This effort will result in assisting acquisition professionals in improving their decision-making among competing programs and in selecting those that satisfy Navy objectives, thus achieving the Navy's goal of improved operational capability.

Keywords: Lexical Link Analysis, text mining, data mining, Program Elements, Major DoD Acquisition Programs, Universal Joint Task Lists, resource allocation, warfighters' requirement, Urgent Need Statements, unstructured data, data-driven automation

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Executive Summary

DoD acquisition is an extremely complex system comprised of myriad stakeholders, processes, people, activities, and organizational structures. Processes within this complex system are encumbered by the development of large amounts of unstructured and unformatted acquisition program data, which, due to its enormity and complexity, is narrowly useful and difficult to aggregate across the enterprise. Acquisition analysts and decision-makers must, however, analyze all types and spectrums of the available data in order to obtain a complete and understandable picture. From the point of view of the work that acquisitions systems must accomplish, there exists a lack of internal congruence between multiple points at which the system should have knowledge of itself and of decision-makers who depend on aggregate information. Current information and decision support systems may not readily help overcome this difficulty, and they present users within the acquisition community with conditions of information overload and limited situational awareness. We believe that application of a data-driven automation system—namely, Lexical Link Analysis (LLA)—can facilitate acquisition researchers' data sense-making dilemma and help reveal important connections (concepts) and patterns derived from dynamic, voluminous, and on-going data collection.

In this past year, we have demonstrated the LLA method to discover valid associations among disparate, unstructured data sets that would have otherwise required lengthy and expensive man-hours to achieve. The LLA technology and methodology was used to uncover and graphically display relationships among competing programs and to compare their features with Navy-driven requirements. In the past year, we tested our method using samples of acquisition data for visualization and validity. The achievements we made in our research over the past year are summarized as follows:

- We analyzed three lists of classified needs statements and links to Trident Warrior 10 technology capabilities with classified Navy Urgent

Need Statements (UNSs), including UNSs from C5F (5th Fleet) and the Integrated Priority List (IPL) from U.S. CENTCOM and NAVCENT. We developed three lexical link visualizations—network, radar, and gap views—to visualize the lexical links of two systems in support of this effort. We tested the initial validity of these LLA results using subject-matter experts.

- We validated lexical links against the links identified by human experts in the context of realistic, large-scale data sets to realize the potential of the LLA method. We collected large-scale, open-source acquisition data sets, including the data of congressional budget justification with Program Elements (PEs) for Research, Development, Technology, and Evaluation (RDT&E); Major DoD Acquisition Programs (MDAPs); programs in Acquisition Category II (ACAT II); warfighters' requirements as defined in Universal Joint Task Lists (UJTLs); and final DoD products defined in the *Program Acquisition Costs by Weapon System*, known commonly as the "Weapon Book" (DoD, 2007), all from the DoD open-source websites. The data spanned eight years (2002–2009), came from three Services (Air Force, Army, and Navy), and totaled about 5,000 documents. The data sets were voluminous and much study had been done before our research to look for relationships among all the data elements.

- We demonstrated how to use the LLA methods to enable human analysts to automatically extract the relationships among the data elements (e.g., to discover statistically significant correlations) that otherwise might require expensive manpower to perform using the large data sets. This effort would normally have required many contractors continually looking through documentation and adding excerpts to categories of interest in various spreadsheets. We found that the LLA-identified links and the human analyst–identified links were reasonably correlated with statistical significance. We also found that the number of lexical links can be used as a metric to measure interdependencies among programs or projects. The LLA method can be potentially used to automatically extract the program interdependencies in the future. We discovered that highly interconnected programs were statistically significantly and more expensive than the less interconnected programs. Using the large data set, we discovered that the past congressional RDT&E budget justification practice from 2002 to 2009 tended to allocate resources (i.e., dollar amounts) to fund new and unique projects instead of projects that overlapped with other projects. We also discovered that the PEs that matched the warfighters' requirements obtained more overall attention and less budget reduction compared to the ones without matches.

- We demonstrated how to use the LLA method to discover the areas in which PEs, programs, and products matched well to the warfighters' requirements as well as to the areas in which they matched poorly to the requirements (i.e., gaps), therefore providing insights for decision-makers to improve future investment decisions. We also showed how to use the LLA method to form a *social network* of PEs to decide the importance of a PE from a network point of view. Such views can be used to influence the decisions of increasing or decreasing program budgets and to improve future resource allocations.

- We researched and laid out a detailed plan for follow-on research to extend the LLA method to an operational capability and to facilitate a wider range of acquisition research applications.

There are two parts of the report for our project. Part 1 summarizes the work done from October 2009–February 2010 and details various areas to which our method can be applied. Part 2 summarizes the work from March 2010–August 2010 and details a focused area of the large-scale data sets from the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD[AT&L]). Part 1 was published in the *Proceedings of the Seventh Annual Acquisition Research Symposium*, held in May 2010.

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Part 1: Report from October 2009–February 2010

Introduction

DoD acquisition is an extremely complex system, comprised of myriad stakeholders, processes, people, activities, and organizations in an effort to provide the most useful capabilities to warfighters at the best possible value to the government. According to the *Chairman of the Joint Chiefs of Staff Instruction for Joint Capabilities Integration and Development System* (JCIDS; Chairman of the Joint Chiefs of Staff [CJCS], 2009), there are three key processes in the DoD that must work in concert to deliver the capabilities required by the warfighters: the requirements process; the acquisition process; and the Planning, Programming, Budget, and Execution (PPBE) process. In particular, the requirements process is implemented in a process called the Joint Capabilities Integration and Development System (JCIDS), as shown in Figure 1. JCIDS plays a key role in identifying the capabilities required by the warfighters to support the National Defense Strategy, the National Military Strategy, and the National Strategy for Homeland Defense. The Defense Acquisition System (DAS) looks at enterprise asset acquisition based on JCIDS requirements, and PPBE is focused on the management of financial resources in accomplishing enterprise asset creation, sustainment, and reuse. The leadership and decision-makers constantly contend with two major questions:

- Are we responding to strategic guidance and joint capability needs?
- Are we getting the best value for taxpayers?

As shown in Figure 1, JCIDS alone produces a large amount of detailed documents (e.g., Initial Capabilities Document [ICD], Formal Capability Development Document [CDD], documents for material solutions or doctrine, organization, training, materiel, leadership and education, personnel, or facilities [DOTMLPF], Change Recommendations [DCR] for non-material solutions, and Capability Production Document [CPD]). Each involves diversified stakeholders such as

sponsors, program managers, developers, the Joint Requirements Oversight Council (JROC), and the Milestone Decision Authority (MDA).

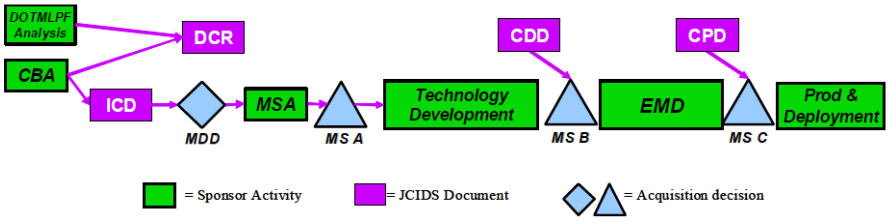


Figure 1. JCIDS Process and Acquisition Decisions
(JCIDS, 2009)

Warfighters' requirements are documented in Universal Joint Task Lists (UJTLs) or Joint Capability Areas (JCAs), which are collections of required capabilities functionally grouped to support mission analysis, capability analysis, strategy development, investment decision-making, capability portfolio management, and capabilities-based force development and operational planning.

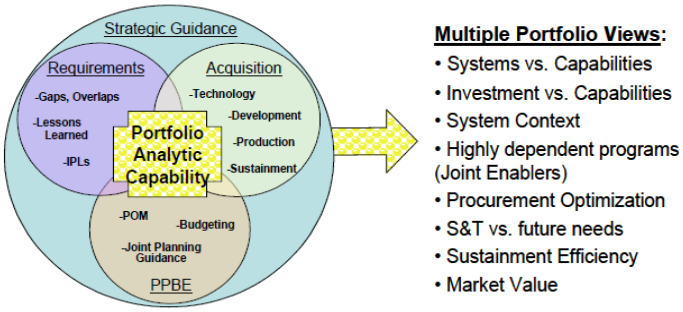


Figure 2. Portfolio Analytic Capability
(Appleton, 2009)

In summary, the major challenges in the current process can be summarized as follows:

- To make optimal investment decisions, acquisition managers must analyze a full spectrum of data, including data that encompasses capability requirements, planning, development, integration, testing, architecture, standards, cost, and schedules. This can be a daunting, if not impossible, task.
- The pace of technology change also requires agile decision-making and challenges program management to maintain constant awareness of what is available for acquisition.
- When considering an overall demand and supply in the trade space management of the Department of Defense, as shown in Figure 2, decision-makers require advanced portfolio analytic capability that can intercept all three business processes of requirements, acquisition, and PPBE under the DoD warfighting strategic guidance in the contexts of many factors, such as systems versus capabilities, investments versus capabilities, highly dependent programs, etc., in order to maximize Return of Management (ROM) and Yield on Cost (YOC; Appleton, 2009).
- The information produced in the process is voluminous and unformatted to lend itself to analysis on a large scale. Decision-makers require large-scale automation and discovery tools that can speed up the analysis quickly in response to the pace of technology change, therefore adapting DoD program development and associated funding mechanisms in an agile manner. The decision-makers also require a much more fine-grained level of analysis for program-to-program elements analysis using the unstructured documents directly. This is a big leap that is not provided by the current analysis capabilities.

One method to reduce unknown performance measures is through participation in annual large-scale field experimentation exercises as part of the Research, Development, Test, & Evaluation (RDT&E). These experiments can provide close interaction among users, developers, the test community, and decision-makers. At the Distributed Information Systems Experimentation (DISE)

laboratory at the NPS, we collect and analyze data and help the Navy learn and manage information and knowledge resulting from large-scale annual experimentation (e.g., Trident Warrior and Empire Challenge). We believe this experiential data, together with Lexical Link Analysis methods, will produce deepened awareness of current program effectiveness for acquisition decision-makers.

Methods

Program Self-Awareness

Here we consider that the cognitive interface between decision-makers and a complex system may be expressed in a range of terms or *features* (i.e., specific vocabulary or lexicon, to describe attributes and the surrounding environment of a system). This process is similar to, or can be modeled, using human cognitive processes, where the simplest form of such a model is relationships between noun/verb. In math, the model becomes variable/function; in engineering it becomes operand/operator; in information technology, it becomes data/process or description/procedure. We have borrowed from notions of *awareness*, and implement the term self-awareness of a complex system as the collective and integrated understanding of system features. A related term, *situational awareness* is used in military operations and carries with it a sense of immediacy and cognitive understanding of the warfighting situation. Here, system self-awareness, or program awareness (Gallup, MacKinnon, Zhao, Robey, & Odel, 2009), allows decision-makers to be aware of what systems, programs, and products are available for acquisition, how they match warfighters' needs and requirements, recognize relationships among them, improve efficiency of available collaboration, reduce duplication of effort, and re-use components to support cost effective management—with greater immediacy, possibly in real-time.

Through our research, we present a data-driven automation method, namely, a Lexical Link Analysis (LLA) for program self-awareness. This methodology is

demonstrated by extracting realistic sample data related to systems and programs included in experimentation programs, Urgent Needs Statements (UNS), and CENTCOM/NAVCENT warfighting gap/priority lists, a large-scale data set from the Office of the Secretary of Defense (OSD) with regard to Major Defense Acquisition Programs (MDAPs), and Acquisition Category II (ACATII) weapon systems and their RDT&E documentations.

Lexical Link Analysis (LLA)

Data mining includes analytic tools that may be applied to both structured and unstructured data to confirm previously determined patterns, or to discover new patterns that are yet unknown. Text mining is the application of data mining to unstructured or less structured text files. Text mining represents an emerging field with a wide range of software implementing innovative visualization and navigation techniques. These techniques graphically represent networks of documentation that are related conceptually. Visualization of relationships enables concept discovery, automated classification, and understandable categorization of unstructured documents.

Lexical analysis ("Lexical Analysis," 2010) is a form of text mining in which word meanings are developed from the context from which they are derived. Lexical analysis can also be used in a learning mode, where such words and context associations are initially unknown and are constantly being "learned," updated, and improved as more data become available. Link analysis, a subset of network analysis that explores associations between objects, reveals the crucial relationships between objects when collected data may not be complete. Lexical Link Analysis (LLA) is an extended lexical analysis and link analysis enabled in a learning mode.

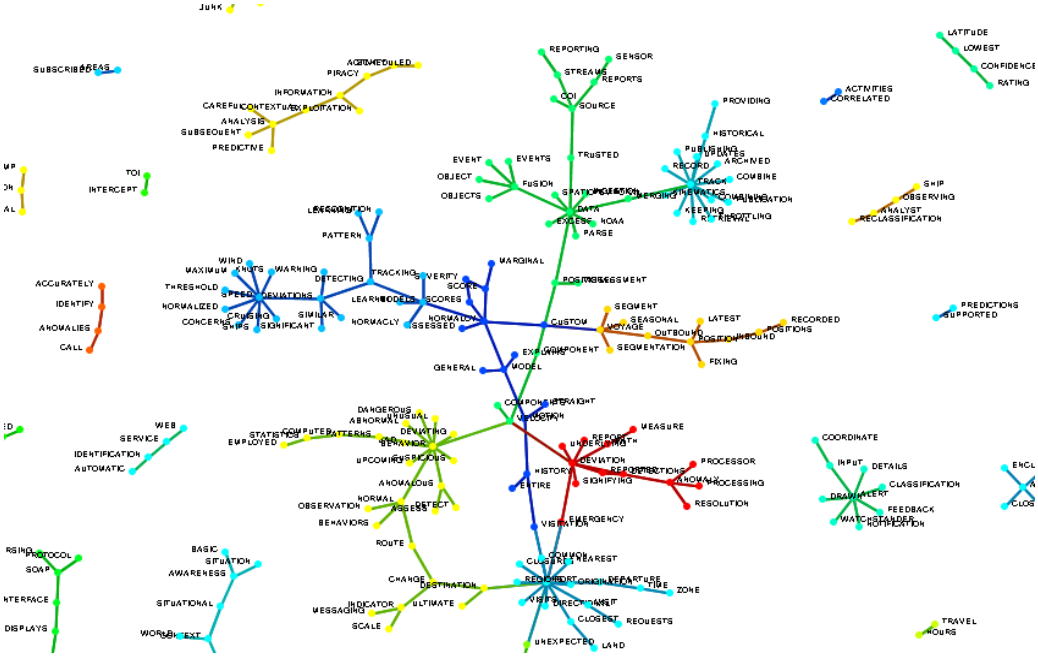


Figure 3. A Word Hub Showing the Detail on the Linkage

This approach clusters words and then correlates words with their textual contexts (co-occurrence), and produces a data-driven and dynamic word network. This approach is related to a number of extant tools for text mining, including Latent Semantic Analysis (LSA; Dumais, Furnas, Landauer, Deerwester, & Harshman, 1998), advanced search engine (Foltz, 2002), keyword analysis and tagging technology (Gerber, 2005), and intelligence analysis ontology for cognitive assistants (Tecuci et al., 2007). What results from this process is a learning model—like an ethnographic *code book* (Schensul, Schensul, & LeCompte, 1999)—containing descriptions of both patterns and anomalies and generated using encountered terms. As an example shown in Figures 3 and 4, we applied our approach to Maritime Domain Awareness (MDA) technologies that were evaluated in Trident Warrior 08. Figure 3 shows a visualization of LLA with connected keywords or concepts extracted from the documents of MDA technologies. Words are linked as word pairs that appear next to each other in the original documents. Different colors indicate different clusters of centralization among word groups. They are produced using a link analysis method, which is a social network grouping method

(Girvan & Newman, 2001): words are connected as shown in one color as if they are in a social community. A *hub* is a word centered with a list of other words ("fan-out" words) centered around other words. For instance, in Figure 4, the word *behavior* is centered with *suspicious*, *bad*, *dangerous*, *abnormal*, *usual*, and *anomalous*, etc., showing the ways to describe *behavior* in the MDA area.

Figures 5 and 6 show a visualization of lexical links between Systems 1 and 2. Each node is a feature, or word hub; each color refers to the collection of lexicon (features) to describe a system, the overlapping area nodes refer to lexical links between systems. The nodes toward the two ends of the links represent the unique features related to each system.

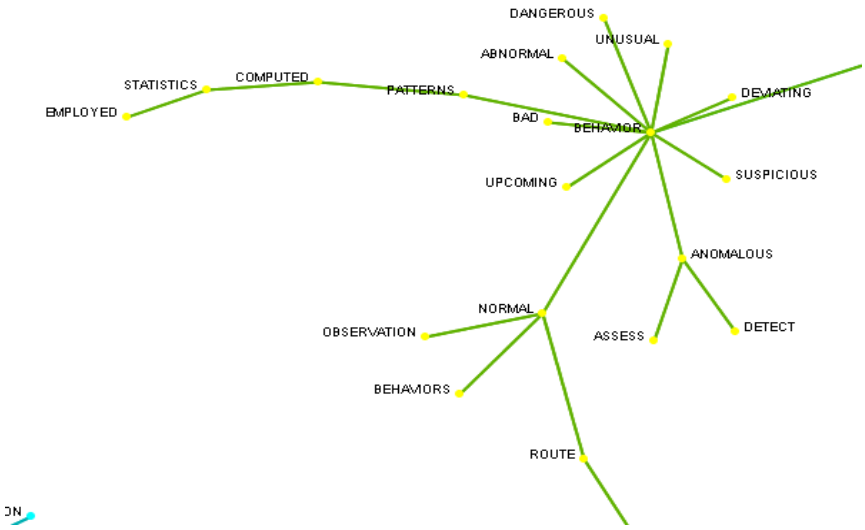


Figure 4. A Word Hub Showing the Detail on the Linkage in Figure 3

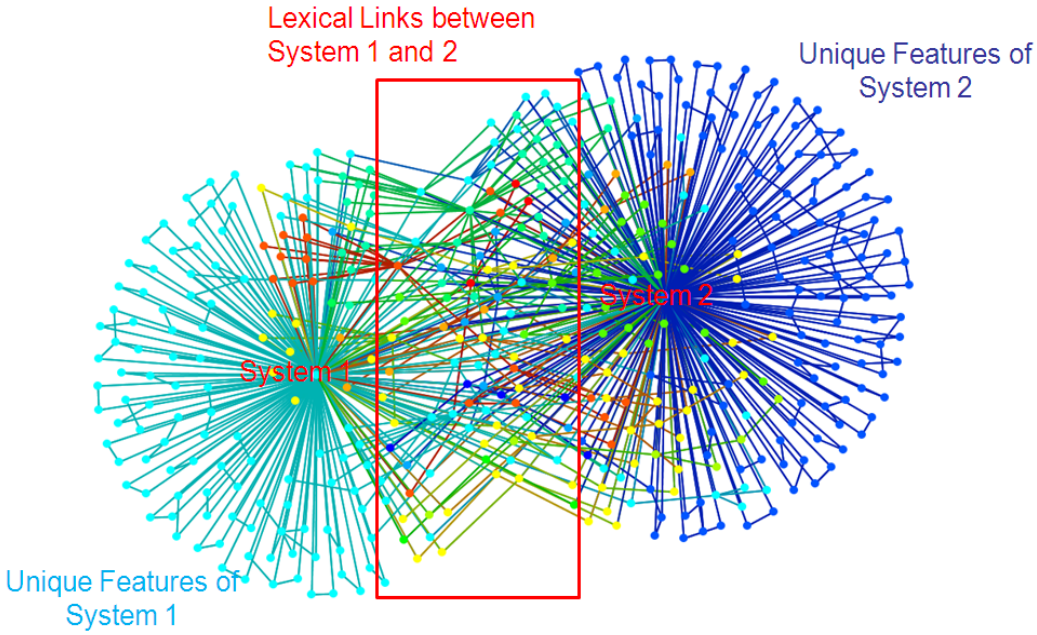


Figure 5. Visualization of Lexical Links

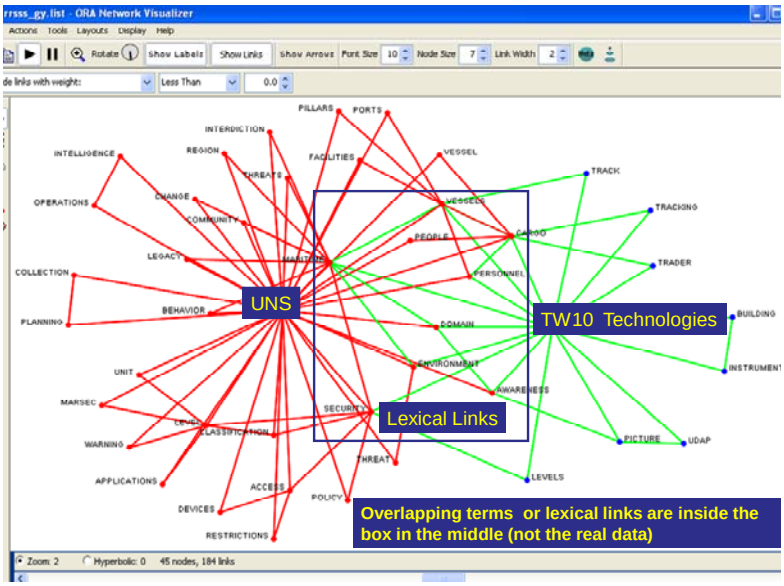


Figure 6. Overlapping Terms or Lexical Links, Shown in the Middle of Two Word Networks as the Result of the LLA Analysis

In summary, LLA provides a methodology and tools to address the following specific areas that can impact acquisition decision-making:

- LLA provides a metric to link warfighters' needs with capabilities by directly comparing the documents that resulted from the business process—for example, linking programs, specifically MDAPs, to operational capabilities. The number of lexical links, extracted to reflect the meaning of the documents between two systems or programs, can be a measure of consensus or synergy between the two. This compelling perspective is central to the notion of portfolio management, for example, to answer the questions: What are the programs (e.g., MDAPs) related to a given capability? What are the gaps of warfighters' requirements not addressed by current programs? Currently, human analysts are responsible for answering these questions manually. Automation is needed to facilitate human analysis and to process large volumes of data quickly.

- LLA visualization is also important for acquisition decision-making. Producing a picture illustrating where the needs are met and where the overlapping efforts and gaps are will allow decision-makers to become aware of the overall situation, thus allowing them to see trends in a larger, broader scale and in a longer timeframe. For example, combining the analyses of the Army, Navy, and Air Force from RDT&E and procurement documents might show the linkages within and among programs as they mature from development to production. Modified programs can be illustrated to show the trend toward (or deviation away from) warfighters' needs during the program's life span. One may also visually see the resource sharing (or wasting) practices and note opportunities for growth when all the data can be summarized in a discernable picture.

- LLA discovers latent, implicit, or second-order relationships by examining the detailed budget justification documents. In general, programs retain their identities from development to production; however, they may change their names or be re-designated resulting from a milestone decision or other action. The "New Attack Sub" or "NSSN" during development, for instance, was referred to as the "Virginia Class Sub" in production. The "Joint Strike Fighter" and the "F-35" are also synonymous. The official "decoder" for these transformations is the Defense Acquisition Management Information Retrieval (DAMIR) system. We note that the mapping of MDAPs to their predecessors, successors, constituents, or dependent partners is non-trivial and is, in fact, one of the fundamental challenges for acquisition analysts.

- LLA could affect the fundamentals of acquisition processes through automation and discovery. In the defense acquisition community, decision-makers are interested in determining the costs of these

programs relative to their predicted baselines (e.g., Milestone B or C). They must also determine why costs change over time. Historically, acquisition researchers only considered endogenous factors (e.g., poor program management skills) as drivers of cost changes. The notion of interdependence as a potential driver of cost may be determined by LLA. It may also help determine whether this interdependence among programs may be manifested in the sharing of resources among programs, as described by the budget artifacts. Budget artifact data are voluminous and unstructured, which makes empirical analysis extremely difficult—if not humanly impractical. Previous research has been done in this area using manually identified program interdependencies (M. Brown, personal communication, 2010) and has made great progress in establishing that interdependence exists and how it might be correlated with the program costs. LLA could automate this process of identifying interdependencies and, thus, reveal aspects of interdependence that would otherwise remain obscure.

LLA Processes

The LLA Analysis

We began at the Naval Postgraduate School (NPS) by using Collaborative Learning Agents (CLA; Quantum Intelligence [QI], 2009) and expanded to other tools, including AutoMap (Center for Computational Analysis of Social and Organizational Systems [CASOS], 2009) for improved visualizations. Results from these efforts arose from leveraging intelligent agent technology via an educational license with Quantum Intelligence, Inc. CLA is a computer-based learning agent or agent collaboration, capable of ingesting and processing data sources. Each CLA is capable of revealing patterns that occur frequently and anomalies that occur rarely. Anomalies that might be interesting are thus revealed so that human analysts are alerted and can further investigate them. The CLA is able to separate the patterns from anomalies using a patterns and anomalies separation algorithm in each CLA to select feature-like word pairs for the LLA method.

The following are the steps for the LLA analysis:

- Read two documents into the CLA (e.g., Urgent Needs Statement [UNS]) and a targeted technology document set (e.g., Trident Warrior 2010 [TW10]).
- Select feature-like word pairs based on clusters using the CLA anomaly search method (Zhao & Zhou, 2008a).
- Apply a social network algorithm to group the word pairs into word categories.
- Apply AutoMap to visualize the associations of the requirement document set (UNS) and targeted technologies (TW10) document sets, as shown in Figures 5 and 6.
- Generate lexical link matrices used for further analyses, as shown in Figures 8, 9, and 10.

When mining text data or performing lexical analysis, we also apply entity extraction, known as Named Entity Recognition (NER; Nadeau, Turney, & Matwin, 2006; "Named Entity Recognition," 2010), which recognizes named entities such as persons, organizations, locations, expressions of times, quantities, monetary values, and percentages in context. The extracted entities could also be examined separately. Excluding these modifiers from the terms resulting from Lexical Link Analysis (LLA) can provide an improved comparison by focusing on term semantics.

In some applications, differentiating nouns from verbs and adjectives, or having the ability to parse the syntax into nouns, verbs, subjects, and objects, could be helpful to acquisition managers to develop understanding. We also use a Part-of-Speech (POS) *tagger* as pre- or post-processing filters for this purpose. A POS tagger is a piece of software that reads text in some language and assigns parts of speech to each word, such as a noun, verb, adjective, etc. We have chosen the Stanford Natural Language Processing (NLP) tool (Stanford National Language Processing Group, 2009; Toutanova, Klein, Manning, & Singer, 2003) to perform this task. The POS taggers are usually language dependent. Our method is statistically based and can, therefore, employ NER and POS as pre- or post-processing filters.

Data Sets

We report a case study using LLA comparing U.S. Navy Urgent Need Statements (UNS) with Trident Warrior 10 Technologies. The goal is to compare the two respective data sets, the first one is an Excel file (UNS.xls) representing Urgent Need Statements collected from Command, Control, Communications, Computers and Intelligence (C4I) users. Each urgent need is listed as a statement. The UNS.xls is classified; therefore, details of this document set are not reported in this paper. The second data set is called "Focus Area Assignment TW 10.xls," also in an Excel format. It includes information from each selected technology in Trident Warrior 10.

Trident Warrior (TW) is an annual Navy FORCEnet operational experiment. At the Distributed Information Systems Experimentation (DISE) laboratory at NPS, we collect and analyze data from this and other experimentation venues to help the Navy learn and manage information and knowledge resulting from large field experiments such as Trident Warrior to provide a basis for DoD acquisition of systems and technologies. The technology information includes each technology's objective(s) for the experimentation, including Concept of Operations (e.g., how a warfighter will utilize it), and what each technology provider intends to learn from the experimentation (e.g., decrease timeline, standardized process, and/or reduced workload, etc.). TW data also includes decisions that may affect experimentation findings.

Result Presentation and Visualization Tools

Figure 7 illustrates a result summary revealing terms or word pairs combined into word categories, which are displayed in a radial graph. The categories with radius = 2 represent overlapping word categories that are found in both requirements (UNS) and technologies (TW10). The categories with radius = 1 indicate where gaps exist (i.e., terms that show in the UNS but not in the TW10 technologies or vice versa). We determined that there is between a 60% and 70%

match overlap of technology correlations between UNS and TW 10 technologies. For example, 42 of 67 (62%) of the UNS word categories matched (were served by) with TW10 technologies.

In addition, word network views of lexical links are produced using a network tool, AutoMap. We also developed several outputs to view the detailed LLA analysis results as shown in Figures 8, 9, and 10. Figure 8 shows an Excel document output, including a few columns of information as follows:

- Terms: Matching terms or word categories discovered automatically via the LLA method.
- UNS: Values can be 0, 1, 2, specifically:
  - 0: terms not found in UNS,
  - 1: terms only found in UNS, and
  - 2: terms found in both UNS and TW10.
- UNS IDS: UNS documents in which the terms can be found.
- TW10: Values can be 0, 1, 2.
  - 0: terms not found in TW10,
  - 1: terms only found in UNS, and
  - 2: terms found in both UNS and TW10.
- TW10 IDS: TW10 documents in which the terms can be found.
- Tech Features: Terms that only belong to TW10.
- As one scrolls down, if there is “0” in the TW10 column, then it indicates a gap area for TW10. Similarly, in scrolling further, if there is a “0” in the UNS column, then this indicates a gap in UNS.

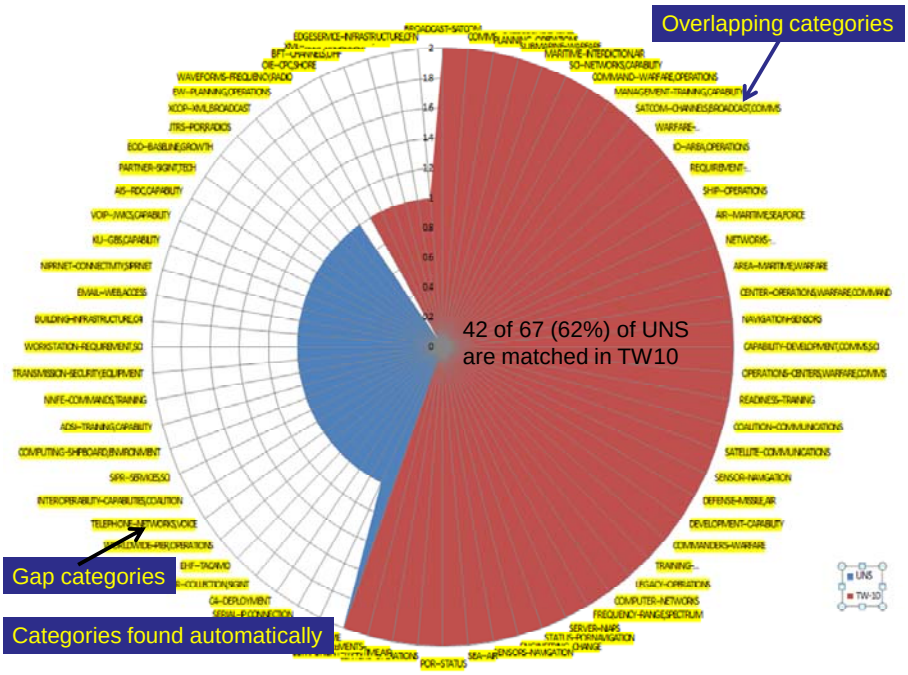


Figure 7. Resulting View and Visualization Illustrating "Overlapping" and "Gap" Word Categories

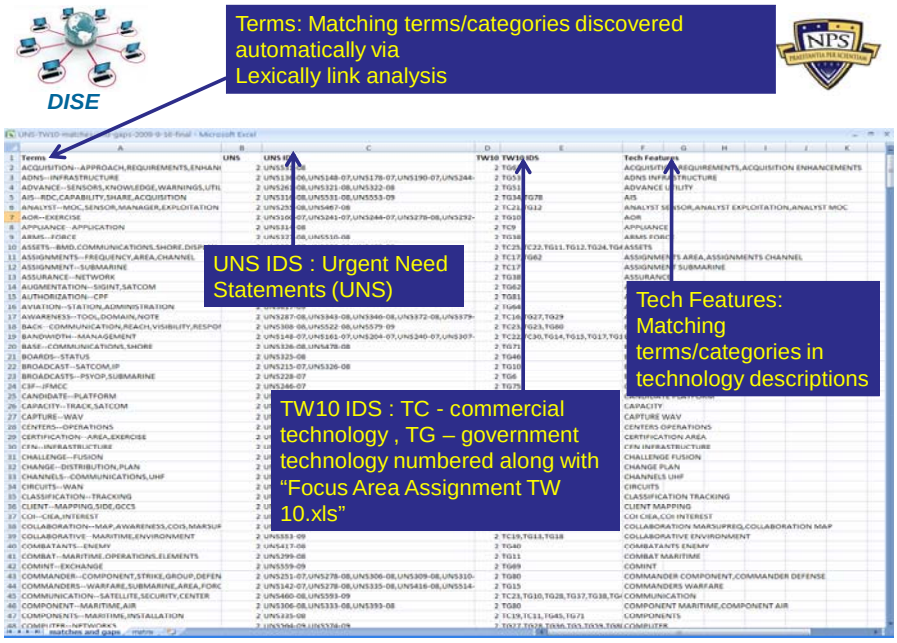


Figure 8. The Spreadsheet View of the LLA Analysis with "Matched" Terms and "Gap" Terms

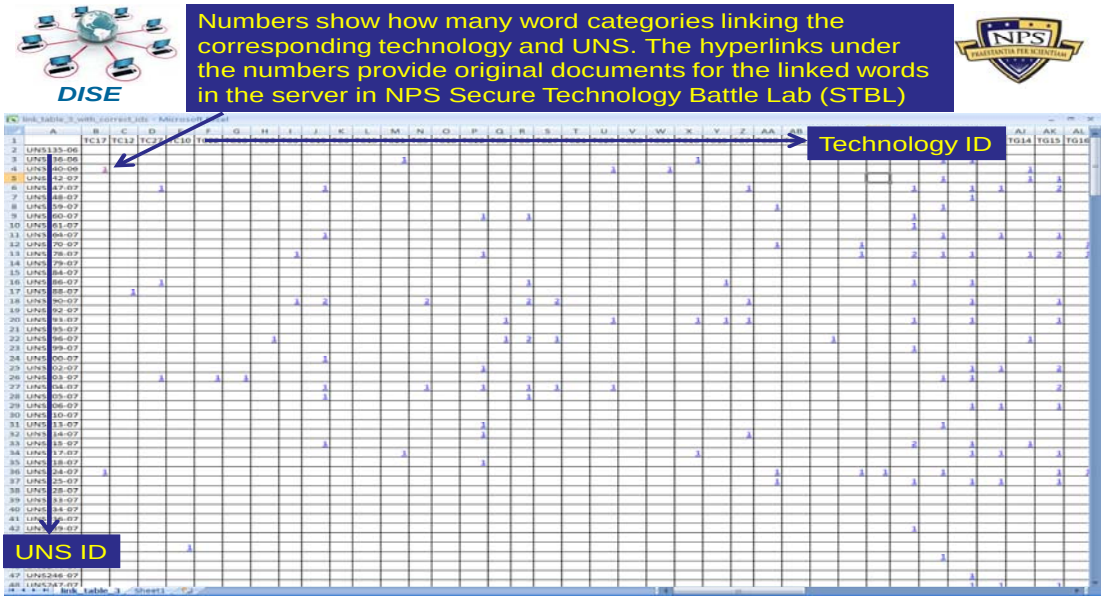
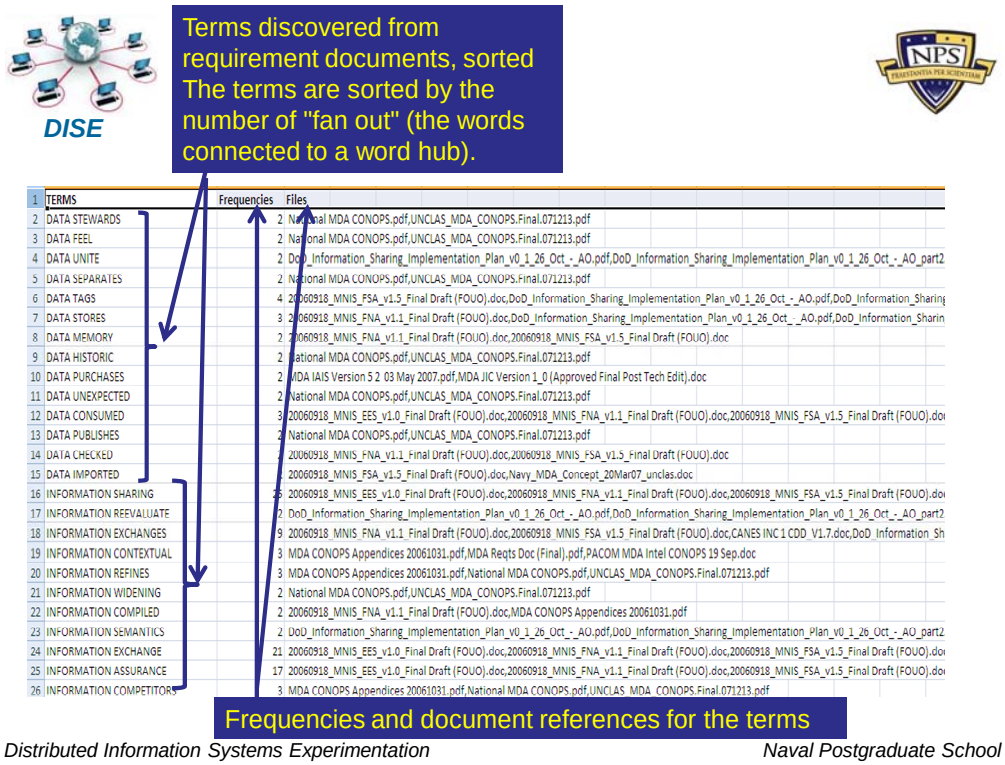


Figure 9. The Matrix View of the LLA Analysis

Figure 9 shows a matrix view of UNS to TW 10 technologies. Where numbers are seen indicates a numerical reference to the number of the concepts (terms or word categories) included between UNS and technologies that are being satisfied. Usually, there are multiple concepts within a UNS statement and a technology description. Each number is also a hyperlink back to the original document in a server where it is stored (e.g., the server in the NPS Secure Technology Battle Lab [STBL] for classified documents).

These results can be increasingly focused as the Intelligent Agent (IA) becomes tuned to, or learns, what it is that the researcher is attempting to understand. This effort can then become increasingly automated.



	TERMS	Frequencies	Files
2	DATA STEWARDS	2	National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
3	DATA FEEL	2	National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
4	DATA UNITE	2	DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO.pdf,DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO_part2
5	DATA SEPARATES	2	National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
6	DATA TAGS	4	20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc,DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO.pdf,DoD_Information_Sharing
7	DATA STORES	3	20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO.pdf,DoD_Information_Sharin
8	DATA MEMORY	2	20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc
9	DATA HISTORIC	2	National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
10	DATA PURCHASES	2	MDA IAIS Version 5 2 03 May 2007.pdf,MDA JIC Version 1_0 (Approved Final Post Tech Edit).doc
11	DATA UNEXPECTED	2	National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
12	DATA CONSUMED	3	20060918_MNIS_EES_v1.0_Final Draft (FOUO).doc,20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc
13	DATA PUBLISHES	2	National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
14	DATA CHECKED	2	20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc
15	DATA IMPORTED	2	20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc,Navy_MDA_Concept_20Mar07_unclas.doc
16	INFORMATION SHARING	25	20060918_MNIS_EES_v1.0_Final Draft (FOUO).doc,20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc
17	INFORMATION REEVALUATE	2	DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO.pdf,DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO_part2
18	INFORMATION EXCHANGES	9	20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc,CANES INC 1 CDD_V1.7.doc,DoD_Information_Sh
19	INFORMATION CONTEXTUAL	3	MDA CONOPS Appendices 20061031.pdf,MDA Reqts Doc (Final).pdf,PACOM MDA Intel CONOPS 19 Sep.doc
20	INFORMATION REFINES	3	MDA CONOPS Appendices 20061031.pdf,National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
21	INFORMATION WIDENING	2	National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf
22	INFORMATION COMPILED	2	20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,MDA CONOPS Appendices 20061031.pdf
23	INFORMATION SEMANTICS	2	DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO.pdf,DoD_Information_Sharing_Implementation_Plan_v0_1_26_Oct_-_AO_part2
24	INFORMATION EXCHANGE	21	20060918_MNIS_EES_v1.0_Final Draft (FOUO).doc,20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc
25	INFORMATION ASSURANCE	17	20060918_MNIS_EES_v1.0_Final Draft (FOUO).doc,20060918_MNIS_FNA_v1.1_Final Draft (FOUO).doc,20060918_MNIS_FSA_v1.5_Final Draft (FOUO).doc
26	INFORMATION COMPETITORS	3	MDA CONOPS Appendices 20061031.pdf,National MDA CONOPS.pdf,UNCLAS_MDA_CONOPS.Final.071213.pdf

Figure 10. Frequency Count and Document References

Figure 10 shows a summary spreadsheet listing the terms and number of files in which the terms appear. This output can be used to discover concepts (terms) that are cross-validated by at least two documents in a document set. The terms are sorted by the number of "fan out" words (the words connected to a word hub), showing the critical concepts being addressed across multiple documents. The top few sorted word groups (e.g., *data* and *information* in this case) are the key requirements that result in substantial consensus across different levels of requirement generation mechanisms—for example, Joint Integrating Concept (JIC), Joint Capability Areas (JCA), the Universal Joint Task List (UJTL), and user communities such as the U.S. Northern Command, the U.S. Pacific Command, and sponsors that are interested in Interagency Investment Strategies (IISs).

Validity

Several methods were being investigated to validate LLA methods. Currently, we have shown these proof-of-concept results to subject-matter experts (SMEs) from various organizations (e.g., Joint Force Development and Integration, the J-7 Staff) for evaluation and comment. One MDA expert commented on the summary spreadsheet by saying, “it is very useful, particularly the frequency count and the documented reference.” Another SME commented that “LLA has great potential to help us link the UNS with the technology and further fill in the gaps that are out there.” A third SME stated, “This would be highly useful and has great potential to help us in the larger N9/Sea Trial construct and spoke further of the possibility of using LLA at the Joint Warfighter Challenges level.” We will consider quantitative content validation methods between SMEs and LLA, such as correlation and inter-rater reliability scores (Cohen's Kappa; Kerlinger & Lee, 1992), as well as large-scale correlation calculations used in the following sections.

Towards a Large-Scale Example of Program Self-Awareness

We have worked with the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD[AT&L]) on the broader data sets and a large-scale application of program self-awareness via LLA.

Data Sets

Figure 11. DoD Budget Documentation

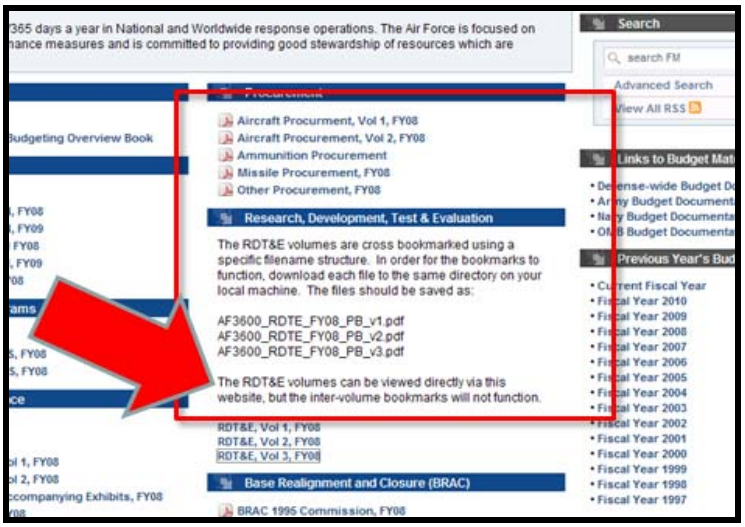


Figure 12. Research, Development Test & Evaluation (RDT&E)

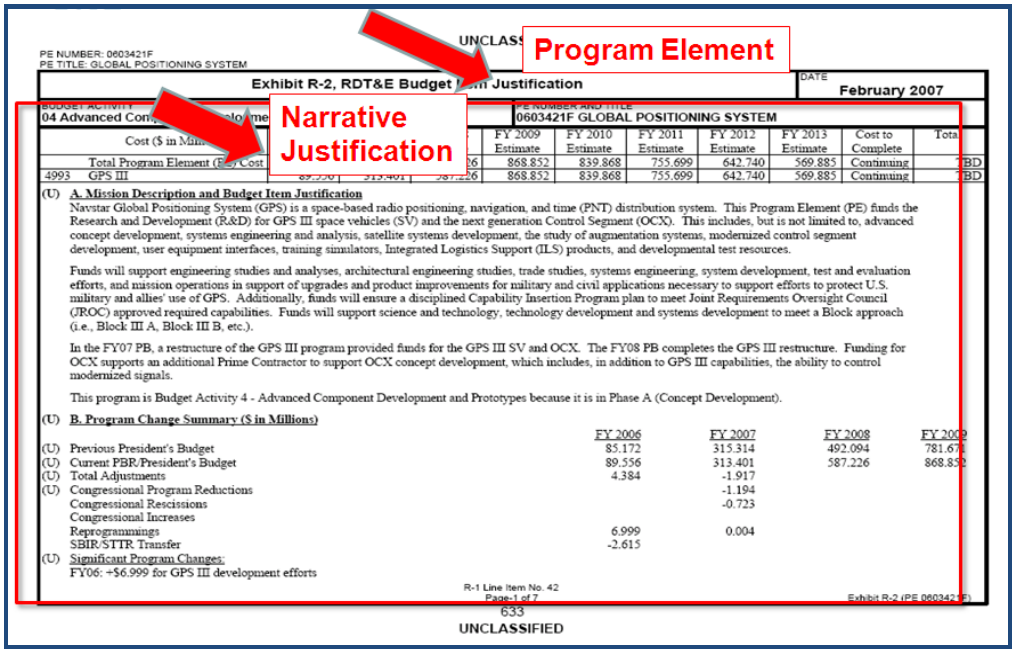


Figure 13. Program Element RDT&E Budget Justification

- We have obtained program element (PE) data, which are used for DoD budget justification each year, as shown in Figure 11. One PE component is Research, Development, Test & Evaluation (RDT&E), which is the budget estimation, allocation, and justification used for programs in the earlier stages of development. The procurement of PE components is the counterpart used for mature products. RDT&E books are obtained from the Air Force, Army (http://asafm.army.mil/Document.aspx?OfficeCode=1200) and Navy (http://www.finance.hq.navy.mil/fmb/11pres/BOOKS.htm) websites.

- The *Weapon Book* (Department of Defense [DoD], 2007), which summarizes weapons and their basic functions and missions, combined total cost from RDT&E and procurement.

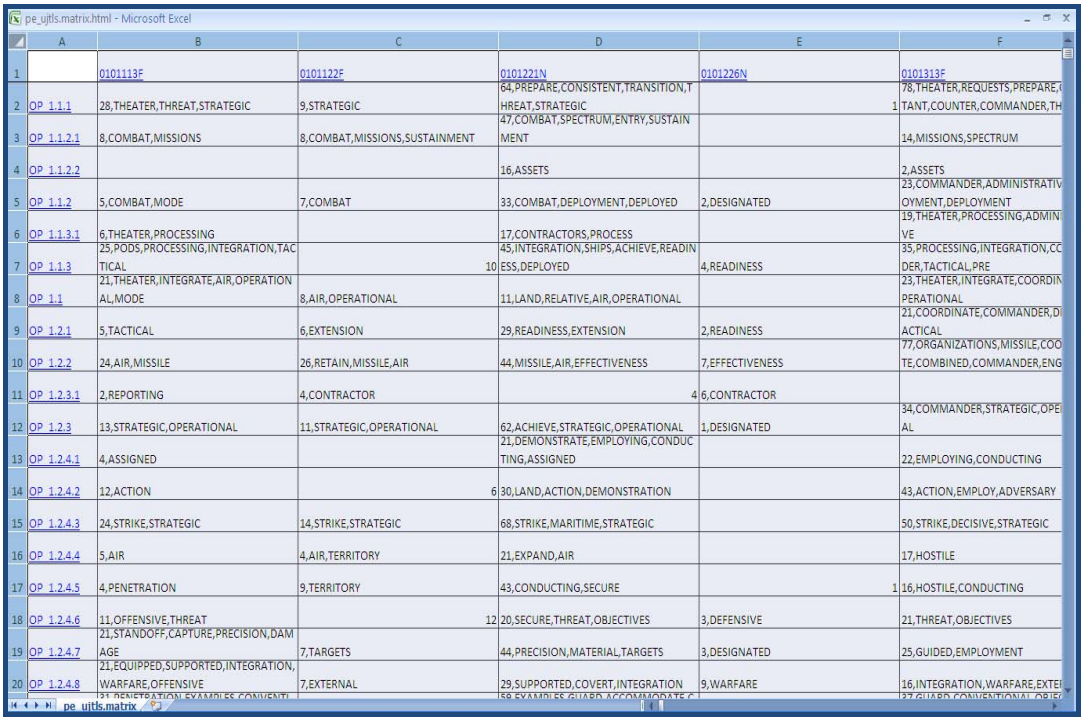
- MMT databases contain cost and schedule information for each program. They consist of MDAPs and weapon systems. MMT databases also contain various program interdependencies identified by human analysts that can be used for validation. MMT databases also contain JCAs and UJTLs mapped to programs that are handmade by human experts.

According to program managers, the data above were so voluminous, unformatted, and unstructured that traditional analysis methods were difficult to apply on this scale; therefore, they are the major focuses of the analysis for LLA.

There were ~500 PEs and ~80 weapon systems extracted from the data with a total size of ~200M. The data was unstructured, and various previous research has been conducted on this data; therefore, it was used to validate the LLA method against human analyses.

LLA Analysis

The focus of this paper is to show that the LLA method is capable of improving system self-awareness. LLA is able to produce the system self-awareness by providing an improved methodology and toolset for automation and discovery of patterns and anomalies within structured and unstructured data. This discovery can be used to produce graphics illustrating gaps and overlaps existing between systems and the needs of the DoD by basing comparisons on the features of each system. This methodology can have the effect of improved savings for the DoD, while developing high-value products that meet warfighters' needs.



	A	B	C	D	E	F
1		0101113F	0101122F	0101221N	0101226N	0101313F
2	OP_1.1.1	28,THEATER,THREAT,STRATEGIC	9,STRATEGIC	64,PREPARE,CONSISTENT,TRANSITION,THREAT,STRATEGIC	1	78,THEATER,REQUESTS,PREPARE,TANT,COUNTER,COMMANDER,TH
3	OP_1.1.2.1	8,COMBAT,MISSIONS	8,COMBAT,MISSIONS,SUSTAINMENT	47,COMBAT,SPECTRUM,ENTRY,SUSTAINMENT		14,MISSIONS,SPECTRUM
4	OP_1.1.2.2			16,ASSETS		2,ASSETS
5	OP_1.1.2	5,COMBAT,MODE	7,COMBAT	33,COMBAT,DEPLOYMENT,DEPLOYED	2,DESIGNATED	23,COMMANDER,ADMINISTRATIVOYMENT,DEPLOYMENT
6	OP_1.1.3.1	6,THEATER,PROCESSING		17,CONTRACTORS,PROCESS		19,THEATER,PROCESSING,ADMINVE
7	OP_1.1.3	25,PODS,PROCESSING,INTEGRATION,TACTICAL	10	45,INTEGRATION,SHIPS,ACHIEVE,READINESS,DEPLOYED	4,READINESS	35,PROCESSING,INTEGRATION,CCDER,TACTICAL,PRE
8	OP_1.1	21,THEATER,INTEGRATE,AIR,OPERATIONAL,MODE	8,AIR,OPERATIONAL	11,LAND,RELATIVE,AIR,OPERATIONAL		23,THEATER,INTEGRATE,COORDINPERATIONAL
9	OP_1.2.1	5,TACTICAL	6,EXTENSION	29,READINESS,EXTENSION	2,READINESS	21,COORDINATE,COMMANDER,DIACTICAL
10	OP_1.2.2	24,AIR,MISSILE	26,RETAIN,MISSILE,AIR	44,MISSILE,AIR,EFFECTIVENESS	7,EFFECTIVENESS	77,ORGANIZATIONS,MISSILE,COOTE,COMBINED,COMMANDER,ENG
11	OP_1.2.3.1	2,REPORTING	4,CONTRACTOR	4	6,CONTRACTOR	
12	OP_1.2.3	13,STRATEGIC,OPERATIONAL	11,STRATEGIC,OPERATIONAL	62,ACHIEVE,STRATEGIC,OPERATIONAL	1,DESIGNATED	34,COMMANDER,STRATEGIC,OPEAL
13	OP_1.2.4.1	4,ASSIGNED		21,DEMONSTRATE,EMPLOYING,CONDUCTING,ASSIGNED		22,EMPLOYING,CONDUCTING
14	OP_1.2.4.2	12,ACTION	6	30,LAND,ACTION,DEMONSTRATION		43,ACTION,EMPLOY,ADVERSARY
15	OP_1.2.4.3	24,STRIKE,STRATEGIC	14,STRIKE,STRATEGIC	68,STRIKE,MARITIME,STRATEGIC		50,STRIKE,DECISIVE,STRATEGIC
16	OP_1.2.4.4	5,AIR	4,AIR,TERRITORY	21,EXPAND,AIR		17,HOSTILE
17	OP_1.2.4.5	4,PENETRATION	9,TERRITORY	43,CONDUCTING,SECURE	1	16,HOSTILE,CONDUCTING
18	OP_1.2.4.6	11,OFFENSIVE,THREAT	12	20,SECURE,THREAT,OBJECTIVES	3,DEFENSIVE	21,THREAT,OBJECTIVES
19	OP_1.2.4.7	21,STANDOFF,CAPTURE,PRECISION,DAMAGE	7,TARGETS	44,PRECISION,MATERIAL,TARGETS	3,DESIGNATED	25,GUIDED,EMPLOYMENT
20	OP_1.2.4.8	21,EQUIPPED,SUPPORTED,INTEGRATION,WARFARE,OFFENSIVE	7,EXTERNAL	29,SUPPORTED,COVERT,INTEGRATION	9,WARFARE	16,INTEGRATION,WARFARE,EXTE

Figure 14. An Example of LLA Matrices of Program Elements (PE) Against UJTLs

First, we want to show how LLA provides a new metric to measure how warfighters' needs are matched with resources and products that are being considered. Figure 14 shows an LLA matrix result using program elements as columns and UJTLs as rows. The number in each cell is a match score generated from the LLA method. Next to the score are word hubs that indicate which term is matched. Sorting this matrix according to the matched scores vertically and horizontally answers the following questions:

- Which programs (e.g., MDAPS) are related to a given capability? Which PEs are related to a given capability?
- How is the acquisition process responding to expressed capability needs? How much of the weapon systems acquisition budget is being allocated to any given operational need (e.g., UJTL)?

Note that this LLA matrix can be generated for any pair of document collections that are desired for comparison (e.g., PEs versus UJTLs, weapon systems versus UJTLs and weapon systems versus weapon systems). When applied to weapon systems (MDAPs) versus UJTLs, we can answer the following question by sorting the LLA matching scores:

- Which capability(ies) does any given MDAP support? How much does the MDAP contribute to this capability?

The LLA matrices may also help to reconcile the gaps between the final products and what warfighters need after the long process of design and development. Furthermore, they may also provide a new perspective for portfolio analysis. A conventional treatment of portfolio analysis is that it is typically expressed as a simple correlation between an MDAP and a capability. This simple correlation ignores the fact that no individual program (system, platform, etc.) can contribute to any capability unless other programs/systems/capabilities are in place. The analogy is that a fighter jet is useless unless it has all the supporting capabilities/infrastructure (airfield, ammo, fuel, personnel, etc.), and complementary systems (e.g., GPS, C2, satellite imagery, mission planning, etc.) to enable it to operate effectively. Considering a single MDAP in terms of how much it contributes

to a given capability without considering its linkages to other systems/programs/capabilities might be counterproductive, and would likely drive bad decisions. The better approach is to consider a program in the context of its interdependencies with respect to their collective contribution to a specific capability. The interdependencies should be identified from operational needs, engineering constructions, and programmatic budget justifications. Therefore, the combinations of the LLA matrices—for example, PEs versus UJTLs, weapon systems versus UJTLs and weapon systems versus weapon systems—may also help to redefine portfolios and improve portfolio management.

Validity

In order to realize the potential of the LLA method, an important first step is to establish the validity of the method in the context of realistic large-scale data sets. For that, we used the matrix generated from PEs versus PEs, compared with what human analysts have identified previously. As shown in Figure 15, in each program element artifact, another program element might be referenced, indicted as precedent or directionally linked program elements. A backward link is usually a stronger indicator of importance of a PE than a forward link. This is similar to the information retrieval or page ranking in a search engine (e.g., Google). Here, we use the number total forward and backward links together, identified by human analysts, as the attributes to validate the LLA method. For example, in Figure 15, PE 0604602F references PE 0605011F, which we define as a forward link, for PE 0604602F; while PE 0605011F is referenced by PE 0604602F, which we define as a backward link, for PE 0605011F. As shown in Figure 16, the top yellow row contains the total number of unique word hubs for a PE, matched with all PEs other than itself; and the bottom yellow row contains the total number of forward and backward links for the same PE. The Pearson correlation of the two rows is 0.39, with a p value < 0.0000001 (bi-directional t test with a sample size N = 461). This indicates that the positive correlation between the LLA-identified links and human analyst-

identified links is statistically significant and, therefore, is a validation for the LLA method.

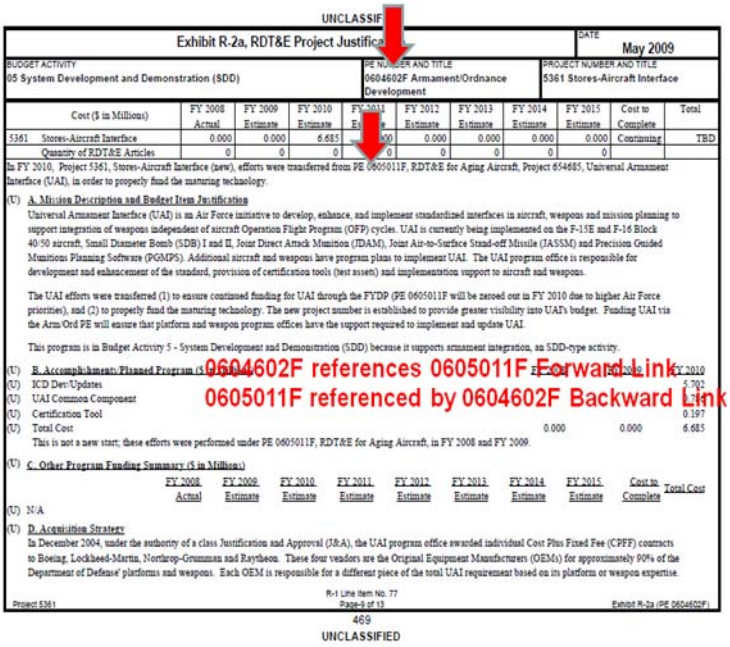


Figure 15. Program Element Cross-References Identified by Human Analysts

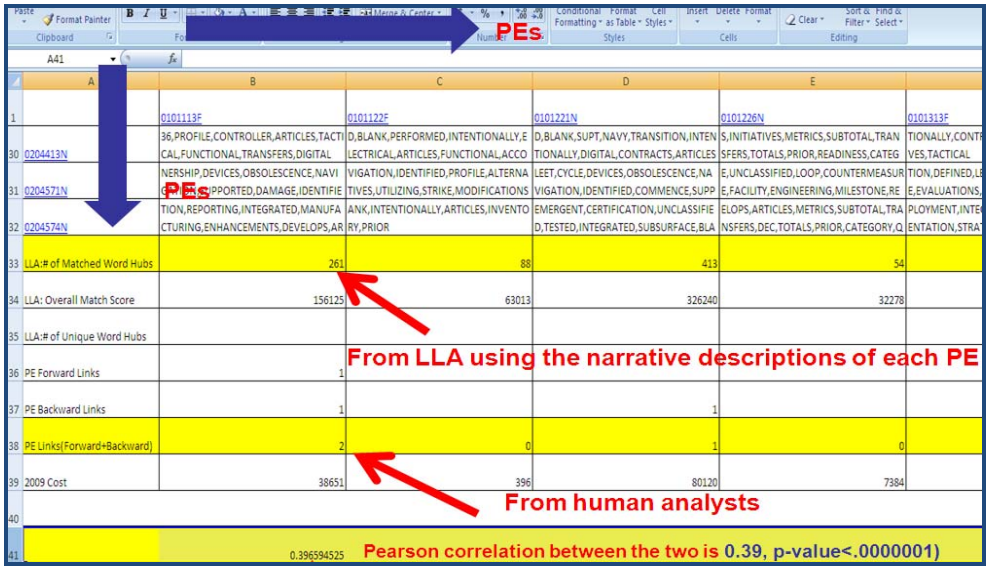


Figure 16. The Correlation Between LLA Word Hubs and PE Links Identified by SMEs Is Statistically Significant

Acquisition Decision-Making

To support effective decision-making, we need to form a full understanding of a program in context; we need to understand the linkages and interdependencies across the operational, constructive, and programmatic domains.

An LLA matrix using programs such as weapon systems as rows as well as columns is shown in Figure 17. The lexical links output from this view show the relationships among weapon systems, therefore representing a constructive view of programs in context. The hypothesis is that more lexical links among programs may be correlated with the overall higher program total costs. The correlation between the overall LLA match score and the program total cost found in the weapon data—which includes RDT&E and procurement costs together—is 0.21, with a *p* value < 0.032. This indicates that there is a statistically significant relationship between the number of lexical links as an interdependency measure among programs and total cost of programs.

Similarly, a programmatic view of an LLA matrix can be generated by using weapon systems as columns and program elements as rows. The correlation between the overall LLA match scores and total program costs is 0.13 with a *p* value < 0.12. This indicates that this correlation is not statistically significant based on the analyzed data.

An operational view of the LLA matrix was generated by using weapon systems as columns and UJTLs as rows. As shown in Figure 19, the correlation between the overall LLA match scores and total program costs is 0.086, with a *p* value < 0.12, indicating that this correlation is not statistically significant.

From an acquisition management and resource analysis perspective, we conclude that

- Major programs are interdependent on one another. Interdependence can be shown by their lexical links in budget documentations in constructive, programmatic, and operational views. The degree that

programs are interdependent can be measured by the number of lexical links.

- Highly interconnected programs in a constructive view are statistically significant and more expensive than less-interconnected programs (correlation 0.21, *p* value < 0.032). The word hubs selected from LLA suggest the "threads" link a portfolio of programs through shared resources. As an example, in Figure 18 Advanced Medium Range Air-to-Air Missile (AMRAAM) and Air Intercept Missile -9X (AIM-9X) are connected through "Countermeasures," which may share resources from PE 030140N.

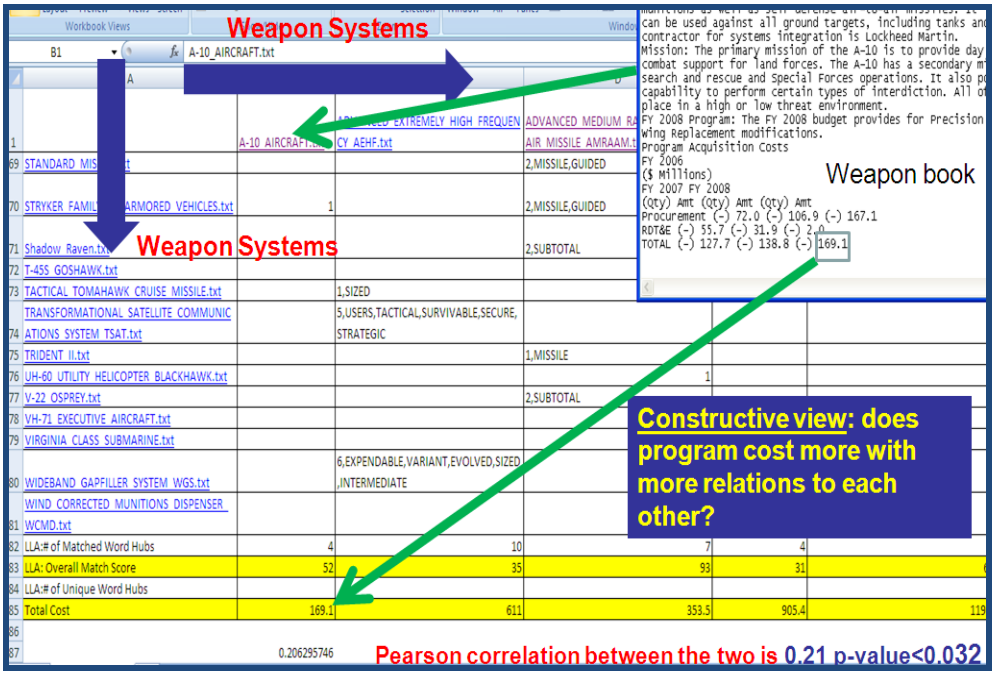


Figure 17. A Constructive View: An LLA Matrix Weapon Systems Versus Weapon Systems

(*Note.* The correlation between the LLA overall match scores and total program costs is statistically significant.)

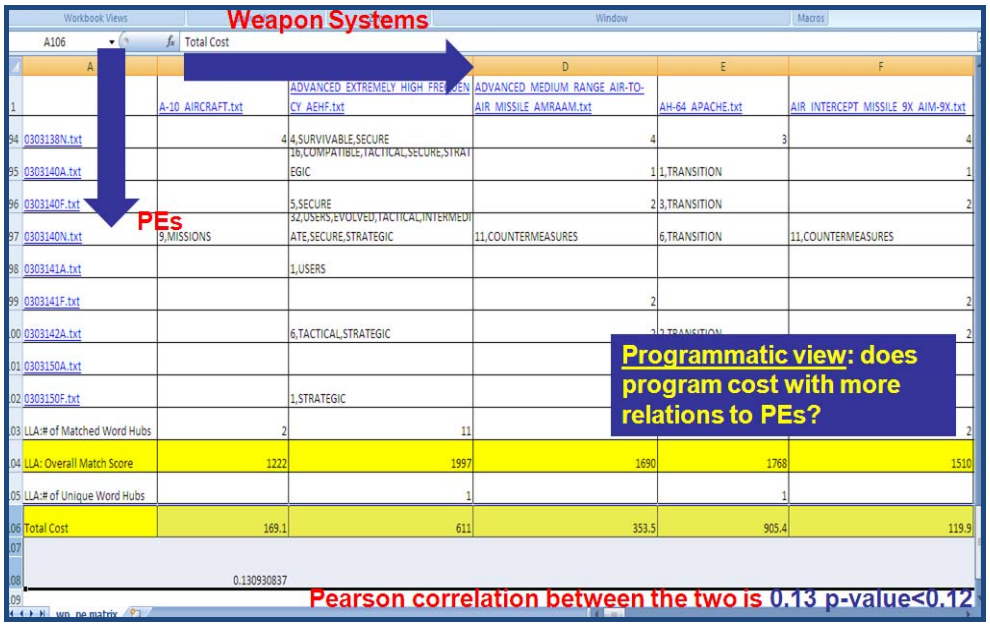


Figure 18. A Programmatic View: Weapon Systems Versus Program Elements

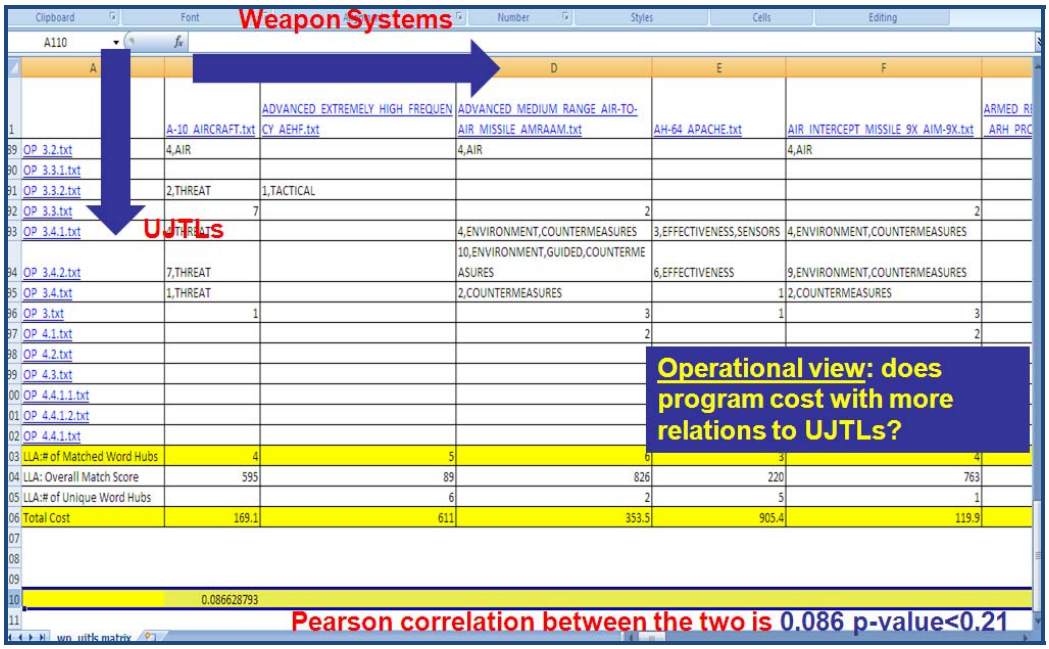


Figure 19. An Operational View: Weapon Systems Versus UJTLS

Our near-term plan is to apply the method jointly with the unstructured data with the MMT databases to illustrate whether the LLA method can be used to address the following questions:

- The narrative sections reference program–to-program interdependencies (e.g., Wideband Gapfiller System flies on an Evolved Expendable Launch Vehicle (EELV). How could this be compared with program interdependence information from the Defense Acquisition Executive Summary (DAES), or the Information Support Plan (ISP) from the data set?
- Are these programs more or less likely to incur cost growth relative to their Milestone B baselines? Are they more or less likely to breach their cost/schedule/performance baselines?
- How do we determine the correlation using metrics that fundamentally affect acquisition decision-making? For example, total program cost and cost growth relative to the Milestone B baseline cost. (To do that, we would need to capture the total program cost—development, procurement, and the two combined—estimated at Milestone B, and compare that with these values at Milestone C. These data are in the MMT data set.)
- Can LLA of budget documentation provide an aggregate dollar figure that describes the value/magnitude of resources being shared among these entities? Is this a reasonable proxy for the degree or significance of interdependence?
- Is there additional latent risk to programs that share resources? Is there potential for an unanticipated ripple effect that could magnify budget perturbations? Can these effects be modeled or predicted? Would this suggest that new approaches to budget analysis are needed?

Large-Scale and Real-Time Consideration

A large number of CLA agents work together in a parallel fashion. Parallel computation allows the LLA method to scale up to distributed, large-scale, and real-time data sources. At the time of this printing, we have prototyped a multi-agent network of ~10 to 100 agents in the NPS High Performance Computing Center (HPC) in the Hamming Linux Cluster (HLC), which provides the requisite

supercomputing for the visualization of the results. Servers are also being built in the NPS Secure Technology Battle Lab (STBL) to process classified data.

Conclusion

We show in this paper how to use the Lexical Link Analysis (LLA) to match system features with those defined in the original requirements, to discover relationships among systems, and to identify gaps with respect to warfighters' needs. We initially validate the LLA method and show results by correlating program interdependencies resulting from the LLA method with those from subject-matter experts. The Pearson correlation for a sample of 461 program elements (PEs) is 0.39 with a p value < 0.0000001. This result indicates the positive correlation between the LLA identified links as compared to human-analyst-identified links and indicates that they are reasonably correlated with statistical significance. We also found that Major Defense Acquisition Programs (MDAPs) are interdependent from one another and that such interdependence can be shown by their lexical links in documentations in constructive, programmatic, and operational views. The number of lexical links can be used as a metric to measure interdependencies among new technologies. Highly interconnected programs in a constructive view are statistically significant and more expensive than the less interconnected programs (correlation 0.21, p value < 0.032). Ultimately, in this vein, we seek to use the LLA method to automate and improve program self-awareness and make it feasible for acquisition decision-makers to analyze and dynamically monitor large-scale acquisition documents. The resulting system analyses will facilitate real-time program awareness and can reduce the workload of decision-makers who would otherwise perform the relations-building task manually, thus making a profound impact on the agility and perhaps the long-term success of acquisition strategies.

Part 2: Report from March 20, 2010–August 20, 2010

Significance of the Research

In Part 1 of this research, we explored various areas to which LLA could be applied. The summary of the significance of the research from March–August 2010 is given in the following paragraphs.

Acquisition research has increased in component, organizational, technical, and management complexity. It is difficult for acquisition professionals to remain continuously aware of their decision-making domains because information is overwhelming and dynamic. According to the *Chairman of the Joint Chiefs of Staff Instruction for Joint Capabilities Integration and Development System (JCIDS)* (CJCS, 2009), there are three key processes in the DoD that must work in concert to deliver the capabilities required by the warfighters: the requirements process; the acquisition process; and the Planning, Programming, Budget, and Execution (PPBE) process.

Each process produces a large amount of data in an unstructured manner; for example, the warfighters' requirements are documented in Universal Joint Task Lists (UJTLs), Joint Capability Areas (JCAs), and Urgent Need Statements (UNSs). These requirements are processed in the JCIDS to become projects and programs, which should result in products such as weapon systems that meet the warfighters' needs. Program data are stored in the Defense Acquisition System (DAS). Programs are divided into Major DoD Acquisition Programs (MDAP), Acquisition Category II (ACATII), etc. Program Elements (PE) are the documents used to fund programs yearly through the congressional budget justification process. Data is too voluminous, too unformatted, and too unstructured to be easily digested and understood—even by a team of acquisition professionals. There is a critical need for

automation to help reveal to decision-makers and researchers the interrelationships within these processes (see Figure 20).

We have attempted to develop and frame our research efforts around research questions in the following categories: conceptual, focused, theory development, and methodology.

Conceptual

1. Can the information that emerges from the acquisition process be used to produce overall awareness of the fit between programs, projects, and systems and of the needs for which they were intended?

2. If a higher level of awareness is possible, will that enable system-level regulation of programs, projects, and systems for improvement of the acquisition system?

Focused

1. Based on the normal evolution of documentation and on the current data-based program information, can requirements (needs) be connected to system capabilities via automation of analysis?

2. Can requirements gaps be revealed?

Theory Development

1. Is there a correlation between system interdependency (links/relationships) and development costs?

Methodology

1. Is it possible to use natural language and other documentation (roughly, unformatted data) to produce visualization of the internal constructs useful for management through Lexical Link Analysis (LLA)?

Lexical analysis ("Lexical Analysis," 2010) is a form of text mining in which word meanings are developed from the context from which they are derived. Link analysis, a subset of network analysis that explores associations between objects,

reveals the crucial relationships between objects when collected data may not be complete. Lexical Link Analysis (LLA) is an extended lexical analysis and link analysis. LLA can also be used in a learning mode in which such features and context associations are initially unknown and are constantly being learned, updated, and improved as more data become available.

We consider that the cognitive interface between decision-makers and a complex system may be expressed in a range of terms or features (i.e., a specific vocabulary or lexicon) to describe attributes and the surrounding environment of a system. Here, system self-awareness, or program awareness (Gallup, MacKinnon, Zhao, Robey, & Odell, 2009) allows decision-makers to be aware of what systems, programs, and products are available for acquisition; to understand how the systems match warfighters needs and requirements; to recognize relationships among them; to improve efficiency of available collaboration; to reduce duplication of effort; and to reuse components to support cost-effective management with greater immediacy, possibly in real-time.

In the past year, we began at the Naval Postgraduate School (NPS) by using Collaborative Learning Agents (CLA; QI, 2009) and expanded to other tools, including AutoMap (CASOS, 2009) for improved visualizations. Results from these efforts arose from leveraging intelligent agent technology via an educational license with Quantum Intelligence, Inc. CLA is a computer-based learning agent, or agent collaboration, capable of ingesting and processing data sources.

This approach is related to a number of extant tools for text mining, including Latent Semantic Analysis (LSA; Dumais et al., 1988), keyword analysis and tagging technology (Foltz, 2002), and intelligence analysis ontology for cognitive assistants (Tecuci et al., 2007). What results from this process is a learning model—like an ethnographic *code book* (Schensul et al., 1999).

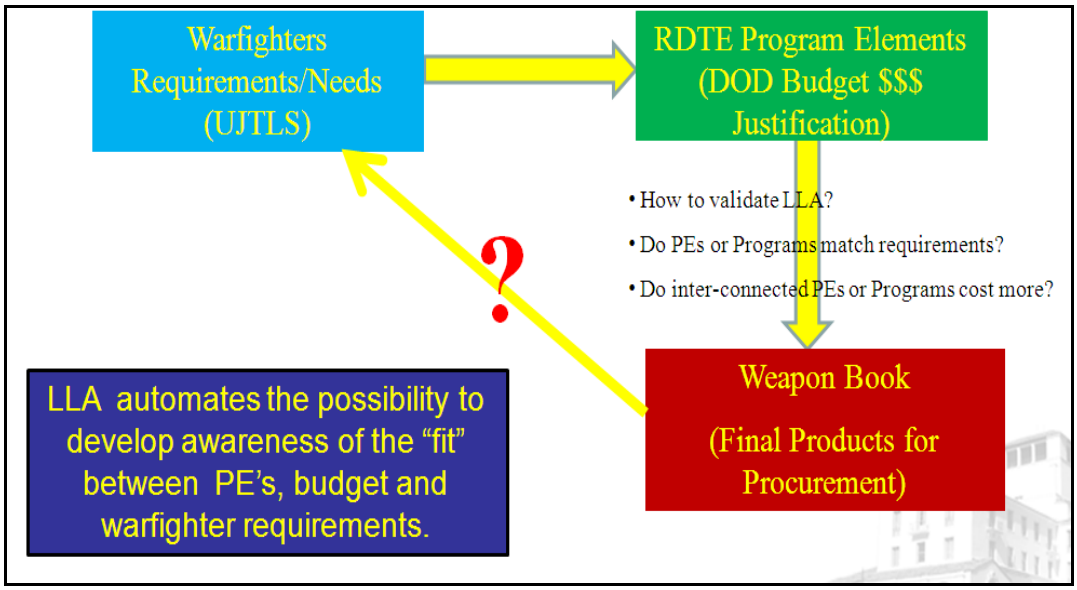


Figure 20. LLA Seeks to Inform the Business Processes Links (e.g., From Requirements to DoD Budget Justification to Final Products) That Are Critical for DoD Acquisition Research

In precise terms, we observed that there were three important processes that seem fundamentally disconnected. They were the congressional budgeting justification process (such as information contained within the PEs), the acquisition process (such as information in the MDAP and ACATII), and the warfighters' requirements (such as information in UNSs and in UJTLs). They were not analyzed and compared together in a dynamic, holistic methodology that could keep up with changes and reflect patterns of relationships.

There had been little previous effort to integrate the data in these three components. For example, the Matrix Mapping Tool (MMT; Dahmann et al., 2005) included MDAP, UJTL, and JCA, yet did not include PE. Furthermore, in MMT, the links among programs and the matches to UJTL were extracted manually and were therefore not updated in a timely fashion. We employed the LLA automation to analyze more data, and we achieved a better outcome and provided dynamic, real-time integration. We focused our efforts on demonstrating validation and visualization and on providing insights for decision-makers on the large-scale data as described in the next section.

The Validation for Using Large-Scale Data

To realize the potential of the LLA method, an important first step was to establish the validity of the method in the context of realistic, large-scale data sets. In the past year, we started to work on larger scale, open-source acquisition data sets. We obtained the Research, Development, Test and Evaluation (RDT&E) congressional budget justification documents (e.g., PEs from the DoD Comptroller website, http://comptroller.defense.gov/defbudget/). We also obtained program data including MDAPs data and ACATII data, UJTLs data, and Weapon Books data from the DoD open-source websites and our OSD contacts.

We first applied LLA to extract the links based on PEs for the RDT&E congressional budget justification process. PEs were at the center of many documents because each PE listed all the programs that the PE funded and their costs for the one- and five-year projections. Specifically, we compared the trends of LLA with what human analysts had identified manually. As shown in Figure 2, in each PE exhibition another PE might be referenced, indicted as precedent or directionally linked PEs. For example, in Figure 21, PE 0604602F referenced PE 0605011F, which we defined as a forward link for PE 0604602F, while PE 0605011F was referenced by PE 0604602F, which we defined as a backward link for PE 0605011F. A backward link was usually a stronger indicator of the importance of a PE than was a forward link. This indicator was similar to the page ranking in a search engine (Gerber, 2005). In this research, we used together the total number of forward and backward links identified by human analysts as the attributes to correlate with the number of lexical links. The Pearson correlation between the links identified by human analysts and by the LLA method was 0.39 with a p value < 0.0000001 (bidirectional t test with a sample size N = 461). This was an earlier validation for the LLA method that was achieved in Part 1 of our research (Zhao et al., 2010).

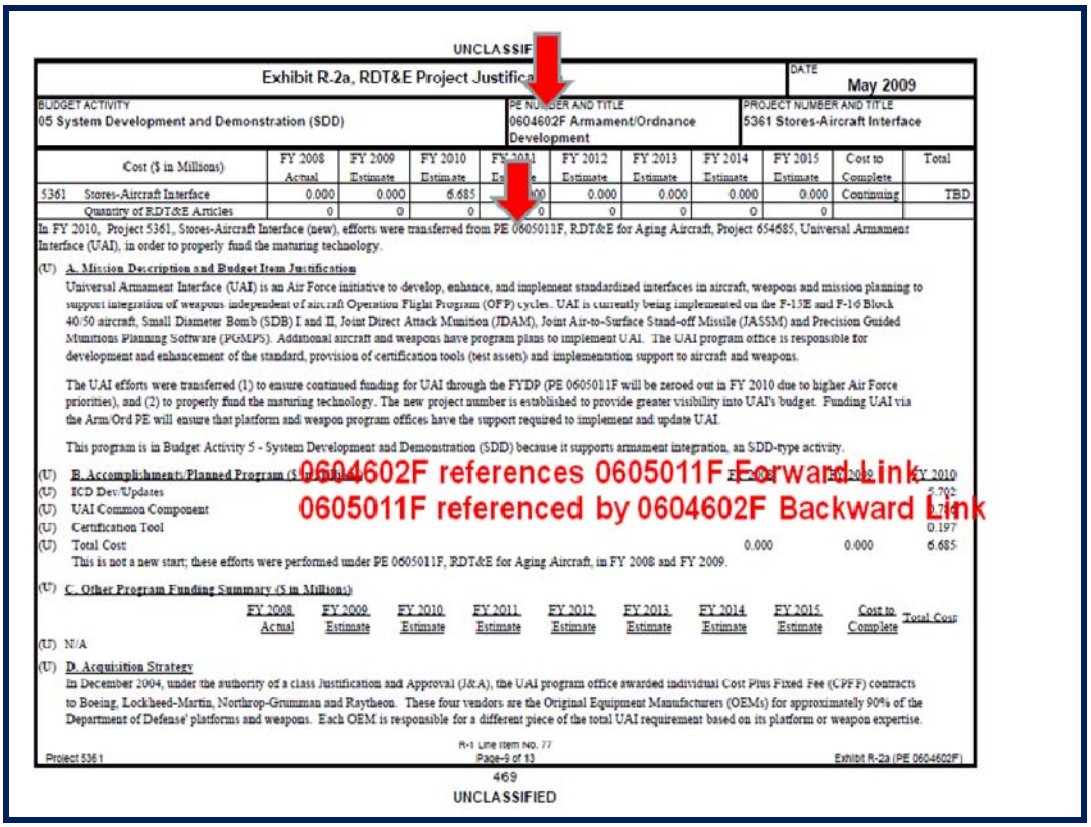


Figure 21. PE Cross-References Identified by Human Analysts

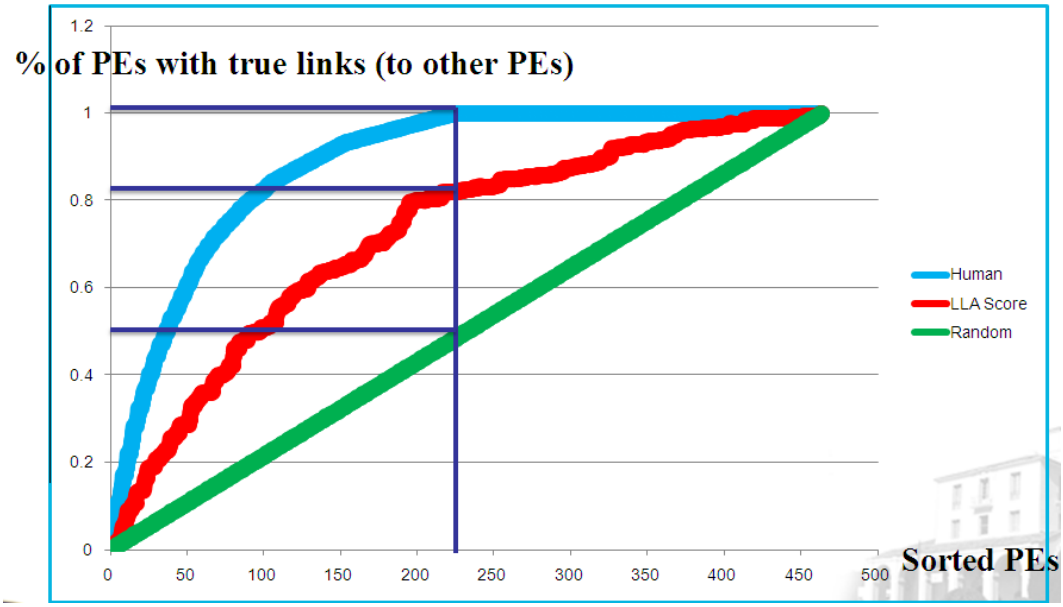


Figure 22. Use of LLA Scores to Predict PE Links: A Gains Chart

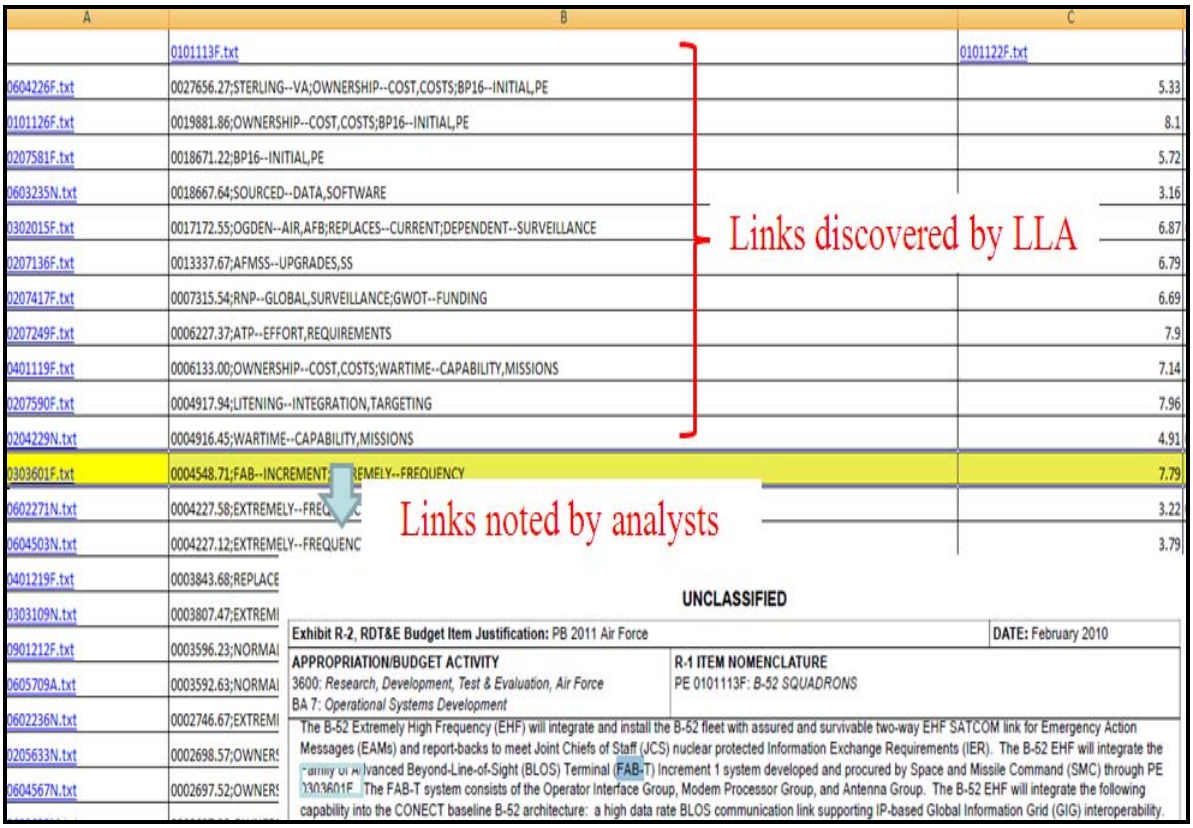


Figure 23. LLA Discovers Links That Are Not Identified by Human Analysts

Figure 22 shows the accuracy of using the LLA method to predict the links between PEs. The *x* axis showed sorted PEs by three methods: random (green), LLA (red), and human (red). The *y* axis showed the corresponding accumulative percentages of the PEs that were predicted correctly and that were linked to other PEs. The *x-y* curve was called a *Gains Chart*. As shown in Figure 22, there were about 225 PEs that had at least one link to other PEs identified by human analysts (the blue line); 80% of them were predicted by the top 225 PEs sorted by the LLA scores (the red line). In other words, LLA was used to predict correctly 80% of the links identified by the human analysts. As shown in Figure 23, LLA was also used to discover the links that human analysts might not be able to identify—in the example, only the yellow link was identified by human analysts.

LLA automation can dramatically speed up efforts to understand the complexity of acquisition issues. For example, in our most recent collaboration with

other acquisition researchers, we extracted PE and program links and program actual costs for eight years (2002–2009) and across three Services (Air Force, Army, and Navy). Each of the 24 sets contained about 200 PDF PEs from http://www.dtic.mil/descriptivesum/, totaling about 5,000 documents. Manually downloading and extracting desired links would be considered extremely difficult and almost impossible. By submitting several parallel jobs to the Naval Postgraduate School (NPS) High Performance Computing (HPC) center, the download took approximately six hours, and the link extraction took less than two hours. The resulting data was used for acquisition risk analysis (Brown, Flowe, & Raja, 2010).

Visualizations and Insights from LLA

We next show a few examples of visualizations from the LLA method that provided insights for acquisition decision-makers to look at resource allocation of programs as a whole.

Theme Extraction for Program Elements and Warfighters' Requirements

We took ~500 DoD Program Elements from three DoD Services in 2009 and compared them with the UJTLs as described in the following paragraphs.

We categorized the information into 35 themes. Each theme contained features in word pairs or terms that were lexically linked and that were found in the PEs and UJTLs. The themes indicated different clusters of centralization among words used in both the PEs and UJTLs. Themes were produced using a social-network grouping method (Girvan & Newman, 2002) and were connected as if they were in a social community. A *hub* was a word node centered with a list of other words connected next to each other within the documents. Figure 24 shows an example of a theme, Theme 1—*Forces* and *Air*, generated using LLA from combined word pairs from PEs and UJTLs. Two hub keywords, *forces* and *air*, were used to summarize the theme, which was a word cluster related to *forces* and *air*. These two hub word nodes had maximum numbers of links, as shown in Figure 24. These themes showed the merged areas of PEs and UJTLs and how they were linked and

matched semantically. Blue word pairs were word pairs only from PEs; green word pairs were only from UJTLs; red word pairs were from both. Figures 25, 26, and 27 showed the word pairs for PEs and UJTLs together and in separate visualizations. As shown in Figure 27, there were very few perfectly matched word pairs (red ones) between UJTLs and PEs in this theme, indicating the gaps.

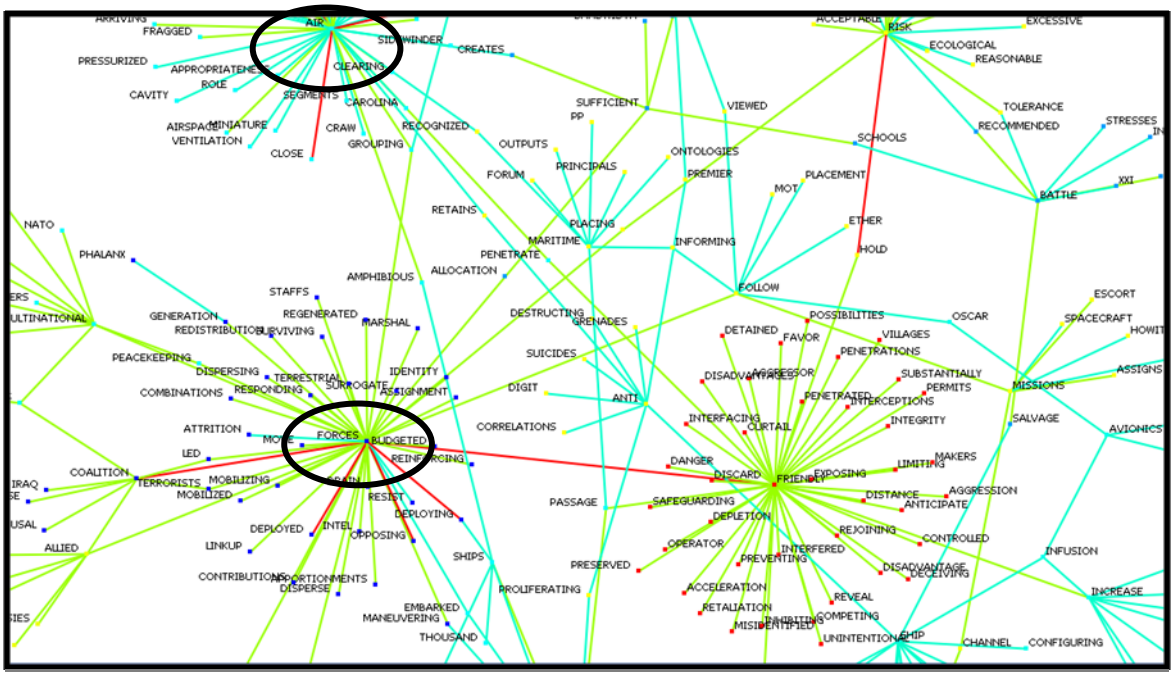


Figure 24. Example of Theme 1—*Forces* and *Air*, Taken From Combined Word Pairs From PEs and UJTLs

(*Note*. Blue word pairs are from PEs; green word pairs are from UJTLs; and red word pairs are from both.)

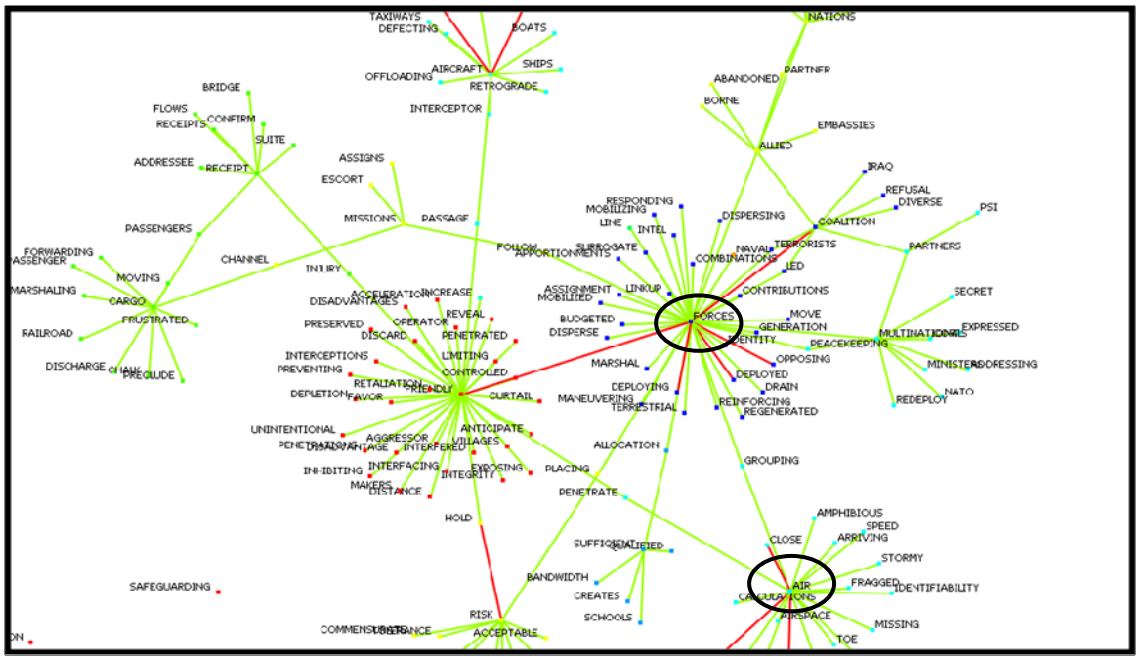


Figure 25. Word Pairs Found Only in UJTLs for Theme 1—*Forces* and *Air*

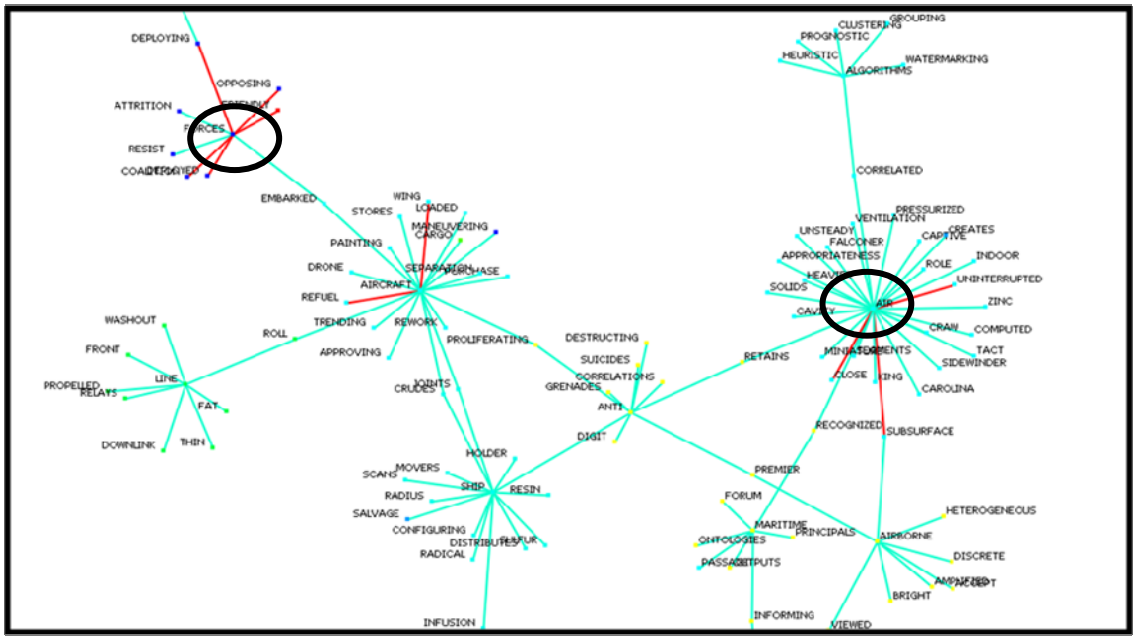


Figure 26. Word Pairs Found Only in PEs for Theme 1—*Forces* and *Air*

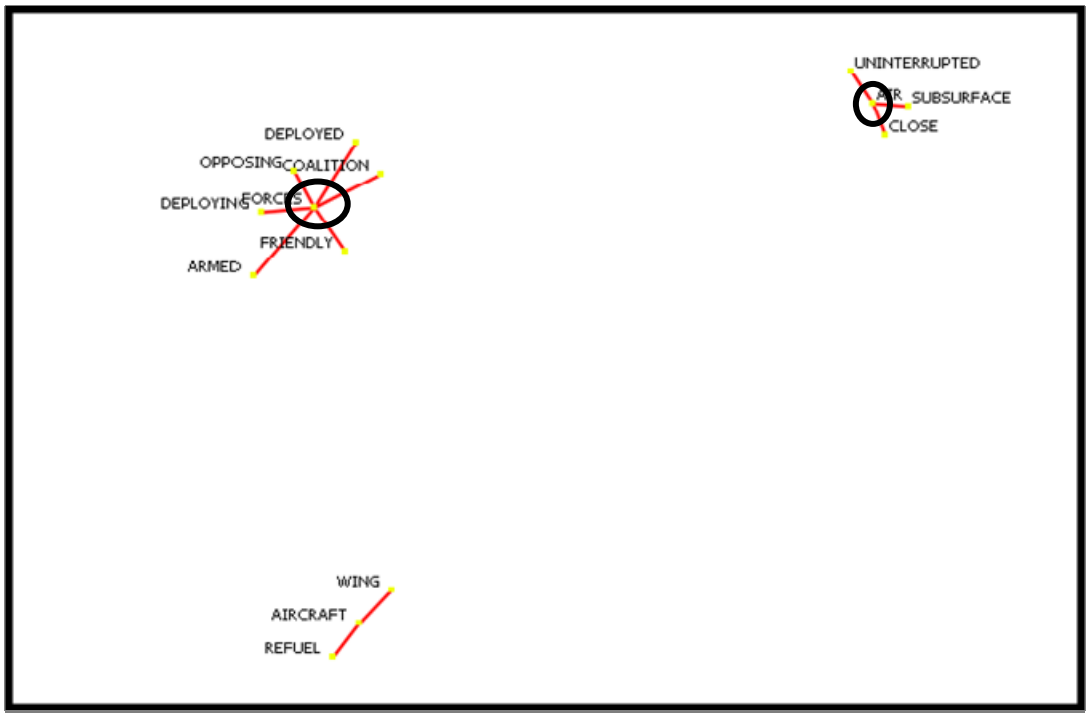
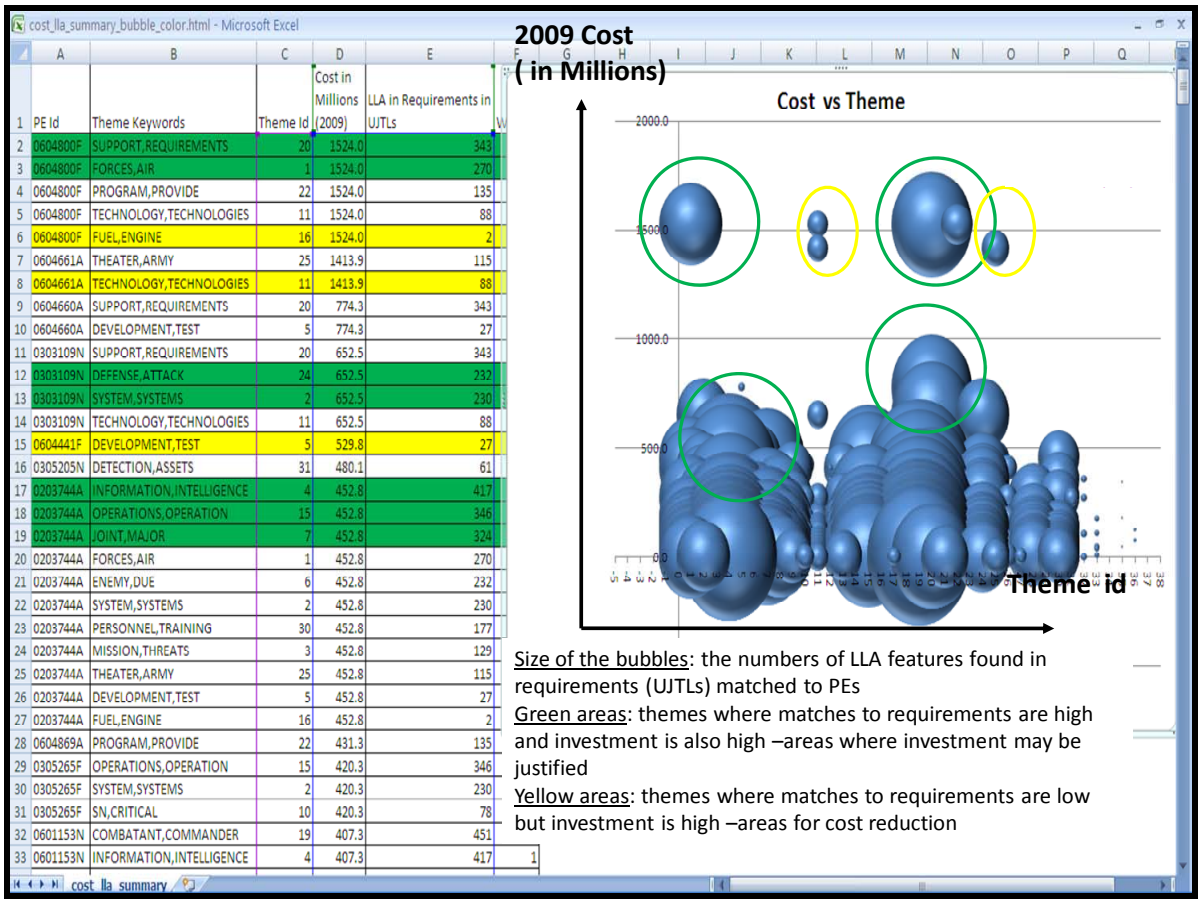


Figure 27. Word Pairs Found in Both PEs and UJTLs for Theme 1—*Forces* and *Air*

Next, we distributed all ~500 PEs into the 35 themes. As shown in Figure 28, we generated a spreadsheet to summarize each PE and its matched themes (where the word pairs meet at the hubs), including PE Id, theme Id and keywords, cost in millions in 2009, and number of LLA features found in UJTLs for the theme. Figure 28 shows the Excel table on the left sorted by the cost and the number of LLA matches of PEs to UJTLs. The bubble plot on the right shows the relationship between costs (*y* axis) and themes (*x* axis). The size of the bubbles represents the number of LLA features found in UJTLs, indicating a degree of a PE linking to an area of the warfighters' requirements. The keywords to summarize a theme were generated automatically by LLA.



	PE Id	Theme Keywords	Theme Id	Cost in Millions (2009)	LLA in Requirements in UJTLs
2	0604800F	SUPPORT,REQUIREMENTS	20	1524.0	343
3	0604800F	FORCES,AIR	1	1524.0	270
4	0604800F	PROGRAM,PROVIDE	22	1524.0	135
5	0604800F	TECHNOLOGY,TECHNOLOGIES	11	1524.0	88
6	0604800F	FUEL,ENGINE	16	1524.0	2
7	0604661A	THEATER,ARMY	25	1413.9	115
8	0604661A	TECHNOLOGY,TECHNOLOGIES	11	1413.9	88
9	0604660A	SUPPORT,REQUIREMENTS	20	774.3	343
10	0604660A	DEVELOPMENT,TEST	5	774.3	27
11	0303109N	SUPPORT,REQUIREMENTS	20	652.5	343
12	0303109N	DEFENSE,ATTACK	24	652.5	232
13	0303109N	SYSTEM,SYSTEMS	2	652.5	230
14	0303109N	TECHNOLOGY,TECHNOLOGIES	11	652.5	88
15	0604441F	DEVELOPMENT,TEST	5	529.8	27
16	0305205N	DETECTION,ASSETS	31	480.1	61
17	0203744A	INFORMATION,INTELLIGENCE	4	452.8	417
18	0203744A	OPERATIONS,OPERATION	15	452.8	346
19	0203744A	JOINT,MAJOR	7	452.8	324
20	0203744A	FORCES,AIR	1	452.8	270
21	0203744A	ENEMY,DUE	6	452.8	232
22	0203744A	SYSTEM,SYSTEMS	2	452.8	230
23	0203744A	PERSONNEL,TRAINING	30	452.8	177
24	0203744A	MISSION,THREATS	3	452.8	129
25	0203744A	THEATER,ARMY	25	452.8	115
26	0203744A	DEVELOPMENT,TEST	5	452.8	27
27	0203744A	FUEL,ENGINE	16	452.8	2
28	0604869A	PROGRAM,PROVIDE	22	431.3	135
29	0305265F	OPERATIONS,OPERATION	15	420.3	346
30	0305265F	SYSTEM,SYSTEMS	2	420.3	230
31	0305265F	SN,CRITICAL	10	420.3	78
32	0601153N	COMBATANT,COMMANDER	19	407.3	451
33	0601153N	INFORMATION,INTELLIGENCE	4	407.3	417

Figure 28. PEs Grouped Into Themes and Sorted by Cost

Our observations were summarized as follows when looking at the investment and at the warfighters' requirements in a joint picture:

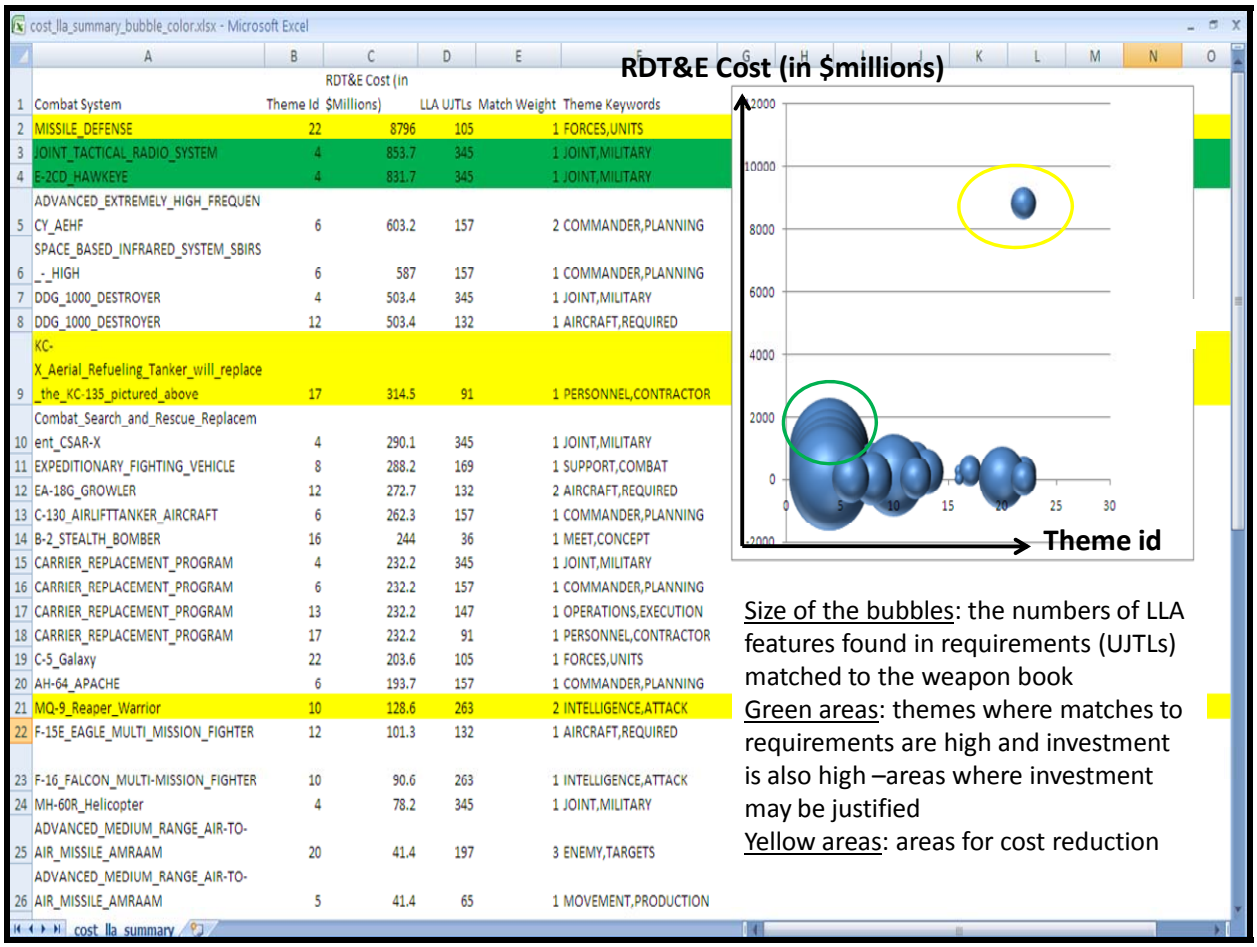
- Larger PEs (> $500 million) tended to be more focused on specific themes; smaller PEs (< $500 million) tended to be more spread out among the themes.
- Green-circled areas indicated the themes (e.g., Theme 20—*Support* and *Requirements*, Theme 1—*Forces* and *Air*, Theme 24—*Defense* and *Attack*, Theme 2—*System* and *Systems*, Theme 4—*Information* and *Intelligence*, Theme 15—*Operations* and *Operation*, and Theme 7—*Joint* and *Major*, listed in the order of the size of investment/cost in Figure 28) in which the investment and the number of warfighters' requirements were both high. These were the areas in which investment seemed appropriate.

- *Yellow-circled areas* of themes (e.g., Theme 16—*Fuel* and *Engine*, Theme 11—*Technology* and *Technologies,* and Theme 5—*Development* and *Test,* listed in the order of the size of investment/cost in Figure 28) were not stated extensively in the UJTLs; therefore, money spent on these areas did not seem to resolve the warfighters' requirements. These areas presented potential opportunities for cost reduction.

In the plan outlined by Defense Secretary Robert M. Gates for the U.S. defense cut to save $100 billion (Hedgpeth, 2010), Gates planned to trim big-ticket military hardware programs and aimed at reducing support contractors. This plan seemed to consider only the cost of large programs and underweighted warfighters' requirements. For example, warfighters' requirements of the supporting functions, as we showed in Figure 28, makes evident through one of the green-circled areas (i.e., Theme 20—*Support* and *Requirements*) that although support contractors were expensive, they are required heavily by warfighters. Consequently, the investment or expenditure in this area was justified.

Weapon Book and UJTLs

We made similar observations when studying the relations between the 2008 Weapon Book and the UJTLs, as shown in Figure 29.



	Combat System	Theme Id	RDT&E Cost (in $Millions)	LLA UJTLs	Match Weight	Theme Keywords
2	MISSILE_DEFENSE	22	8796	105	1	FORCES,UNITS
3	JOINT_TACTICAL_RADIO_SYSTEM	4	853.7	345	1	JOINT,MILITARY
4	E-2CD_HAWKEYE	4	831.7	345	1	JOINT,MILITARY
5	ADVANCED_EXTREMELY_HIGH_FREQUENCY_AEHF	6	603.2	157	2	COMMANDER,PLANNING
6	SPACE_BASED_INFRARED_SYSTEM_SBIRS_-_HIGH	6	587	157	1	COMMANDER,PLANNING
7	DDG_1000_DESTROYER	4	503.4	345	1	JOINT,MILITARY
8	DDG_1000_DESTROYER	12	503.4	132	1	AIRCRAFT,REQUIRED
9	KC-X_Aerial_Refueling_Tanker_will_replace_the_KC-135_pictured_above	17	314.5	91	1	PERSONNEL,CONTRACTOR
10	Combat_Search_and_Rescue_Replacement_CSAR-X	4	290.1	345	1	JOINT,MILITARY
11	EXPEDITIONARY_FIGHTING_VEHICLE	8	288.2	169	1	SUPPORT,COMBAT
12	EA-18G_GROWLER	12	272.7	132	2	AIRCRAFT,REQUIRED
13	C-130_AIRLIFTTANKER_AIRCRAFT	6	262.3	157	1	COMMANDER,PLANNING
14	B-2_STEALTH_BOMBER	16	244	36	1	MEET,CONCEPT
15	CARRIER_REPLACEMENT_PROGRAM	4	232.2	345	1	JOINT,MILITARY
16	CARRIER_REPLACEMENT_PROGRAM	6	232.2	157	1	COMMANDER,PLANNING
17	CARRIER_REPLACEMENT_PROGRAM	13	232.2	147	1	OPERATIONS,EXECUTION
18	CARRIER_REPLACEMENT_PROGRAM	17	232.2	91	1	PERSONNEL,CONTRACTOR
19	C-5_Galaxy	22	203.6	105	1	FORCES,UNITS
20	AH-64_APACHE	6	193.7	157	1	COMMANDER,PLANNING
21	MQ-9_Reaper_Warrior	10	128.6	263	2	INTELLIGENCE,ATTACK
22	F-15E_EAGLE_MULTI_MISSION_FIGHTER	12	101.3	132	1	AIRCRAFT,REQUIRED
23	F-16_FALCON_MULTI-MISSION_FIGHTER	10	90.6	263	1	INTELLIGENCE,ATTACK
24	MH-60R_Helicopter	4	78.2	345	1	JOINT,MILITARY
25	ADVANCED_MEDIUM_RANGE_AIR-TO-AIR_MISSILE_AMRAAM	20	41.4	197	3	ENEMY,TARGETS
26	ADVANCED_MEDIUM_RANGE_AIR-TO-AIR_MISSILE_AMRAAM	5	41.4	65	1	MOVEMENT,PRODUCTION

Figure 29. Comparison of the Word Pairs from the 2008 Weapon Book and UJTLs

(*Note*. The word pairs are categorized into themes using LLA. The weapon systems are sorted according to RDT&E costs and themes.)

The themes were generated from the combined word pairs from the Weapon Book and UJTLs. The spreadsheet on the left of Figure 29 lists the weapon systems, which are end products of MDAPs; they are sorted by the RDT&E costs in 2008 and by their LLA matches to the UJTLs. The size of the bubbles represents the number of LLA features found in requirements matched to the Weapon Book. As shown in Figure 29, there are fewer data points (i.e., bubbles) than in Figure 28 overall, indicating larger gaps between the requirements and the Weapon Book.

In Figure 29, green areas are the areas in which both the warfighters' requirements and the RDT&E costs were high. The yellow areas are the gap areas, representing the areas in which the warfighters' requirements were relatively low but the RDT&E costs were high (e.g., Theme 22—*Force* and *Units* and Theme 91—*Personnel* and *Contractor*), or the areas in which the warfighters' requirements were relatively high but the RDT&E costs were low (e.g., Theme 21—*Intelligence* and *Attack*). The bubble plot on the right of Figure 29 shows the relationship between the costs of weapon systems and how much matched to the warfighters' requirements in each theme. The bubble size represented the number of LLA word pairs from the UJTLs with respect to the themes.

Figures 30 through 35 show examples of word pairs in two sets of themes, Theme 4—*Joint* and *Military* and Theme 22—*Force* and *Units,* from the Weapon Book and UJTLs, jointly for both documents and separately for each document set. Green links were from the UJTLs, and blue links were from the Weapon Book. The red links were from both. The visualizations showed that the word pairs or terms were connected semantically within the themes. These visualizations were more detailed views of the match and gap visualization developed in Part 1 of our research (Zhao et al., 2010). LLA matches listed in Figure 29 were the counts of the word pairs from the UJTLs (green) within the themes. We found that a match between the Weapon Book and the UJTLs was often evidenced at a hub word. The perfectly matched word pairs were rare.

Figure 36 shows all the perfectly matched word pairs from the Weapon Book and the UJTLs. The number of perfect matches was small, indicating that there was a large disconnection between the warfighters' requirements and the final weapon systems, which were the end products of the RDT&E process.

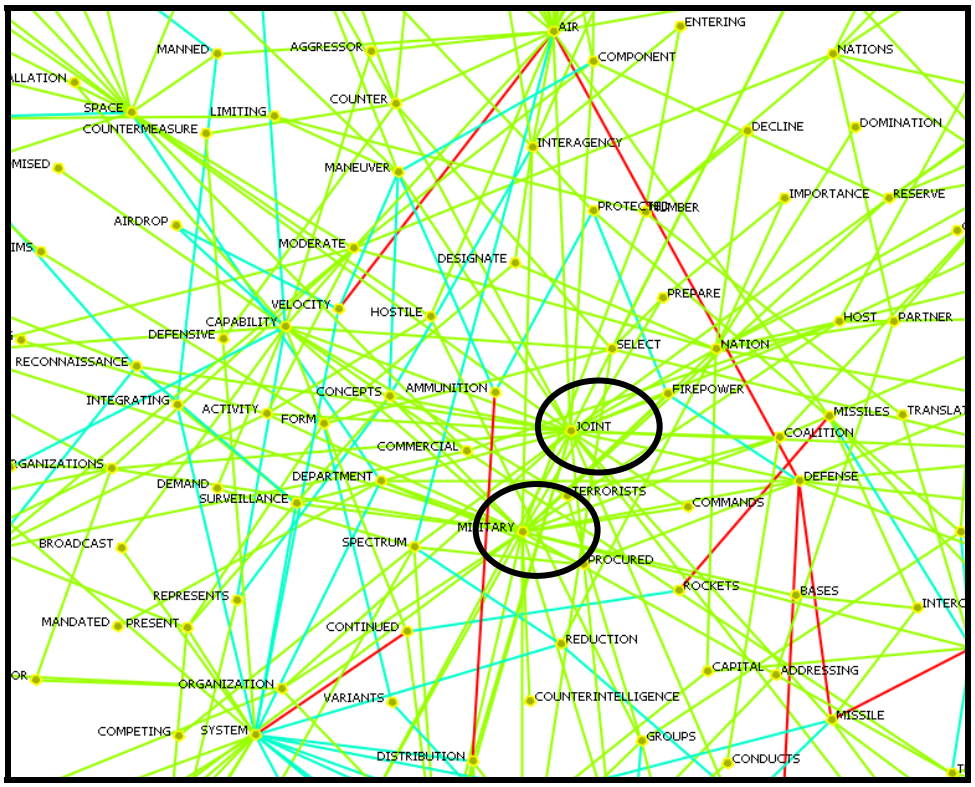


Figure 30. Word Pairs From the Weapon Book and UJTL for Theme 4—*Joint* and *Military*

(*Note*. Green links are from the UJTLs, and blue links are from the Weapon Book. The red links are from both.)

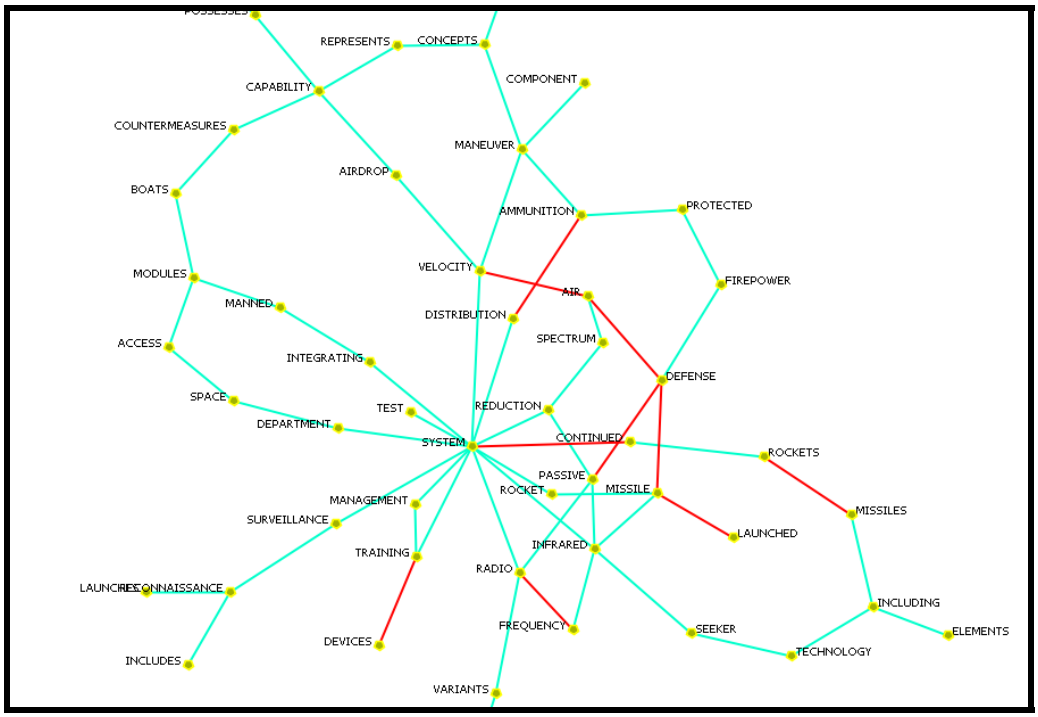


Figure 31. Word Pairs From Only the Weapon Book for Theme 4—*Joint* and Military

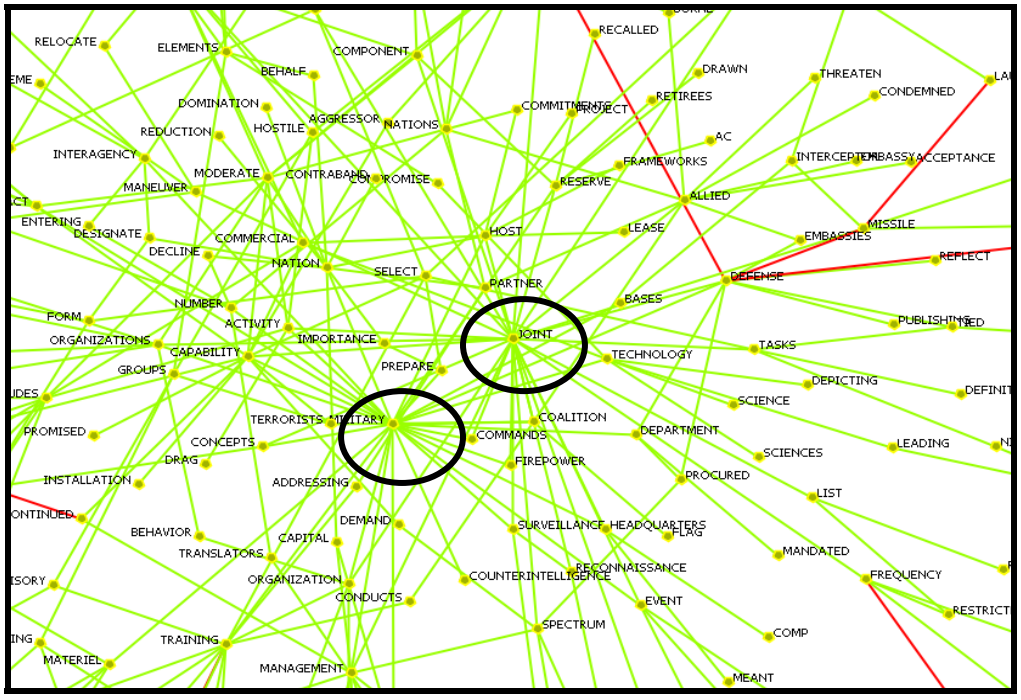


Figure 32. Word Pairs From Only the UJTLs or Theme 4—*Joint* and *Military*

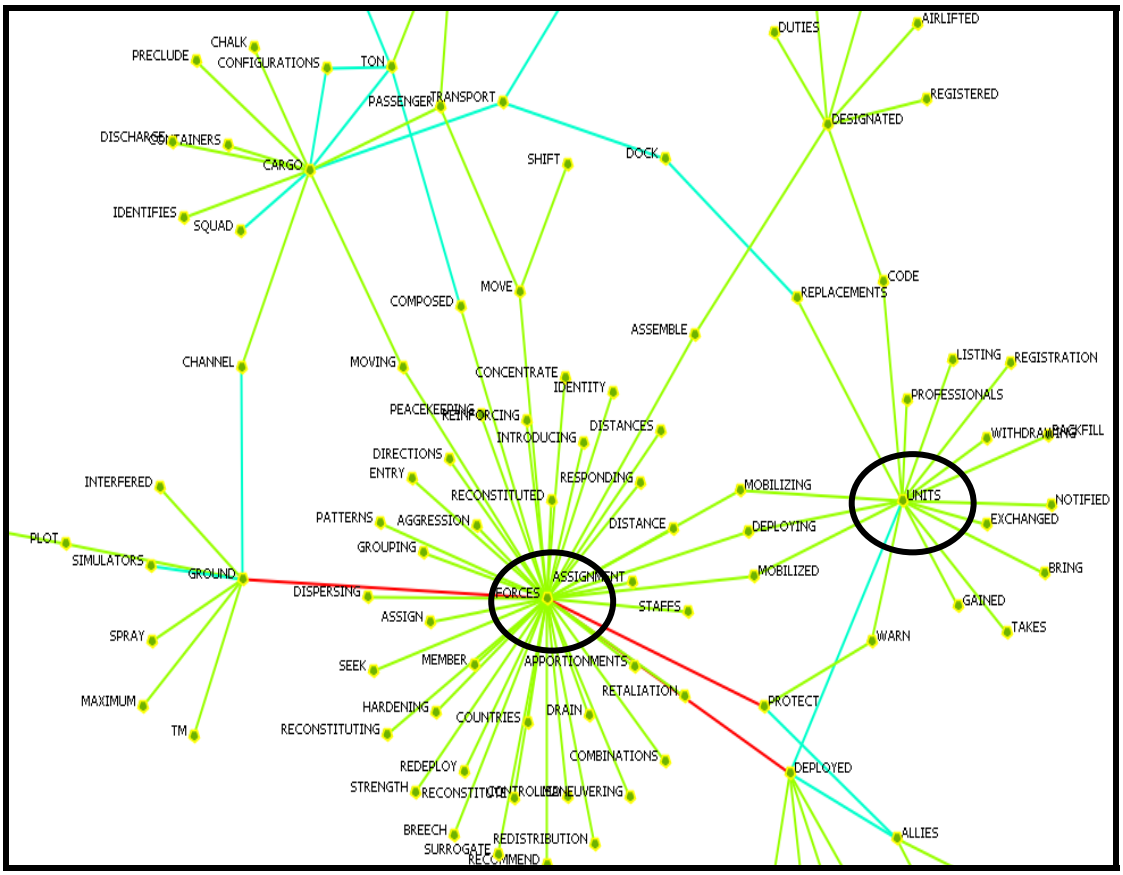


Figure 33. Word Pairs From the Weapon Book and the UJTLs for Theme 22—*Force* and *Units*

(*Note*. Green links are from UJTLs, and blue links are from the Weapon Book. The red links are from both.)

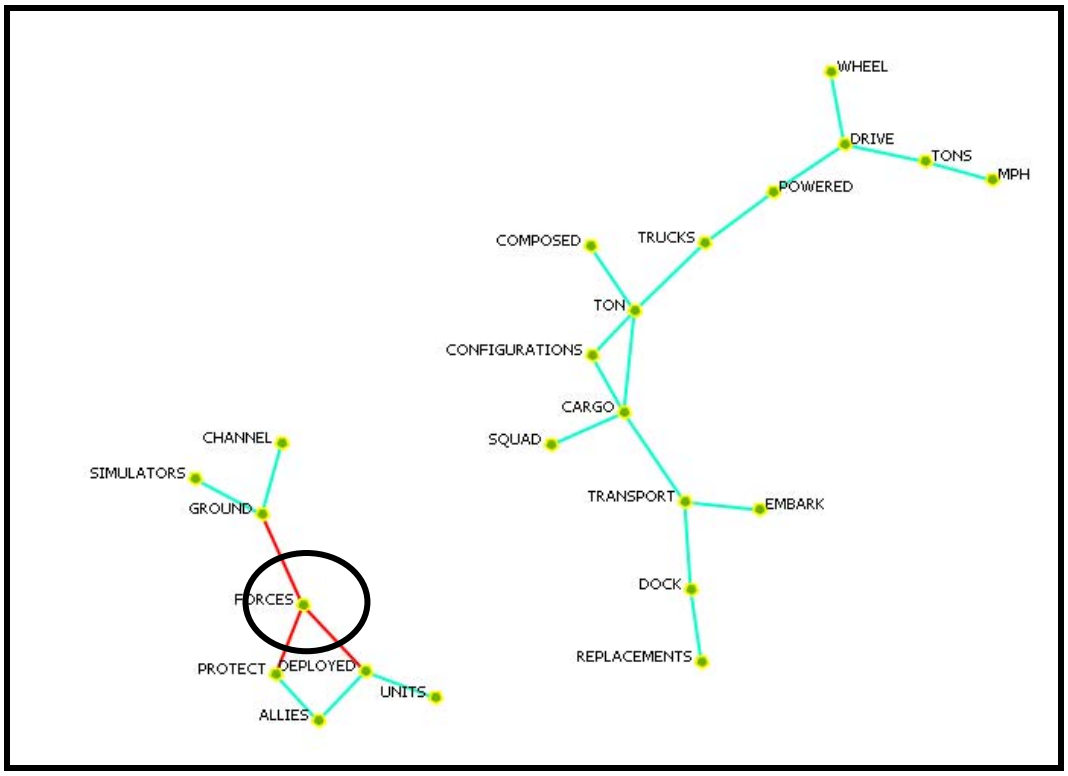


Figure 34. Word Pairs From Only the Weapon Book for Theme 22—*Force* and *Units*, Matched to the Main Idea *Forces* with the Terms *Units*, *Ground*, *Protect*, and *Deployed*

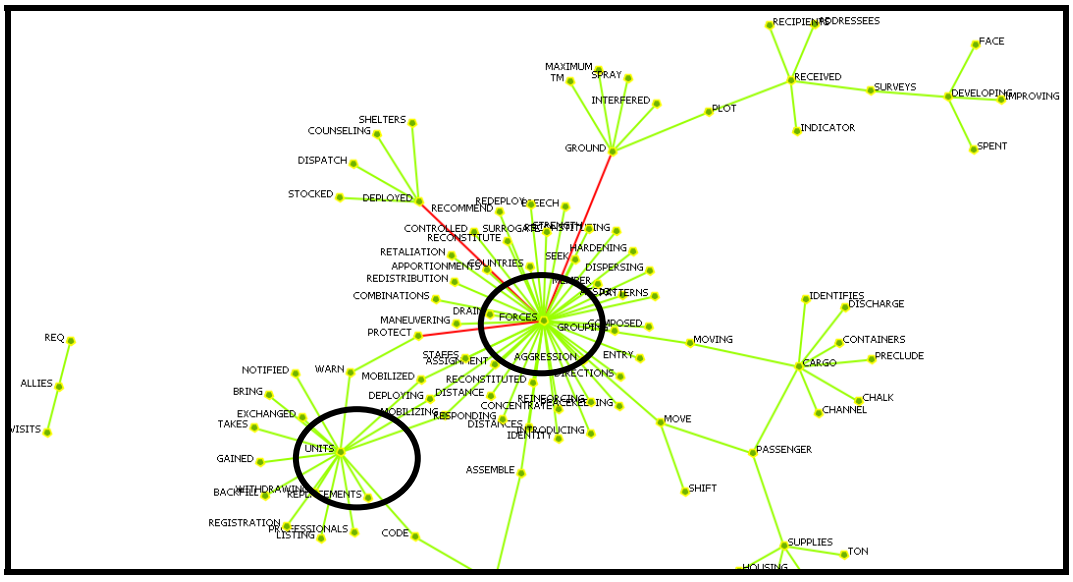


Figure 35. Word Pairs From Only the UJTLs for Theme 22—*Force* and *Units*

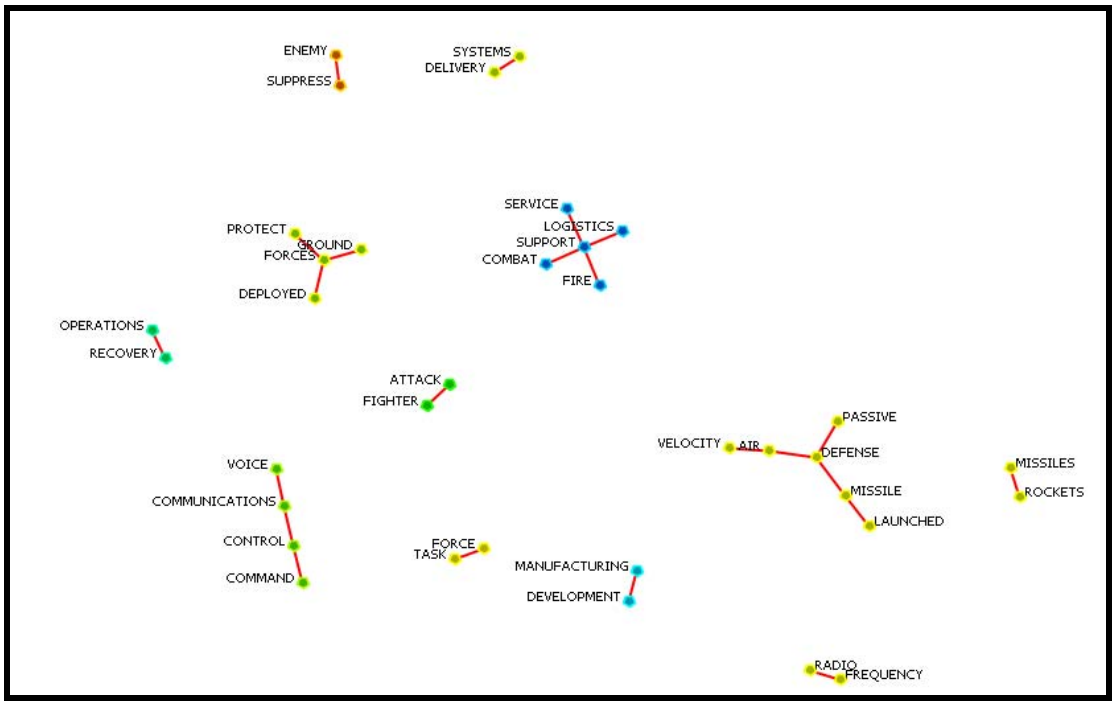


Figure 36. All of the Perfectly Matched Word Pairs From the Weapon Book and the UJTLs

Social Network of PEs

We found it interesting that the LLA method can be used to construct a social network view of PEs. As shown in Figure 37, a PE such as 0603721N_Environmental_Protection is highly linked to another PE 0303109N_Satellite_Communication_Space around the following word hubs:

- Achievable—Current and Sea
- Ownership—Cost and Costs
- Procedural—Security and Product
- Ancillary—Hardware and Equipment
- Northwest—Environmental and Location

The LLA score for the link is 81146—so a red link was given compared to blue and green links in Figure 37. Figure 38 shows a so-called *word cloud* view of the social network in Figure 37. The size of the fonts in Figure 38 is proportional to

the total degree, or how many total links and weights from a node (Wasserman & Faust, 1994) of a PE node. The highly connected nodes stand out in a word cloud graph.

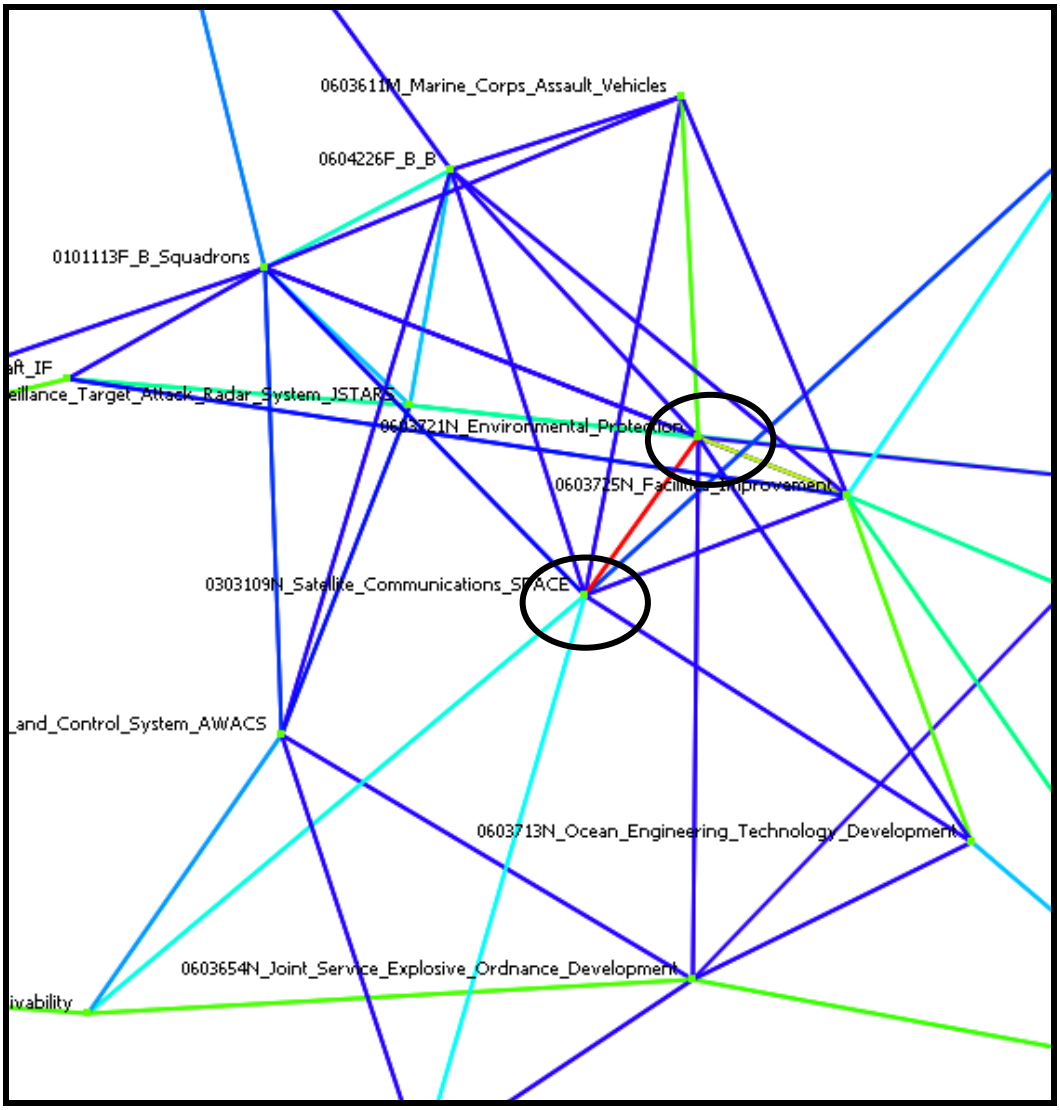


Figure 37. Example of a Social Network View of Program Elements

Figure 38. Example of a Word Cloud Visualization Generated From the Social Network in Figure 20 and Centered Around 0603721N_Environmental_Protection

Figure 39 shows a social network view of the PEs using the links identified by human analysts. In Figure 39, PEs ending with an *A* were Army PEs, with an *F* were Air Force PEs, and with an *N* were Navy PEs. The links in Figure 39 tended to be within the Services; for example, analysts tended to identify Army PEs linked to Army PEs, Air Force to Air Force, and Navy to Navy. Compared to the links identified by human analysts, LLA was used to look into the links among PEs from all of the Services as a whole system, and, therefore, the links discovered were cross-Service and potential cognitive *blind spots* of human analysts. For example, in Figure 39 Navy PE 0603721N_Environmental_Protection is linked to Air Force PE 0401130F_C_Aircraft_IF and Army PE 603747A_Soldier_Support_and_Survivability.

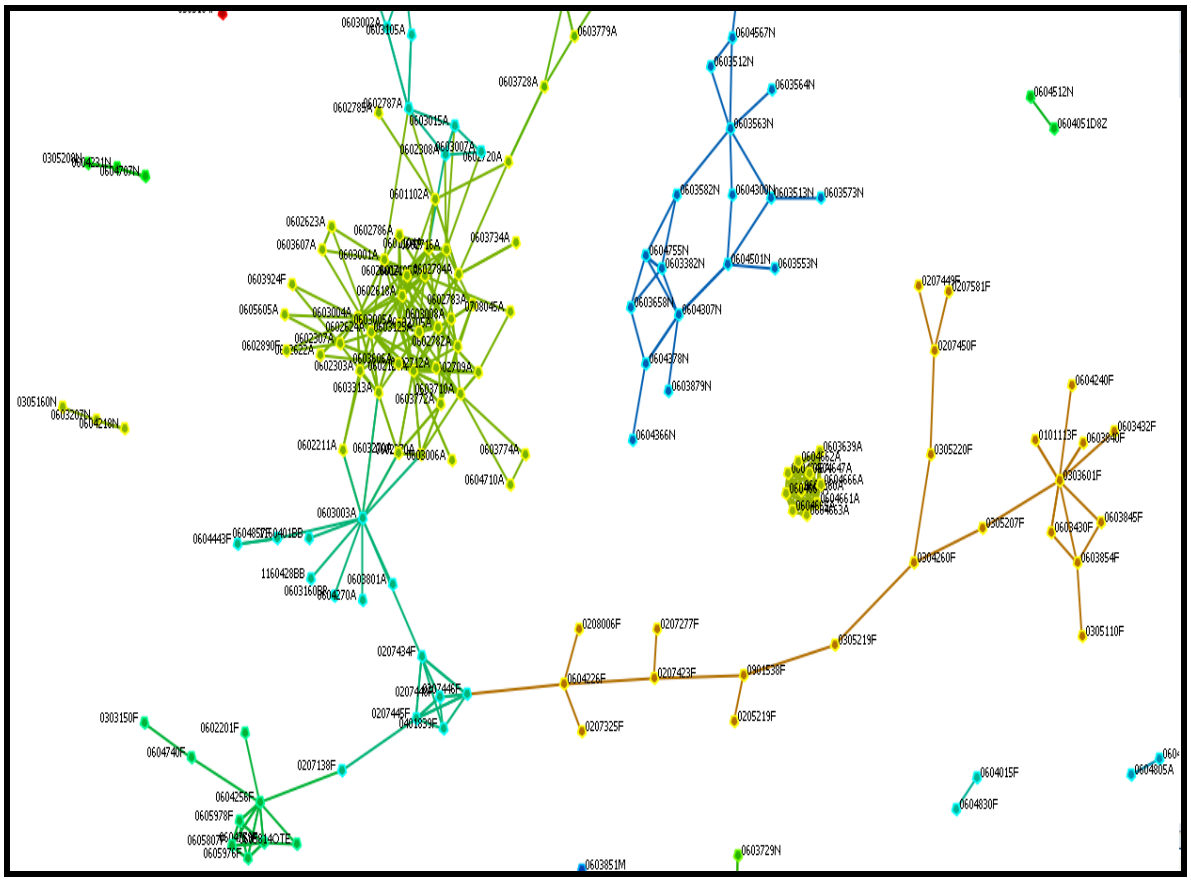


Figure 39. A Social Network View of PEs With the Links Identified by Human Analysts

Summary of the Findings

Table A1 in Appendix A lists ~450 PEs sorted according to the numbers of LLA-generated links for each PE with respect to other PEs. Such links were considered as measures for independencies among PEs. The costs were dollars in millions.

As shown visually in Table A1 in Appendix A, LLA-generated links were correlated with the ones identified by human analysts (i.e., the top portion of the table contained higher numbers of LLA links, which also contained higher numbers of human-identified links). The correlation between columns 3 and 4 in Table A1 in Appendix A was 0.57, shown in the linear relationship in Figure 40. If outliers (circled in Figure 40) were removed, then the correlation was 0.62. This was a better

validation of the LLA method than the one reported in Part 1 of the project (Zhao et al., 2010).

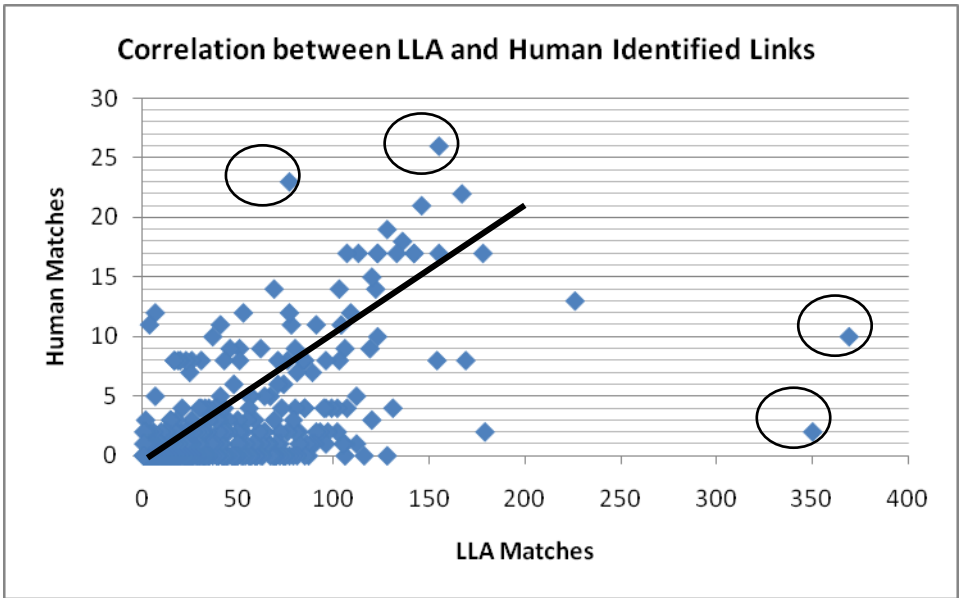


Figure 40. Correlation Between LLA and Human-Identified Matches

We also observed from Table A1 in Appendix A that the RDT&E budget modification practice from 2008–2009 tended to reduce the budget for PEs with more links to other PEs and to increase the budget for the ones with less links. In Table A1 in Appendix A, the average 2009 percentage of increase for PEs from 1–330 was 14%, when the number of LLA links was larger than 10, and the average increase for PEs from 331–450 was 40%, when he number of LLA links was fewer than 10. The total 2009 cost increase was -$558 million for PEs from 1–330 and $434 million for PEs from 331–450. The differences were statistically significant. They showed that the past practice tended to allocate resources to avoid overlapping efforts and to fund new and unique projects.

In contrast to Table A1 in Appendix A, Table A2 listed the same 450 PEs sorted according to the numbers of LLA links with respect to UJTLs. Shown in Table A2 in Appendix A, there were fewer numbers of LLA links observed (column 3), indicating that there were gaps between the RDT&E resource allocation and the warfighters' requirements. In Table A2, for PEs from 1–195 where there was at least

one LLA match, the average percentage cost increase was 10%, compared to 29% for PEs from 196–450 when there were no matches. This indicated a need to consider gaps and the warfighters' requirements as priorities in the RDT&E investment.

We found it interesting that the total cost increase for PEs from 1–195 was $735 million, compared to -$859 million for PEs from 196–450. This indicated that the PEs that matched the warfighters' requirements obtained more overall attention and less budget reduction compared to the ones without matches.

These findings will be useful for implementing Gates' defense cutting plan (Hedgpeth, 2010). For example, Gates said the Pentagon must get "more bang for its buck and shift its focus to the military's needs for the future" (Hedgpeth, 2010). Top acquisition officials in the nation have been looking for ways to squeeze the fat and eliminate inefficiencies and unnecessary overhead. He also planned to add 20,000 acquisition workers to implement the cost reduction. The program awareness implemented via the LLA method will link warfighters' requirements to budget and to final weapon products and help the 200,000 acquisition workers in their decision-making.

Statement of the Work for Phase II

During the research period, we proposed a follow-on research to the NPS Acquisition Research Program using Lexical Link Analysis (LLA). The proposed work will be extended in the following ways:

- Apply LLA to larger-scale data and wider applications and employ parallel computing and dynamic, 3-D visualizations.
- Apply LLA to be a real-time operational capability of program awareness; the results will be periodically updated and presented in a web service.

The proposed tasks are listed as follows:

Task 1: Develop a Web Service to Explore Applications for the Acquisition Research Community

We will focus on developing a web service that links the budgeting process through PEs to the acquisition process via acquisition programs (MDAPs, ACATIIs) to the warfighters' requirements (UNS, UJTL, etc). Our goal is to provide a platform from which to present periodically (e.g., weekly or monthly) all the information in a single location so that users can view the trends based on the data in the three areas. We will gather the most recent documents in three areas and periodically index, analyze, and create analysis reports and visualizations available for acquisition researchers. A web service will be used to present the results per task as follows:

- Index and perform Lexical Link Analysis for search. Lexical links will be highlighted in the search results.
- Compute key metrics such as Lexical Link count, program cost, and diversity to measure overlaps and gaps between PEs and Programs, PEs and UNS/UJTLs, and Programs and UNS/UJTLs.
- Visualize lexical links using networks, matrices, radar graphs, and 3-D navigation. The keywords shown in the visualizations will be linked to the search and indexes.
- Correct the results of fielding demonstrations such as Joint Capability Technology Demonstration (JCTD) experimentations.

We will seek to apply LLA in the workflow that benefits acquisition professionals. Examples include the following:

1. Extract the cost of MDAPs from the PEs;
2. Compare with SAR (Selected Acquisition Report) in the MDAP perspective;
3. Identify more dependent variables and use diversity metrics;
4. Predict program costs and cost growth relative to the Milestone B;

5. Visualize the cascade effect of program costs for modifying, deleting, and inserting programs;

6. Identify links of PEs and Programs and use them as indications of the program importance;

7. Provide an automatic LLA service via Enterprise Lexicon Service or Meta-data Registry;

8. Establish a complex system theory by using Law of Requisite Variety and Design Structure Matrix.

There is also a continuous need to connect what is conceptually important in the data of participating technologies with what warfighters need via UNSs. We will continue providing services to the large-scale experimentation community at DISE/NPS in an effort to facilitate acquisition decision-makers' assessment of technologies from experimentation results.

Task 2: Enhance LLA via Parallel Computing and 3-D Visualizations

We will enhance LLA performance to ingest large volumes of unstructured information via parallel and cloud computing capability using the NPS High Performance Computing center. Hundreds of learning agents can be set up to gather, analyze, and disseminate information in a massive, parallel fashion. We will improve human interactions by presenting acquisition decision-makers with 3-D visualizations that will also provide a platform to navigate lexical links. We will work with the Modeling, Virtual Environments, and Simulation (MOVES) Institute at NPS for 3-D visualization and navigation of the results found via Tasks 1 and 2.

Task 3: Prepare Deliverables

We will prepare the following deliverables:

1. A web service to mine acquisition data and present results and visualizations periodically.

2. A paper submission in April 2011 for the Proceedings of the Eighth Annual Acquisition Research Symposium.

3. A presentation delivered at the Eighth Annual Acquisition Research Symposium in May 2011.

4. An NPS technical report/Acquisition Research Program sponsored report, submitted before September 30, 2011.

5. A journal article submission to the International Journal of Defense Acquisition Management (IJDAM).

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Appendix A. Lexical Links Indentified for PEs

Table A1. LLA Matches for Each PE with Respect to Other PEs

	PE	LLA identified Links	Human Identified Links	2008 Cost	2009 Cost	2009 Cost Increase	2009 Cost Increase %
1	0601102A_Defense_Research_Sciences	369	10	165	194	29	0.18
2	0206313M_Marine_Corps_Communications_Systems	350	2	348	357	9	0.03
3	0601104A_University_and_Industry_Research_Centers	226	13	110	121	12	0.11
4	0601153N_Defense_Research_Sciences	179	2	377	406	28	0.07
5	0604665A_FCS_Sustainment_Training_R_D	178	17	724	820	95	0.13
6	0603640M_USMC_Advanced_Technology_Demonstration_ATD	169	8	91	103	12	0.13
7	0603004A_Weapons_and_Munitions_Advanced_Technology	167	22	85	113	28	0.33
8	0602120A_Sensors_and_Electronic_Survivability	155	26	61	76	15	0.25
9	0604661A_FCS_Systems_of_Systems_Engr_Program_Mgmt	155	17	1293	1022	-270	-0.21
10	0602787A_Medical_Technology	154	8	182	198	17	0.09
11	0603005A_Combat_Vehicle_and_Automotive_Advanced_Technology	146	21	242	270	28	0.12
12	0604663A_FCS_Unmanned_Ground_Vehicles	142	17	79	105	26	0.33
13	0604646A_Non_Line_of_Sight_Launch_System	142	17	246	254	8	0.03
14	0602624A_Weapons_and_Munitions_Technology	136	18	101	106	5	0.05
15	0604660A_FCS_Manned_Grd_Vehicles_Common_Grd_Vehicle	133	17	636	761	125	0.2
16	0603002A_Medical_Advanced_Technology	131	4	299	329	30	0.1
17	0602105A_Materials_Technology	128	19	60	81	20	0.34
18	0604808A_Landmine_Warfare_Barrier_SDD	128	0	172	114	-59	-0.34
19	0604662A_FCS_Reconnaissance_UAV_Platforms	123	17	43	56	13	0.31
20	0604647A_Non_Line_of_Sight_Cannon	123	17	133	87	-46	-0.35
21	0602784A_Military_Engineering_Technology	123	10	55	59	3	0.06
22	0603001A_Warfighter_Advanced_Technology	122	14	65	72	7	0.1
23	0602705A_Electronics_and_Electronic_Devices	120	15	124	99	-25	-0.2
24	0603207N_Air_Ocean_Tactical_Applications	120	3	39	66	26	0.67
25	0602236N_Warfighter_Sustainment_Applied_Research	119	9	101	114	13	0.13
26	0601101A_In_House_Laboratory_Independent_Research	116	0	20	19	0	-0.02
27	0604664A_FCS_Unattended_Ground_Sensors	113	17	22	20	-2	-0.09
28	0604501N_Advanced_Above_Water_Sensors	112	5	113	125	12	0.1
29	0603561N_Advanced_Submarine_System_Development	112	1	152	154	1	0.01

30	0602123N_Force_Protection_Applied_Research	109	12	184	187	3	0.02
31	0604666A_Modular_Brigade_Enhancement	107	17	84	123	39	0.46
32	0305204N_Tactical_Unmanned_Aerial_Vehicles	107	4	67	53	-13	-0.2
33	0602712A_Countermine_Systems	106	9	24	28	4	0.15
34	0604366N_Standard_Missile_Improvements	106	1	215	223	8	0.04
35	0605013N_Information_Technology_Development	106	0	72	100	28	0.39
36	0604807A_Medical_Materiel_Medical_Biological_Defense_Equipment_SDD	105	1	23	41	18	0.76
37	0603772A_Advanced_Tactical_Computer_Science_and_Sensor_Technology	104	11	69	92	22	0.32
38	0603003A_Aviation_Advanced_Technology	103	14	99	102	3	0.03
39	0603008A_Electronic_Warfare_Advanced_Technology	103	8	55	61	6	0.11
40	0603721N_Environmental_Protection	102	4	20	21	0	0.01
41	0206623M_Marine_Corps_Ground_Combat_Supporting_Arms_Systems	102	2	80	103	23	0.28
42	0602211A_Aviation_Technology	99	4	43	46	4	0.09
43	0603807A_Medical_Systems_Adv_Dev	97	2	25	30	4	0.17
44	0207434F_Link_16_Support_and_Sustainment	96	8	186	279	93	0.5
45	0602720A_Environmental_Quality_Technology	96	4	17	16	-1	-0.05
46	0207451F_Single_Integrated_Air_Picture_SIAP	96	1	5	50	45	9.49
47	0604231N_Tactical_Command_System	95	4	87	111	23	0.27
48	0305206F_Airborne_Reconnaissance_Systems	93	2	112	111	-1	-0.01
49	0603710A_Night_Vision_Advanced_Technology	91	11	63	70	7	0.11
50	0604800F_Joint_Strike_Fighter_JSF	91	2	1939	1744	-196	-0.1
51	0603851M_Nonlethal_Weapons	90	1	56	50	-6	-0.11
52	0603804A_Logistics_and_Engineer_Equipment_Adv_Dev	89	7	133	43	-90	-0.68
53	0601152N_In_House_Laboratory_Independent_Research	88	1	16	17	1	0.04
54	0204136N_F_A_18_Squadrons	87	0	43	71	28	0.64
55	0604222F_Nuclear_Weapons_Support	86	1	20	20	0	0.01
56	0602786A_Warfighter_Technology	85	8	37	36	-1	-0.02
57	0602235N_Common_Picture_Applied_Research	85	4	106	90	-16	-0.15
58	0604378N_Naval_Integrated_Fire_Control_Counter_Air_Systems_Engineering	85	4	15	12	-3	-0.17
59	0605803A_Technical_Information_Activities	85	0	44	44	0	-0.01
60	0602270A_Electronic_Warfare_Technology	84	8	26	20	-6	-0.22
61	0205633N_Aviation_Improvements	82	2	96	95	-1	-0.01
62	0604270N_Electronic_Warfare_Development	82	1	51	91	41	0.8
63	0604307N_Surface_Combatant_Combat_System_Engineering	81	7	152	197	45	0.3
64	0603725N_Facilities_Improvement	81	0	9	18	9	0.97
65	0602307A_Advanced_Weapons_Technology	80	9	24	23	-2	-0.07
66	0603779A_Environmental_Quality_Technology	80	4	26	20	-6	-0.23

67	0604710A_Night_Vision_Systems_SDD	80	2	49	97	48	0.98
68	0603105A_Military_HIV_Research	79	3	14	15	0	0.03
69	0603502N_Surface_and_Shallow_Water_Mine_Countermeasures	79	0	88	94	6	0.07
70	0602782A_Command_Control_Communications_Technology	78	11	42	45	3	0.08
71	0602618A_Ballistics_Technology	77	23	90	85	-5	-0.05
72	0602131M_Marine_Corps_Landing_Force_Technology	77	12	31	43	12	0.39
73	0601103N_University_Research_Initiatives	77	0	97	102	6	0.06
74	0602709A_Night_Vision_Technology	76	8	34	45	11	0.32
75	0604804A_Logistics_and_Engineer_Equipment_SDD	76	2	40	30	-10	-0.25
76	0603216N_Aviation_Survivability	75	0	21	15	-6	-0.28
77	0602308A_Advanced_Concepts_and_Simulation	74	6	18	18	0	-0.02
78	0603742F_Combat_Identification_Technology	74	0	25	29	4	0.14
79	0305206N_Airborne_Reconnaissance_Systems	74	0	70	59	-11	-0.16
80	0603123N_Force_Protection_Advanced_Technology	73	4	126	121	-4	-0.03
81	0603734A_Military_Engineering_Advanced_Technology	72	2	35	35	0	0.01
82	0604270A_Electronic_Warfare_Development	72	1	54	38	-16	-0.29
83	0207412F_Control_and_Reporting_Center_CRC	72	0	24	19	-5	-0.22
84	0602303A_Missile_Technology	71	8	67	5	-62	-0.93
85	0602747N_Undersea_Warfare_Applied_Research	71	6	72	61	-10	-0.15
86	0605602A_Army_Technical_Test_Instrumentation_and_Targets	70	1	89	85	-4	-0.05
87	0603581N_Littoral_Combat_Ship_LCS	70	0	309	372	63	0.2
88	0605013M_Information_Technology_Development	70	0	28	33	5	0.18
89	0603313A_Missile_and_Rocket_Advanced_Technology	69	14	77	75	-2	-0.03
90	0602622A_Chemical_Smoke_and_Equipment_Defeating_Technology	69	3	10	9	-1	-0.13
91	0604817A_Combat_Identification	69	0	11	9	-2	-0.17
92	0203758A_Digitization	69	0	10	8	-3	-0.25
93	0206624M_Marine_Corps_Combat_Services_Support	68	0	125	10	-115	-0.92
94	0603015A_Next_Generation_Training_Simulation_Systems	67	5	23	25	1	0.06
95	0603619A_Landmine_Warfare_and_Barrier_Adv_Dev	67	0	19	14	-5	-0.28
96	0401115F_C_130_Airlift_Squadron	66	1	233	169	-65	-0.28
97	0604214N_AV_8B_Aircraft_Eng_Dev	66	1	22	34	12	0.52
98	0604777N_Navigation_ID_System	66	1	43	46	3	0.06
99	0605853N_Management_Technical_International_Support	66	1	47	49	2	0.05
100	0604215N_Standards_Development	65	1	104	68	-36	-0.35
101	0602271N_RF_Systems_Applied_Research	64	5	60	61	1	0.02
102	0708045A_End_Item_Industrial_Preparedness_Activities	64	2	91	89	-2	-0.03
103	0603006A_Command_Control_Communications_Advanced_Technology	64	2	12	11	0	-0.04

104	0604802A_Weapons_and_Munitions_SDD	63	0	63	102	38	0.61
105	0604759F_Major_T_E_Investment	62	9	63	68	5	0.08
106	0604503N_SSN_688_and_Trident_Modernization	62	1	114	131	17	0.15
107	0603611M_Marine_Corps_Assault_Vehicles	62	0	241	256	16	0.06
108	0604800N_Joint_Strike_Fighter_JSF	61	2	1849	1705	-144	-0.08
109	0604814A_Artillery_Munitions	60	0	62	70	8	0.12
110	0401119F_C_5_Airlift_Squadrons_IF	60	0	174	110	-64	-0.37
111	0304260F_Airborne_SIGINT_Enterprise	59	3	138	171	32	0.23
112	0603573N_Advanced_Surface_Machinery_Systems	59	1	2	3	2	1.05
113	0603654N_Joint_Service_Explosive_Ordnance_Development	59	0	31	112	81	2.65
114	0303141A_Global_Combat_Support_System	59	0	125	108	-18	-0.14
115	0604805A_Command_Control_Communications_Systems_SDD	58	1	9	9	0	0.03
116	0603382N_Advanced_Combat_Systems_Technology	57	5	10	12	2	0.25
117	0601103A_University_Research_Initiatives	57	0	80	87	8	0.1
118	0303140F_Information_Systems_Security_Program	57	0	179	163	-16	-0.09
119	0303109N_Satellite_Communications_SPACE	57	0	715	625	-90	-0.13
120	0603235N_Common_Picture_Advanced_Technology	56	5	95	87	-8	-0.09
121	0603747N_Undersea_Warfare_Advanced_Technology	56	4	73	80	7	0.1
122	0604562N_Submarine_Tactical_Warfare_System	56	0	55	65	9	0.17
123	0603739N_Navy_Logistic_Productivity	56	0	19	19	0	-0.02
124	0602435N_Ocean_Warfighting_Environment_Applied_Research	55	3	52	52	-1	-0.01
125	0604602F_Armament_Ordnance_Development	54	1	8	12	5	0.6
126	0303140N_Information_Systems_Security_Program	54	0	32	32	-1	-0.02
127	0602716A_Human_Factors_Engineering_Technology	53	12	39	42	4	0.09
128	0605011F_RDT_E_for_Aging_Aircraft	53	2	27	6	-21	-0.78
129	0207163N_Advanced_Medium_Range_Air_to_Air_Missile_AMRAAM	53	0	2	7	4	1.77
130	0901220F_Personnel_Administration	52	0	23	19	-4	-0.17
131	0602114N_Power_Projection_Applied_Research	51	9	104	102	-2	-0.02
132	0603236N_Warfighter_Sustainment_Advanced_Technology	51	8	90	111	21	0.23
133	0205601N_HARM_Improvement	51	2	70	39	-31	-0.44
134	0602785A_Manpower_Personnel_Training_Technology	51	1	16	16	0	0.02
135	0604567N_Ship_Contract_Design_Live_Fire_T_E	50	3	62	85	23	0.38
136	0305207F_Manned_Reconnaissance_Systems	50	2	24	18	-7	-0.27
137	0603254N_ASW_Systems_Development	50	1	21	38	18	0.86
138	0603755N_Ship_Self_Defense	50	0	11	10	-1	-0.08
139	0603237N_Deployable_Joint_Command_and_Control	50	0	9	7	-2	-0.23
140	0207134F_F_15E_Squadrons	49	0	115	204	89	0.77

141	0307207N_Aerial_Common_Sensor_ACS	49	0	8	34	26	3.19
142	0603563N_Ship_Concept_Advanced_Design	48	6	40	36	-3	-0.09
143	0204229N_Tomahawk_and_Tomahawk_Mission_Planning_Center_TMPC	48	0	15	18	3	0.2
144	0303141F_Global_Combat_Support_System	48	0	15	9	-6	-0.41
145	0207601F_USAF_Modeling_and_Simulation	47	0	21	28	7	0.35
146	0203761N_Rapid_Technology_Transition_RTT	47	0	39	40	2	0.04
147	0303140A_Information_Systems_Security_Program	47	0	52	41	-11	-0.21
148	0603639A_Tank_and_Medium_Caliber_Ammunition	46	9	46	40	-7	-0.14
149	0603635M_Marine_Corps_Ground_Combat_Support_System	45	3	4	58	54	13.97
150	0605857A_Environmental_Quality_Technology_Mgmt_Support	45	2	9	10	1	0.13
151	0401132F_C_130J_Program	45	0	62	25	-37	-0.59
152	0604854A_Artillery_Systems	44	0	31	32	2	0.05
153	0604373N_Airborne_MCM	44	0	55	41	-15	-0.27
154	0603606A_Landmine_Warfare_and_Barrier_Advanced_Technology	43	8	30	37	7	0.23
155	0602782N_Mine_and_Expeditionary_Warfare_Applied_Research	43	4	70	53	-17	-0.24
156	0603729N_Warfighter_Protection_Advanced_Technology	43	2	51	53	2	0.04
157	0204163N_Fleet_Telecommunications_Tactical	43	0	23	28	5	0.21
158	0605801A_Programwide_Activities	43	0	72	73	0	0
159	0603854F_Wideband_Global_SATCOM_RDT_E_Space	42	4	21	30	9	0.41
160	0604558N_New_Design_SSN	42	1	240	184	-56	-0.23
161	0203726A_Adv_Field_Artillery_Tactical_Data_System	42	0	16	16	0	0
162	0203744A_Aircraft_Modifications_Product_Improvement_Programs	42	0	327	299	-29	-0.09
163	0602601A_Combat_Vehicle_and_Automotive_Technology	41	11	87	84	-3	-0.03
164	0604755N_Ship_Self_Defense_Detect_Control	41	5	35	44	9	0.27
165	0605805A_Munitions_Standardization_Effectiveness_and_Safety	41	1	40	44	5	0.11
166	0603007A_Manpower_Personnel_and_Training_Advanced_Technology	40	3	7	7	0	0.01
167	0603512N_Carrier_Systems_Development	40	2	86	178	92	1.08
168	0804757F_Joint_National_Training_Center	40	0	3	3	0	0.03
169	0604269N_EA_18	40	0	269	116	-154	-0.57
170	0603728A_Environmental_Quality_Technology_Demonstrations	39	4	15	17	2	0.15
171	0603114N_Power_Projection_Advanced_Technology	39	3	94	97	3	0.03
172	0603851F_Intercontinental_Ballistic_Missile	39	0	26	59	33	1.26
173	0102326F_Region_Sector_Operation_Control_Center_Modernization_Program	39	0	23	23	1	0.02
174	0603271N_RF_Systems_Advanced_Technology	38	4	44	56	12	0.29
175	0605500N_Multi_mission_Maritime_Aircraft_MMA	38	1	861	1090	229	0.27
176	0603270A_Electronic_Warfare_Technology	37	10	42	33	-9	-0.22
177	0205658N_Navy_Science_Assistance_Program	37	0	6	6	0	0.05

178	0604240F_B_2_Advanced_Technology_Bomber	36	1	278	384	106	0.38
179	0604226F_B_1B	35	4	180	158	-22	-0.12
180	0604857F_Operationally_Responsive_Space	35	3	87	229	142	1.63
181	0604760A_Distributive_Interactive_Simulations_DIS_SDD	35	0	20	19	-1	-0.04
182	0305221F_Network_Centric_Collaborative_Targeting	35	0	12	9	-3	-0.27
183	0603747A_Soldier_Support_and_Survivability	35	0	37	18	-19	-0.51
184	0207417F_Airborne_Warning_and_Control_System_AWACS	35	0	146	122	-24	-0.16
185	0604741A_Air_Defense_Command_Control_and_Intelligence_SDD	35	0	57	22	-35	-0.62
186	0604425F_Space_Situation_Awareness_Systems	34	2	206	211	5	0.02
187	0604273N_VH_71A_Executive_Helo_Development	34	0	226	757	530	2.34
188	0602623A_Joint_Service_Small_Arms_Program	33	4	7	9	2	0.35
189	0605326A_Concepts_Experimentation_Program	33	0	29	33	4	0.15
190	0303142A_SATCOM_Ground_Environment_SPACE	33	0	45	47	1	0.03
191	0604264N_Air_Crew_Systems_Development	33	0	23	16	-8	-0.33
192	0604818A_Army_Tactical_Command_Control_Hardware_Software	33	0	110	64	-46	-0.42
193	0604707N_Space_and_Electronic_Warfare_SEW_Architecture_Engineering_Support	32	2	40	46	6	0.14
194	0604601A_Infantry_Support_Weapons	32	2	60	58	-2	-0.03
195	0604261N_Acoustic_Search_Sensors	32	0	19	38	20	1.05
196	0205632N_MK_48_ADCAP	32	0	20	26	6	0.32
197	0605103A_Rand_Arroyo_Center	32	0	19	20	1	0.06
198	0203759A_Force_XXI_Battle_Command_Brigade_and_Below_FBCB2	32	0	31	23	-8	-0.27
199	0605807F_Test_and_Evaluation_Support	31	8	753	756	3	0
200	0401839F_Air_Mobility_Tactical_Data_Link	31	4	4	8	3	0.79
201	0305913F_NUDET_Detection_System_SPACE	31	2	38	41	3	0.07
202	0605013A_Information_Technology_Development	31	0	171	68	-103	-0.6
203	0603782N_Mine_and_Expeditionary_Warfare_Advanced_Technology	30	4	28	35	6	0.23
204	0605873M_Marine_Corps_Program_Wide_Support	30	1	33	27	-6	-0.19
205	0603506N_Surface_Ship_Torpedo_Defense	30	0	33	48	16	0.48
206	0604201A_Aircraft_Avionics	30	0	53	61	8	0.15
207	0603805A_Combat_Service_Support_Control_System_Evaluation_and_Analysis	30	0	14	18	3	0.23
208	0604329F_Small_Diameter_Bomb_SDB	29	2	148	123	-25	-0.17
209	0603438F_Space_Control_Technology	29	1	62	86	24	0.4
210	0604212N_Other_Helo_Development	29	0	51	53	2	0.03
211	0604759A_Major_T_E_Investment	29	0	65	63	-2	-0.03
212	0207253F_Compass_Call	29	0	13	5	-9	-0.66
213	0708611F_Support_Systems_Development	28	0	33	22	-11	-0.33
214	0603845F_Transformational_SATCOM_TSAT	27	2	777	429	-348	-0.45

215	0604756N_Ship_Self_Defense_Engage_Hard_Kill	27	0	74	55	-19	-0.25
216	0305208F_Distributed_Common_Ground_Surface_Systems	27	0	100	75	-25	-0.25
217	0605978F_Facilities_Sustainment_Test_and_Evaluation_Support	26	8	34	30	-4	-0.12
218	0603430F_Advanced_EHF_MILSATCOM_SPACE	26	3	612	460	-152	-0.25
219	0305940F_Space_Situation_Awareness_Operations	26	2	39	16	-23	-0.6
220	0207581F_Joint_Surveillance_Target_Attack_Radar_System_JSTARS	26	1	338	98	-240	-0.71
221	0101313F_Strat_War_Planning_System_USSTRATCOM	26	1	25	17	-8	-0.32
222	0207701F_Full_Combat_Mission_Training	26	0	60	77	17	0.29
223	0604230N_Warfare_Support_System	26	0	6	12	6	1.01
224	0603713N_Ocean_Engineering_Technology_Development	26	0	9	9	1	0.08
225	0207170F_Joint_Helmet_Mounted_Cueing_System_JHMCS	26	0	4	3	-1	-0.27
226	0207448F_C2ISR_Tactical_Data_Link	25	7	2	2	0	-0.04
227	0605154N_Center_for_Naval_Analyses	25	1	47	46	-1	-0.03
228	0604512N_Shipboard_Aviation_Systems	25	1	37	50	13	0.34
229	0708610F_Logistics_Information_Technology_LOGIT	25	0	105	145	40	0.38
230	0604504N_Air_Control	25	0	4	8	4	0.83
231	0603790F_NATO_Research_and_Development	25	0	4	4	0	0.02
232	0901212F_Service_Wide_Support_Not_Otherwise_Accounted_For	25	0	6	4	-3	-0.43
233	0604443F_Third_Generation_Infrared_Surveillance_3GIRS	24	2	75	1	-74	-0.99
234	0207325F_Joint_Air_to_Surface_Standoff_Missile_JASSM	24	1	12	32	20	1.73
235	0207410F_Air_Space_Operations_Center_AOC	24	1	97	96	-1	-0.01
236	0603260F_Intelligence_Advanced_Development	24	0	6	7	1	0.12
237	0207418F_Tactical_Airborne_Control_Systems	24	0	3	1	-2	-0.56
238	0605863N_RDT_E_Ship_and_Aircraft_Support	24	0	179	172	-6	-0.03
239	0605301A_Army_Kwajalein_Atoll	24	0	181	169	-11	-0.06
240	0207446F_Bomber_Tactical_Data_Link	23	8	38	22	-17	-0.44
241	0605605A_DOD_High_Energy_Laser_Test_Facility	23	2	8	7	-2	-0.19
242	0604300N_SC_21_Total_Ship_System_Engineering	23	2	623	507	-116	-0.19
243	0603801A_Aviation_Adv_Dev	23	1	9	7	-2	-0.19
244	0207133F_F_16_Squadrons	23	0	77	124	47	0.61
245	0604272N_Tactical_Air_Directional_Infrared_Countermeasures_TADIRCM	23	0	32	43	10	0.32
246	0603651M_Joint_Non_Lethal_Weapons_Technology_Development	23	0	11	13	3	0.26
247	0604715A_Non_System_Training_Devices_SDD	23	0	35	37	1	0.04
248	0605702A_Meteorological_Support_to_RDT_E_Activities	23	0	8	8	0	0
249	0207131F_A_10_Squadrons	23	0	6	4	-3	-0.39
250	0204575N_Electronic_Warfare_EW_Readiness_Support	22	2	35	24	-11	-0.33
251	0305164F_NAVSTAR_Global_Positioning_System_User_Equipment_SPACE	22	1	151	122	-29	-0.19

252	0207438F_Theater_Battle_Management_TBM_C4I	22	1	12	19	7	0.56
253	0708011N_Industrial_Preparedness	22	0	57	60	3	0.05
254	0305887F_Intelligence_Support_to_Information_Warfare	22	0	5	5	0	0.02
255	0604780A_Combined_Arms_Tactical_Trainer_CATT_Core	22	0	35	33	-2	-0.06
256	0604441F_Space_Based_Infrared_System_SBIRS_High_EMD	22	0	583	542	-41	-0.07
257	0603607A_Joint_Service_Small_Arms_Program	21	4	16	9	-8	-0.48
258	0604757N_Ship_Self_Defense_Engage_Soft_Kill_EW	21	0	36	57	21	0.57
259	0605976F_Facilities_Restoration_and_Modernization_Test_and_Evaluation_Support	20	8	61	47	-14	-0.23
260	0401318F_CV_22	20	2	23	18	-5	-0.23
261	0603860N_Joint_Precision_Approach_and_Landing_Systems	20	0	67	74	7	0.11
262	0303158N_Joint_Command_and_Control_Program_JC2	20	0	5	4	-1	-0.12
263	0604216N_Multi_Mission_Helicopter_Upgrade_Development	20	0	74	68	-6	-0.09
264	0604771N_Medical_Development	20	0	50	39	-10	-0.21
265	0305178F_National_Polar_Orbiting_Operational_Environmental_Satellite_System_NPOESS	20	0	331	288	-43	-0.13
266	0207445F_Fighter_Tactical_Data_Link	19	8	57	55	-2	-0.04
267	0604329N_Small_Diameter_Bomb_SDB	19	2	11	19	8	0.68
268	0207138F_F_22A_Squadrons	19	2	608	580	-28	-0.05
269	0604227N_HARPOON_Modifications	19	1	42	44	2	0.04
270	0604421F_Counterspace_Systems	19	1	59	64	5	0.08
271	0304785N_Tactical_Cryptologic_Systems	19	1	38	18	-20	-0.52
272	0604759N_Major_T_E_Investment	19	0	41	51	10	0.24
273	0305099F_Global_Air_Traffic_Management_GATM	19	0	7	11	3	0.47
274	0604604F_Submunitions	19	0	2	2	0	-0.13
275	0603889N_Counterdrug_RDT_E_Projects	19	0	65	62	-3	-0.04
276	0203740A_Maneuver_Control_System	19	0	44	36	-8	-0.17
277	0901538F_Financial_Management_Information_Systems_Development	18	3	29	23	-6	-0.2
278	0604262N_V_22A	18	2	125	66	-59	-0.47
279	0204152N_E_2_Squadrons	18	0	19	52	33	1.76
280	0603724N_Navy_Energy_Program	18	0	6	10	4	0.72
281	1001004F_International_Activities	18	0	4	4	0	-0.03
282	0603542N_Radiological_Control	18	0	3	1	-2	-0.6
283	0604822A_General_Fund_Enterprise_Business_System_GFEBS	18	0	108	50	-58	-0.54
284	0602783A_Computer_and_Software_Technology	17	8	9	8	-1	-0.1
285	0603125A_Combating_Terrorism_Technology_Development	17	8	13	13	-1	-0.04
286	0305208N_Distributed_Common_Ground_Surface_Systems	17	2	21	44	23	1.09
287	0603827A_Soldier_Systems_Advanced_Development	17	2	26	42	15	0.59
288	0305160N_Navy_Meteorological_and_Ocean_Sensors_Space_METOC	17	1	5	8	3	0.69

289	0604256A_Threat_Simulator_Development	17	1	23	22	-1	-0.04
290	0604633A_Air_Traffic_Control	17	0	12	16	4	0.38
291	0605706A_Materiel_Systems_Analysis	17	0	17	17	1	0.03
292	0603790A_NATO_Research_and_Development	17	0	5	5	0	0.02
293	0604870A_Nuclear_Arms_Control_Monitoring_Sensor_Network	16	0	7	6	-1	-0.13
294	0303131F_Minimum_Essential_Emergency_Communications_Network_MEECN	16	0	85	81	-4	-0.05
295	0603582N_Combat_System_Integration	15	3	52	62	10	0.19
296	0603513N_Shipboard_System_Component_Development	15	3	43	36	-7	-0.16
297	0603562N_Submarine_Tactical_Warfare_Systems	15	1	15	14	-1	-0.06
298	0207449F_Command_and_Control_C2_Constellation	15	1	43	31	-12	-0.28
299	0604746A_Automatic_Test_Equipment_Development	15	0	12	17	5	0.47
300	0207605F_Wargaming_and_Simulation_Centers	15	0	6	4	-2	-0.39
301	0605101F_RAND_Project_Air_Force	15	0	40	38	-3	-0.07
302	0605804N_Technical_Information_Services	15	0	21	16	-5	-0.23
303	0401134F_Large_Aircraft_IR_Countermeasures_LAIRCM	14	1	18	22	5	0.28
304	0207590F_Seek_Eagle	14	1	23	21	-1	-0.06
305	0604402N_Unmanned_Combat_Air_Vehicle_UCAV_Advanced_Component_and_Prototype_Development	14	0	154	266	113	0.73
306	0605601A_Army_Test_Ranges_and_Facilities	14	0	350	357	7	0.02
307	0605606A_Aircraft_Certification	14	0	5	5	0	0.08
308	0605604A_Survivability_Lethality_Analysis	14	0	41	40	-1	-0.02
309	0208058A_Joint_High_Speed_Vessel_JHSV	14	0	5	3	-2	-0.4
310	0305173F_Space_and_Missile_Test_and_Evaluation_Center	14	0	5	2	-3	-0.61
311	0401219F_KC_10s	14	0	14	4	-10	-0.72
312	0603774A_Night_Vision_Systems_Advanced_Development	13	2	3	3	0	0
313	0702207N_Depot_Maintenance_Non_IF	13	1	21	10	-11	-0.53
314	0603103A_Explosives_Demilitarization_Technology	13	1	21	17	-4	-0.18
315	0605864N_Test_and_Evaluation_Support	13	0	334	351	16	0.05
316	0605718A_Simulation_Modeling_for_Acq_Rqts_Tng_SMART	13	0	5	5	0	0
317	0604245N_H_1_Upgrades	13	0	4	4	0	-0.09
318	0205604N_Tactical_Data_Links	13	0	5	4	-1	-0.21
319	0604703N_Personnel_Training_Simulation_and_Human_Factors	13	0	9	5	-3	-0.4
320	0305924F_National_Security_Space_Office	13	0	15	8	-8	-0.5
321	0604218N_Air_Ocean_Equipment_Engineering	12	2	5	5	1	0.13
322	0605024F_Anti_Tamper_Technology_Executive_Agency	12	0	12	20	8	0.65
323	0205620N_Surface_ASW_Combat_System_Integration	12	0	16	22	5	0.32
324	0604617F_Agile_Combat_Support	12	0	12	5	-7	-0.62
325	0208053A_Joint_Tactical_Ground_System	12	0	23	2	-21	-0.92

326	0604234N_Advanced_Hawkeye	12	0	786	468	-318	-0.4
327	0204571N_Consolidated_Training_Systems_Development	11	0	15	25	10	0.66
328	0303158M_Joint_Command_and_Control_Program_JC2	11	0	1	2	1	0.49
329	0604713A_Combat_Feeding_Clothing_and_Equipment	11	0	2	2	0	0
330	0603261N_Tactical_Airborne_Reconnaissance	10	2	7	6	-1	-0.16
331	0605450N_Joint_Air_to_Ground_Missile_JAGM	10	1	62	55	-7	-0.11
332	0604270F_Electronic_Warfare_Development	10	1	76	66	-10	-0.13
333	0203735A_Combat_Vehicle_Improvement_Programs	10	0	43	139	96	2.25
334	0308699F_Shared_Early_Warning_SEW	10	0	3	3	0	0.01
335	0303150F_Global_Command_and_Control_System	9	1	3	3	0	-0.02
336	0305204A_Tactical_Unmanned_Aerial_Vehicles	9	1	188	100	-88	-0.47
337	0603758N_Navy_Warfighting_Experiments_and_Demonstrations	9	0	41	65	24	0.59
338	0207163F_Advanced_Medium_Range_Air_to_Air_Missile_AMRAAM	9	0	36	44	7	0.2
339	0604221N_P_3_Modernization_Program	9	0	5	3	-1	-0.23
340	0604233F_Specialized_Undergraduate_Flight_Training	9	0	14	12	-2	-0.16
341	0604742A_Constructive_Simulation_Systems_Development	9	0	31	25	-6	-0.18
342	0603778A_MLRS_Product_Improvement_Program	8	0	42	54	12	0.27
343	0305116F_Aerial_Targets	8	0	6	11	5	0.93
344	0203801A_Missile_Air_Defense_Product_Improvement_Program	8	0	29	34	5	0.17
345	0305114F_Air_Traffic_Control_Approach_and_Landing_System_ATCALS	8	0	6	9	2	0.38
346	0804758N_Service_Support_to_JFCOM_JNTC	8	0	5	5	0	0.01
347	0604256F_Threat_Simulator_Development	7	12	36	34	-2	-0.05
348	0305165F_NAVSTAR_Global_Positioning_System_Space_and_Control_Segments	7	5	110	87	-24	-0.21
349	0702239N_Avionics_Component_Improvement_Program	7	1	2	2	0	0.12
350	0604258N_Target_Systems_Development	7	0	32	76	44	1.41
351	0605716A_Army_Evaluation_Center	7	0	59	61	2	0.04
352	0308601N_Modeling_and_Simulation_Support	7	0	8	8	0	0.02
353	0603791F_International_Space_Cooperative_R_D	7	0	1	1	0	0.02
354	0408011F_Special_Tactics_Combat_Control	7	0	8	8	0	-0.04
355	0603609N_Conventional_Munitions	7	0	7	6	-1	-0.09
356	0604735F_Combat_Training_Ranges	7	0	16	12	-3	-0.21
357	0603653A_Advanced_Tank_Armament_System_ATAS	7	0	128	76	-52	-0.4
358	0603308A_Army_Missile_Defense_Systems_Integration_Space	6	2	58	53	-5	-0.08
359	0603790N_NATO_Research_and_Development	6	1	11	11	0	-0.02
360	0602651M_Joint_Non_Lethal_Weapons_Applied_Research	6	1	6	5	-1	-0.2
361	0604827A_Soldier_Systems_Warrior_Dem_Val	6	0	2	20	19	12
362	0401218F_KC_135s	6	0	8	12	4	0.52

363	0305174F_Space_Warfare_Center	6	0	2	3	1	0.78
364	0901202F_Joint_Personnel_Recovery_Agency	6	0	5	6	0	0.08
365	0208021F_Information_Warfare_Support	6	0	12	12	0	0.01
366	0605856N_Strategic_Technical_Support	6	0	3	4	0	0.04
367	0207247F_AF_TENCAP	6	0	11	12	0	0.01
368	0303158A_Joint_Command_and_Control_Program_JC2	6	0	16	13	-2	-0.16
369	0305182F_Spacelift_Range_System_SPACE	6	0	25	13	-12	-0.47
370	0208006F_Mission_Planning_Systems	5	1	102	95	-7	-0.07
371	0603782A_Warfighter_Information_Network_Tactical	5	0	309	382	73	0.24
372	0604869A_Patriot_MEADS_Combined_Aggregate_Program_CAP	5	0	402	455	53	0.13
373	0203761F_Warfighter_Rapid_Acquisition_Process_WRAP_Rapid_Transition_Fund	5	0	22	30	8	0.38
374	0604256N_Threat_Simulator_Development	5	0	24	24	1	0.02
375	0305128F_Security_and_Investigative_Activities	5	0	2	2	0	0.02
376	0702207F_Depot_Maintenance_Non_IF	5	0	1	1	0	0.02
377	0605712F_Initial_Operational_Test_Evaluation	5	0	30	29	-1	-0.03
378	0603287F_Physical_Security_Equipment	5	0	3	2	-1	-0.4
379	0804731F_General_Skill_Training	5	0	3	1	-2	-0.58
380	0204311N_Integrated_Surveillance_System	5	0	31	29	-2	-0.07
381	0303150A_WWMCCS_Global_Command_and_Control_System	5	0	24	13	-12	-0.48
382	0604823A_Firefinder	5	0	85	65	-20	-0.23
383	0303601F_MILSATCOM_Terminals	4	11	363	278	-85	-0.23
384	0305219F_MQ_1_Predator_A_UAV	4	2	38	39	1	0.03
385	0603879N_Single_Integrated_Air_Picture_SIAP_System_Engineer_SE	4	1	46	41	-5	-0.11
386	0207161F_Tactical_AIM_Missiles	4	1	8	6	-2	-0.27
387	0604727N_Joint_Standoff_Weapon_Systems	4	1	29	22	-7	-0.24
388	0605502N_Small_Business_Innovative_Research	4	0	327	402	75	0.23
389	0207136F_Manned_Destructive_Suppression	4	0	1	5	5	9.83
390	0207161N_Tactical_AIM_Missiles	4	0	5	8	4	0.75
391	0604706F_Life_Support_Systems	4	0	13	15	2	0.13
392	0604750F_Intelligence_Equipment	4	0	5	2	-3	-0.55
393	0401138F_Joint_Cargo_Aircraft_JCA	4	0	20	16	-4	-0.2
394	0605864F_Space_Test_Program_STP	4	0	50	45	-5	-0.11
395	0603627A_Smoke_Obscurant_and_Target_Defeating_Sys_Adv_Dev	4	0	9	4	-5	-0.59
396	0605860F_Rocket_Systems_Launch_Program_SPACE	4	0	24	17	-7	-0.29
397	0305149N_COBRA_JUDY	4	0	132	101	-31	-0.24
398	0603795N_Land_Attack_Technology	4	0	50	16	-34	-0.68
399	0604220A_Armed_Deployable_OH_58D	4	0	176	63	-113	-0.64

400	0603840F_Global_Broadcast_Service_GBS	3	2	21	17	-4	-0.18
401	0604610N_Lightweight_Torpedo_Development	3	1	26	45	19	0.71
402	0205219F_MQ_9_UAV	3	1	56	57	1	0.02
403	0401130F_C_17_Aircraft_IF	3	1	166	183	17	0.1
404	0604853F_Evolved_Expendable_Launch_Vehicle_Program_SPACE	3	0	7	44	37	5.71
405	0602234N_Materials_Electronics_and_Computer_Technology	3	0	2	7	5	2.77
406	0605861N_RDT_E_Science_and_Technology_Management	3	0	68	70	2	0.03
407	0605866N_Navy_Space_and_Electronic_Warfare_SEW_Support	3	0	2	3	0	0.14
408	0603850F_Integrated_Broadcast_Service	3	0	21	21	0	0.01
409	0604287F_Physical_Security_Equipment	3	0	0	0	0	0.55
410	0204574N_Cryptologic_Direct_Support	3	0	1	1	0	0
411	0604518N_Combat_Information_Center_Conversion	3	0	18	17	-1	-0.05
412	0604604A_Medium_Tactical_Vehicles	3	0	5	2	-2	-0.53
413	0207423F_Advanced_Communications_Systems	2	3	30	28	-2	-0.07
414	0604740F_Integrated_Command_Control_Applications_IC2A	2	2	28	10	-18	-0.65
415	0603305A_Army_Missile_Defense_Systems_Integration_Non_Space	2	2	129	91	-38	-0.3
416	0305110F_Satellite_Control_Network_SPACE	2	1	24	55	31	1.32
417	0702806F_Acquisition_and_Management_Support	2	1	26	41	15	0.6
418	0603564N_Ship_Preliminary_Design_Feasibility_Studies	2	1	26	23	-3	-0.11
419	0603327A_Air_and_Missile_Defense_Systems_Engineering	2	1	156	116	-40	-0.26
420	0605212N_CH_53K_RDTE	2	0	386	544	158	0.41
421	0604429F_Airborne_Electronic_Attack	2	0	23	42	19	0.82
422	0604761N_Intelligence_Engineering	2	0	10	24	13	1.29
423	0101226N_Submarine_Acoustic_Warfare_Development	2	0	4	7	3	0.82
424	0603859F_Pollution_Prevention	2	0	11	14	3	0.27
425	0901218F_Civilian_Compensation_Program	2	0	13	15	1	0.1
426	0204413N_Amphibious_Tactical_Support_Units_Displacement_Craft	2	0	2	2	0	0.27
427	0605865N_Operational_Test_and_Evaluation_Capability	2	0	12	12	0	0
428	0604311N_LPD_17_Class_Systems_Integration	2	0	4	1	-3	-0.77
429	0305220F_Global_Hawk_UAV	1	2	275	279	4	0.02
430	0307141F_Information_Operations_Technology_Integration_Tool_Development	1	1	21	18	-3	-0.15
431	0305205N_Endurance_Unmanned_Aerial_Vehicles	1	0	111	424	313	2.81
432	0101402N_Navy_Strategic_Communications	1	0	36	41	5	0.15
433	0605867N_SEW_Surveillance_Reconnaissance_Support	1	0	24	25	1	0.05
434	0603925N_Directed_Energy_and_Electric_Weapon_Systems	1	0	3	5	1	0.31
435	0604654N_Joint_Service_Explosive_Ordnance_Development	1	0	10	11	1	0.1
436	0604601N_Mine_Development	1	0	2	2	0	-0.02

437	0101122F_Air_Launched_Cruise_Missile_ALCM	1	0	5	0	-4	-0.91
438	0604622A_Family_of_Heavy_Tactical_Vehicles	1	0	15	5	-10	-0.7
439	0207268F_Aircraft_Engine_Component_Improvement_Program		4	159	146	-12	-0.08
440	0603432F_Polar_MILSATCOM_SPACE		1	172	221	49	0.29
441	0604280N_Joint_Tactical_Radio_System_Navy_JTRS_Navy		1	831	824	-7	-0.01
442	0305111F_Weather_Service		0	40	46	6	0.15
443	0604609A_Smoke_Obscurant_and_Target_Defeating_Sys_SDD		0	1	5	4	3.17
444	0808716F_Other_Personnel_Activities		0	0	1	1	8.76
445	0603860F_Joint_Precision_Approach_and_Landing_Systems		0	6	7	1	0.15
446	0305885N_Tactical_Cryptologic_Activities		0	1	2	0	0.33
447	0207697F_Distributed_Training_and_Exercises		0	7	7	0	0.02
448	0303158F_Joint_Command_and_Control_Program_JC2		0	6	3	-2	-0.44
449	0305193F_Intelligence_Support_to_Information_Operations_IO		0	8	4	-5	-0.56
450	0208058N_Joint_High_Speed_Vessel_JHSV		0	18	12	-7	-0.37

Table A2. LLA Matches for Each PE with Respect to the Warfighters' Requirements

	PE	# of LLA Matched Word Hubs	2008 Cost	2009 Cost	2009 Cost Increase	Increase %
1	0603721N_Environmental_Protection	11	20.4	20.6	0.1	0.01
2	0604231N_Tactical_Command_System	9	87.4	110.6	23.2	0.27
3	0206313M_Marine_Corps_Communications_Systems	8	347.5	356.6	9	0.03
4	0602787A_Medical_Technology	7	181.5	198.1	16.6	0.09
5	0601102A_Defense_Research_Sciences	5	164.6	194	29.3	0.18
6	0601153N_Defense_Research_Sciences	5	377.4	405.6	28.2	0.07
7	0601104A_University_and_Industry_Research_Centers	5	109.5	121.3	11.8	0.11
8	0205633N_Aviation_Improvements	5	95.7	95.1	-0.6	-0.01
9	0605013N_Information_Technology_Development	5	71.7	99.6	27.9	0.39
10	0602271N_RF_Systems_Applied_Research	5	60.2	61.4	1.3	0.02
11	0602747N_Undersea_Warfare_Applied_Research	5	71.8	61.4	-10.4	-0.15
12	0603747N_Undersea_Warfare_Advanced_Technology	5	73.1	80.3	7.2	0.1
13	0603002A_Medical_Advanced_Technology	4	299.4	329.3	29.8	0.1
14	0602236N_Warfighter_Sustainment_Applied_Research	4	100.9	114.3	13.4	0.13
15	0603207N_Air_Ocean_Tactical_Applications	4	39.3	65.5	26.2	0.67
16	0603640M_USMC_Advanced_Technology_Demonstration_ATD	4	90.7	102.5	11.9	0.13

17	0602705A_Electronics_and_Electronic_Devices	4	124.1	99.1	-25	-0.2
18	0601152N_In_House_Laboratory_Independent_Research	4	16.4	17.1	0.7	0.04
19	0603236N_Warfighter_Sustainment_Advanced_Technology	4	90.4	110.9	20.6	0.23
20	0605853N_Management_Technical_International_Support	4	46.9	49.3	2.4	0.05
21	0604807A_Medical_Materiel_Medical_Biological_Defense_Equipment_SDD	4	23.4	41.1	17.7	0.76
22	0602123N_Force_Protection_Applied_Research	3	183.7	186.6	3	0.02
23	0604215N_Standards_Development	3	104	67.8	-36.2	-0.35
24	0602120A_Sensors_and_Electronic_Survivability	3	61.2	76.2	15	0.25
25	0602235N_Common_Picture_Applied_Research	3	105.7	89.7	-16.1	-0.15
26	0604567N_Ship_Contract_Design_Live_Fire_T_E	3	61.5	84.6	23.1	0.38
27	0605805A_Munitions_Standardization_Effectiveness_and_Safety	3	39.8	44.3	4.5	0.11
28	0604270A_Electronic_Warfare_Development	3	53.8	38.3	-15.6	-0.29
29	0603123N_Force_Protection_Advanced_Technology	3	125.9	121.5	-4.4	-0.03
30	0204163N_Fleet_Telecommunications_Tactical	3	23.1	28	4.9	0.21
31	0603235N_Common_Picture_Advanced_Technology	3	94.9	86.6	-8.4	-0.09
32	0604818A_Army_Tactical_Command_Control_Hardware_Software	3	109.9	63.6	-46.4	-0.42
33	0101313F_Strat_War_Planning_System_USSTRATCOM	3	25.2	17	-8.1	-0.32
34	0207412F_Control_and_Reporting_Center_CRC	3	24.1	18.7	-5.4	-0.22
35	0603542N_Radiological_Control	3	2.7	1.1	-1.6	-0.6
36	0208021F_Information_Warfare_Support	3	11.6	11.8	0.1	0.01
37	0604665A_FCS_Sustainment_Training_R_D	2	724.4	819.7	95.3	0.13
38	0204571N_Consolidated_Training_Systems_Development	2	14.8	24.6	9.8	0.66
39	0603804A_Logistics_and_Engineer_Equipment_Adv_Dev	2	133	42.9	-90.1	-0.68
40	0604661A_FCS_Systems_of_Systems_Engr_Program_Mgmt	2	1292.5	1022.2	-270.3	-0.21
41	0603004A_Weapons_and_Munitions_Advanced_Technology	2	84.7	112.5	27.9	0.33
42	0303140N_Information_Systems_Security_Program	2	32.5	31.8	-0.7	-0.02
43	0602131M_Marine_Corps_Landing_Force_Technology	2	31.3	43.5	12.2	0.39
44	0603001A_Warfighter_Advanced_Technology	2	65.5	72.3	6.8	0.1
45	0205658N_Navy_Science_Assistance_Program	2	5.8	6.2	0.3	0.05
46	0303109N_Satellite_Communications_SPACE	2	715.2	625.2	-90	-0.13
47	0604755N_Ship_Self_Defense_Detect_Control	2	34.6	43.8	9.2	0.27
48	0603003A_Aviation_Advanced_Technology	2	99.5	102.2	2.8	0.03
49	0206624M_Marine_Corps_Combat_Services_Support	2	125	10.3	-114.6	-0.92
50	0603512N_Carrier_Systems_Development	2	85.7	178.1	92.4	1.08
51	0604707N_Space_and_Electronic_Warfare_SEW_Architecture_Engineering_Support	2	40.4	46.3	5.8	0.14
52	0603216N_Aviation_Survivability	2	21.3	15.4	-5.9	-0.28
53	0604501N_Advanced_Above_Water_Sensors	2	113.1	124.9	11.8	0.1

54	0605873M_Marine_Corps_Program_Wide_Support	2	33.5	27.1	-6.3	-0.19
55	0605602A_Army_Technical_Test_Instrumentation_and_Targets	2	89.3	84.9	-4.4	-0.05
56	0603772A_Advanced_Tactical_Computer_Science_and_Sensor_Technology	2	69.3	91.7	22.5	0.32
57	0604201A_Aircraft_Avionics	2	52.8	60.8	8	0.15
58	0604759A_Major_T_E_Investment	2	64.5	62.7	-1.8	-0.03
59	0604425F_Space_Situation_Awareness_Systems	2	206.4	211.3	4.9	0.02
60	0605803A_Technical_Information_Activities	2	44.5	44.1	-0.4	-0.01
61	0602782A_Command_Control_Communications_Technology	2	42	45.4	3.3	0.08
62	0203726A_Adv_Field_Artillery_Tactical_Data_System	2	16.1	16.2	0.1	0
63	0303142A_SATCOM_Ground_Environment_SPACE	2	45.3	46.8	1.5	0.03
64	0603790F_NATO_Research_and_Development	2	4.2	4.2	0.1	0.02
65	0603779A_Environmental_Quality_Technology	2	26.5	20.4	-6	-0.23
66	0604817A_Combat_Identification	2	10.9	9	-1.9	-0.17
67	0605857A_Environmental_Quality_Technology_Mgmt_Support	2	8.8	10	1.2	0.13
68	0603879N_Single_Integrated_Air_Picture_SIAP_System_Engineer_SE	2	45.6	40.6	-5	-0.11
69	0604822A_General_Fund_Enterprise_Business_System_GFEBS	2	108.4	50.3	-58.1	-0.54
70	0603237N_Deployable_Joint_Command_and_Control	2	8.9	6.9	-2	-0.23
71	0604853F_Evolved_Expendable_Launch_Vehicle_Program_SPACE	2	6.5	43.6	37.1	5.71
72	0605804N_Technical_Information_Services	2	20.9	16	-4.9	-0.23
73	0207131F_A_10_Squadrons	2	6.5	4	-2.5	-0.39
74	0305128F_Security_and_Investigative_Activities	2	1.9	2	0	0.02
75	0702806F_Acquisition_and_Management_Support	2	25.6	41.1	15.4	0.6
76	0206623M_Marine_Corps_Ground_Combat_Supporting_Arms_Systems	1	80.5	103.1	22.6	0.28
77	0603561N_Advanced_Submarine_System_Development	1	152.5	153.8	1.3	0.01
78	0603005A_Combat_Vehicle_and_Automotive_Advanced_Technology	1	242.3	270.2	27.9	0.12
79	0604710A_Night_Vision_Systems_SDD	1	48.8	96.7	47.9	0.98
80	0203744A_Aircraft_Modifications_Product_Improvement_Programs	1	327.3	298.6	-28.7	-0.09
81	0604663A_FCS_Unmanned_Ground_Vehicles	1	78.8	104.6	25.7	0.33
82	0603502N_Surface_and_Shallow_Water_Mine_Countermeasures	1	88.4	94.4	6	0.07
83	0602784A_Military_Engineering_Technology	1	55.2	58.7	3.5	0.06
84	0602114N_Power_Projection_Applied_Research	1	103.7	101.6	-2.2	-0.02
85	0602601A_Combat_Vehicle_and_Automotive_Technology	1	87.1	84.4	-2.7	-0.03
86	0604373N_Airborne_MCM	1	55.4	40.7	-14.7	-0.27
87	0601101A_In_House_Laboratory_Independent_Research	1	19.7	19.4	-0.3	-0.02
88	0604660A_FCS_Manned_Grd_Vehicles_Common_Grd_Vehicle	1	635.8	760.7	124.9	0.2
89	0603581N_Littoral_Combat_Ship_LCS	1	309.4	372	62.6	0.2
90	0603747A_Soldier_Support_and_Survivability	1	36.9	18.1	-18.8	-0.51

91	0204136N_F_A_18_Squadrons	1	43	70.8	27.7	0.64
92	0603313A_Missile_and_Rocket_Advanced_Technology	1	77.2	75	-2.2	-0.03
93	0603725N_Facilities_Improvement	1	9.2	18	8.9	0.97
94	0602618A_Ballistics_Technology	1	89.5	84.8	-4.7	-0.05
95	0305206F_Airborne_Reconnaissance_Systems	1	111.8	111.2	-0.7	-0.01
96	0603710A_Night_Vision_Advanced_Technology	1	62.6	69.8	7.2	0.11
97	0303140F_Information_Systems_Security_Program	1	178.7	162.8	-15.9	-0.09
98	0602435N_Ocean_Warfighting_Environment_Applied_Research	1	52.5	51.9	-0.6	-0.01
99	0604741A_Air_Defense_Command_Control_and_Intelligence_SDD	1	56.5	21.7	-34.8	-0.62
100	0303140A_Information_Systems_Security_Program	1	52	41.2	-10.9	-0.21
101	0602709A_Night_Vision_Technology	1	34.4	45.3	10.9	0.32
102	0305204N_Tactical_Unmanned_Aerial_Vehicles	1	66.8	53.5	-13.3	-0.2
103	0604646A_Non_Line_of_Sight_Launch_System	1	246.1	253.7	7.6	0.03
104	0605013M_Information_Technology_Development	1	28.1	33.1	5	0.18
105	0604662A_FCS_Reconnaissance_UAV_Platforms	1	42.8	55.9	13.2	0.31
106	0603807A_Medical_Systems_Adv_Dev	1	25.2	29.6	4.4	0.17
107	0604805A_Command_Control_Communications_Systems_SDD	1	9.2	9.5	0.3	0.03
108	0604230N_Warfare_Support_System	1	6.1	12.3	6.2	1.01
109	0604212N_Other_Helo_Development	1	51.5	53.3	1.8	0.03
110	0603778A_MLRS_Product_Improvement_Program	1	42.4	54	11.6	0.27
111	0603254N_ASW_Systems_Development	1	20.6	38.4	17.7	0.86
112	0603724N_Navy_Energy_Program	1	6	10.3	4.3	0.72
113	0602720A_Environmental_Quality_Technology	1	16.7	15.8	-0.9	-0.05
114	0207417F_Airborne_Warning_and_Control_System_AWACS	1	146.3	122.4	-23.9	-0.16
115	0605326A_Concepts_Experimentation_Program	1	28.9	33.2	4.3	0.15
116	0401115F_C_130_Airlift_Squadron	1	233.3	168.7	-64.6	-0.28
117	0401119F_C_5_Airlift_Squadrons_IF	1	174	110.2	-63.8	-0.37
118	0603270A_Electronic_Warfare_Technology	1	41.9	32.5	-9.4	-0.22
119	0604256N_Threat_Simulator_Development	1	23.5	24.1	0.6	0.02
120	0604814A_Artillery_Munitions	1	62.5	70	7.5	0.12
121	0604715A_Non_System_Training_Devices_SDD	1	35.4	36.8	1.5	0.04
122	0207133F_F_16_Squadrons	1	76.8	123.7	46.9	0.61
123	0207410F_Air_Space_Operations_Center_AOC	1	96.6	95.9	-0.7	-0.01
124	0208006F_Mission_Planning_Systems	1	101.7	94.6	-7.1	-0.07
125	0305160N_Navy_Meteorological_and_Ocean_Sensors_Space_METOC	1	4.6	7.7	3.1	0.69
126	0604261N_Acoustic_Search_Sensors	1	18.7	38.4	19.7	1.05
127	0603382N_Advanced_Combat_Systems_Technology	1	9.6	12.1	2.5	0.25

128	0604854A_Artillery_Systems	1	30.6	32.3	1.7	0.05
129	0602712A_Countermine_Systems	1	24.3	27.8	3.6	0.15
130	0604562N_Submarine_Tactical_Warfare_System	1	55.1	64.5	9.4	0.17
131	0603734A_Military_Engineering_Advanced_Technology	1	34.6	34.9	0.4	0.01
132	0604378N_Naval_Integrated_Fire_Control_Counter_Air_Systems_Engineering	1	14.6	12.1	-2.5	-0.17
133	0604218N_Air_Ocean_Equipment_Engineering	1	4.7	5.4	0.6	0.13
134	0605801A_Programwide_Activities	1	72.4	72.7	0.2	0
135	0603611M_Marine_Corps_Assault_Vehicles	1	240.5	256	15.5	0.06
136	0207134F_F_15E_Squadrons	1	114.9	203.8	89	0.77
137	0603851M_Nonlethal_Weapons	1	56.5	50.4	-6	-0.11
138	0604870A_Nuclear_Arms_Control_Monitoring_Sensor_Network	1	7	6.1	-0.9	-0.13
139	0203801A_Missile_Air_Defense_Product_Improvement_Program	1	29.2	34.2	5	0.17
140	0603261N_Tactical_Airborne_Reconnaissance	1	6.8	5.7	-1.1	-0.16
141	0601103A_University_Research_Initiatives	1	79.5	87.5	7.9	0.1
142	0604622A_Family_of_Heavy_Tactical_Vehicles	1	15	4.6	-10.5	-0.7
143	0603758N_Navy_Warfighting_Experiments_and_Demonstrations	1	41.1	65.2	24.1	0.59
144	0305208N_Distributed_Common_Ground_Surface_Systems	1	21.1	44.2	23.1	1.09
145	0203759A_Force_XXI_Battle_Command_Brigade_and_Below_FBCB2	1	31	22.7	-8.3	-0.27
146	0304785N_Tactical_Cryptologic_Systems	1	38.3	18.2	-20	-0.52
147	0602783A_Computer_and_Software_Technology	1	8.7	7.8	-0.9	-0.1
148	0207449F_Command_and_Control_C2_Constellation	1	43	30.8	-12.1	-0.28
149	0603782A_Warfighter_Information_Network_Tactical	1	309.1	382.1	73.1	0.24
150	0207325F_Joint_Air_to_Surface_Standoff_Missile_JASSM	1	11.8	32.1	20.4	1.73
151	0207163N_Advanced_Medium_Range_Air_to_Air_Missile_AMRAAM	1	2.5	6.9	4.4	1.77
152	0702239N_Avionics_Component_Improvement_Program	1	1.6	1.8	0.2	0.12
153	0101402N_Navy_Strategic_Communications	1	35.6	41	5.4	0.15
154	0604222F_Nuclear_Weapons_Support	1	19.7	19.8	0.1	0.01
155	0603782N_Mine_and_Expeditionary_Warfare_Advanced_Technology	1	28.2	34.6	6.4	0.23
156	0604273N_VH_71A_Executive_Helo_Development	1	226.5	756.6	530.1	2.34
157	0305208F_Distributed_Common_Ground_Surface_Systems	1	100.3	75.3	-25.1	-0.25
158	0605718A_Simulation_Modeling_for_Acq_Rqts_Tng_SMART	1	5.2	5.2	0	0
159	0401134F_Large_Aircraft_IR_Countermeasures_LAIRCM	1	17.6	22.5	4.9	0.28
160	0604703N_Personnel_Training_Simulation_and_Human_Factors	1	8.6	5.1	-3.5	-0.4
161	0603840F_Global_Broadcast_Service_GBS	1	21.4	17.5	-3.9	-0.18
162	0603287F_Physical_Security_Equipment	1	2.8	1.7	-1.1	-0.4
163	0207138F_F_22A_Squadrons	1	607.8	579.7	-28.1	-0.05
164	0303141A_Global_Combat_Support_System	1	125.5	107.7	-17.8	-0.14

165	0605154N_Center_for_Naval_Analyses	1	47.4	46.1	-1.3	-0.03
166	0605866N_Navy_Space_and_Electronic_Warfare_SEW_Support	1	2.4	2.7	0.3	0.14
167	0604617F_Agile_Combat_Support	1	11.9	4.5	-7.3	-0.62
168	0204575N_Electronic_Warfare_EW_Readiness_Support	1	35	23.5	-11.4	-0.33
169	0203740A_Maneuver_Control_System	1	43.6	36.1	-7.5	-0.17
170	0603805A_Combat_Service_Support_Control_System_Evaluation_and_Analysis	1	14.4	17.7	3.3	0.23
171	0604601N_Mine_Development	1	2	2	0	-0.02
172	0603438F_Space_Control_Technology	1	61.7	86.1	24.5	0.4
173	0205604N_Tactical_Data_Links	1	5.1	4.1	-1.1	-0.21
174	0605103A_Rand_Arroyo_Center	1	18.6	19.8	1.2	0.06
175	0303158A_Joint_Command_and_Control_Program_JC2	1	15.7	13.2	-2.4	-0.16
176	0207170F_Joint_Helmet_Mounted_Cueing_System_JHMCS	1	4.2	3.1	-1.1	-0.27
177	0605013A_Information_Technology_Development	1	171.4	68.2	-103.3	-0.6
178	0605502N_Small_Business_Innovative_Research	1	326.7	402.1	75.4	0.23
179	0604441F_Space_Based_Infrared_System_SBIRS_High_EMD	1	583.3	542.4	-40.9	-0.07
180	0603791F_International_Space_Cooperative_R_D	1	0.6	0.6	0	0.02
181	0305913F_NUDET_Detection_System_SPACE	1	38.3	41.1	2.8	0.07
182	0408011F_Special_Tactics_Combat_Control	1	7.9	7.5	-0.3	-0.04
183	0603007A_Manpower_Personnel_and_Training_Advanced_Technology	1	6.6	6.7	0.1	0.01
184	0604604F_Submunitions	1	2	1.7	-0.3	-0.13
185	0102326F_Region_Sector_Operation_Control_Center_Modernization_Program	1	22.6	23.2	0.5	0.02
186	0605856N_Strategic_Technical_Support	1	3.4	3.5	0.1	0.04
187	0604869A_Patriot_MEADS_Combined_Aggregate_Program_CAP	1	401.6	454.7	53.1	0.13
188	0303158N_Joint_Command_and_Control_Program_JC2	1	4.6	4	-0.6	-0.12
189	0605865N_Operational_Test_and_Evaluation_Capability	1	12.1	12	0	0
190	1001004F_International_Activities	1	3.9	3.8	-0.1	-0.03
191	0604287F_Physical_Security_Equipment	1	0	0.1	0	0.55
192	0804731F_General_Skill_Training	1	2.9	1.2	-1.7	-0.58
193	0205219F_MQ_9_UAV	1	55.9	57.2	1.3	0.02
194	0305219F_MQ_1_Predator_A_UAV	1	37.6	38.6	1	0.03
195	0604804A_Logistics_and_Engineer_Equipment_SDD		40	29.9	-10.1	-0.25
196	0604777N_Navigation_ID_System		43.5	46.1	2.6	0.06
197	0602624A_Weapons_and_Munitions_Technology		101	106.3	5.3	0.05
198	0604503N_SSN_688_and_Trident_Modernization		114.4	131.2	16.8	0.15
199	0604270N_Electronic_Warfare_Development		50.9	91.4	40.5	0.8
200	0602786A_Warfighter_Technology		36.8	35.9	-0.9	-0.02
201	0604558N_New_Design_SSN		239.8	184.1	-55.7	-0.23

202	0604800N_Joint_Strike_Fighter_JSF		1848.9	1704.6	-144.3	-0.08
203	0604512N_Shipboard_Aviation_Systems		37.5	50.4	12.9	0.34
204	0604366N_Standard_Missile_Improvements		214.6	222.9	8.3	0.04
205	0602105A_Materials_Technology		60.3	80.7	20.4	0.34
206	0604759F_Major_T_E_Investment		62.6	67.9	5.3	0.08
207	0603271N_RF_Systems_Advanced_Technology		43.6	56.1	12.5	0.29
208	0205620N_Surface_ASW_Combat_System_Integration		16.5	21.8	5.3	0.32
209	0603635M_Marine_Corps_Ground_Combat_Support_System		3.9	57.7	53.9	13.97
210	0602211A_Aviation_Technology		42.5	46.2	3.7	0.09
211	0602303A_Missile_Technology		67.1	4.8	-62.3	-0.93
212	0604780A_Combined_Arms_Tactical_Trainer_CATT_Core		34.7	32.5	-2.1	-0.06
213	0604307N_Surface_Combatant_Combat_System_Engineering		151.6	197	45.4	0.3
214	0603563N_Ship_Concept_Advanced_Design		39.7	36.2	-3.4	-0.09
215	0204229N_Tomahawk_and_Tomahawk_Mission_Planning_Center_TMPC		14.6	17.6	2.9	0.2
216	0708045A_End_Item_Industrial_Preparedness_Activities		91.3	89	-2.3	-0.03
217	0708011N_Industrial_Preparedness		56.9	60	3.1	0.05
218	0604808A_Landmine_Warfare_Barrier_SDD		172.1	113.6	-58.6	-0.34
219	0205601N_HARM_Improvement		70.1	39.3	-30.8	-0.44
220	0603654N_Joint_Service_Explosive_Ordnance_Development		30.6	111.9	81.2	2.65
221	0604272N_Tactical_Air_Directional_Infrared_Countermeasures_TADIRCM		32.4	42.8	10.5	0.32
222	0603008A_Electronic_Warfare_Advanced_Technology		55.3	61.2	5.9	0.11
223	0603739N_Navy_Logistic_Productivity		18.9	18.5	-0.4	-0.02
224	0603742F_Combat_Identification_Technology		25.2	28.7	3.5	0.14
225	0604756N_Ship_Self_Defense_Engage_Hard_Kill		73.8	55.3	-18.5	-0.25
226	0203761N_Rapid_Technology_Transition_RTT		38.8	40.5	1.7	0.04
227	0603582N_Combat_System_Integration		52.3	62.5	10.2	0.19
228	0603513N_Shipboard_System_Component_Development		42.6	35.7	-6.8	-0.16
229	0604214N_AV_8B_Aircraft_Eng_Dev		22.1	33.7	11.5	0.52
230	0602782N_Mine_and_Expeditionary_Warfare_Applied_Research		69.8	53.1	-16.8	-0.24
231	0605500N_Multi_mission_Maritime_Aircraft_MMA		861.1	1089.7	228.5	0.27
232	0604504N_Air_Control		4.3	8	3.6	0.83
233	0605864N_Test_and_Evaluation_Support		334.1	350.5	16.4	0.05
234	0604256A_Threat_Simulator_Development		22.9	22	-0.9	-0.04
235	0207434F_Link_16_Support_and_Sustainment		186.4	279	92.6	0.5
236	0604771N_Medical_Development		49.7	39.5	-10.2	-0.21
237	0603114N_Power_Projection_Advanced_Technology		94	96.8	2.8	0.03
238	0604258N_Target_Systems_Development		31.5	76	44.5	1.41

239	0604240F_B_2_Advanced_Technology_Bomber		277.9	384.2	106.3	0.38
240	0604664A_FCS_Unattended_Ground_Sensors		22	20.1	-1.9	-0.09
241	0604713A_Combat_Feeding_Clothing_and_Equipment		2.4	2.4	0	0
242	0604757N_Ship_Self_Defense_Engage_Soft_Kill_EW		36.5	57.2	20.7	0.57
243	0204152N_E_2_Squadrons		19	52.3	33.4	1.76
244	0604760A_Distributive_Interactive_Simulations_DIS_SDD		19.7	19	-0.7	-0.04
245	0604233F_Specialized_Undergraduate_Flight_Training		14	11.8	-2.2	-0.16
246	0605807F_Test_and_Evaluation_Support		753.2	756.3	3.1	0
247	0604262N_V_22A		125.2	66	-59.1	-0.47
248	0603639A_Tank_and_Medium_Caliber_Ammunition		46.2	39.6	-6.6	-0.14
249	0603860N_Joint_Precision_Approach_and_Landing_Systems		66.8	74.1	7.3	0.11
250	0603713N_Ocean_Engineering_Technology_Development		8.8	9.5	0.7	0.08
251	0604800F_Joint_Strike_Fighter_JSF		1939.1	1743.6	-195.5	-0.1
252	0304260F_Airborne_SIGINT_Enterprise		138.3	170.7	32.4	0.23
253	0604823A_Firefinder		84.5	64.8	-19.7	-0.23
254	0603573N_Advanced_Surface_Machinery_Systems		1.6	3.2	1.6	1.05
255	0603562N_Submarine_Tactical_Warfare_Systems		14.7	13.7	-0.9	-0.06
256	0602716A_Human_Factors_Engineering_Technology		38.6	42.2	3.6	0.09
257	0604264N_Air_Crew_Systems_Development		23.3	15.7	-7.6	-0.33
258	0603015A_Next_Generation_Training_Simulation_Systems		23.3	24.8	1.5	0.06
259	0602308A_Advanced_Concepts_and_Simulation		18.5	18.2	-0.3	-0.02
260	0604245N_H_1_Upgrades		4.5	4	-0.4	-0.09
261	0604666A_Modular_Brigade_Enhancement		84.1	122.8	38.7	0.46
262	0207581F_Joint_Surveillance_Target_Attack_Radar_System_JSTARS		337.6	97.6	-239.9	-0.71
263	0605601A_Army_Test_Ranges_and_Facilities		349.9	356.7	6.8	0.02
264	0305206N_Airborne_Reconnaissance_Systems		70.2	58.8	-11.4	-0.16
265	0605604A_Survivability_Lethality_Analysis		40.7	40	-0.7	-0.02
266	0604602F_Armament_Ordnance_Development		7.6	12.1	4.5	0.6
267	0604857F_Operationally_Responsive_Space		87	228.5	141.6	1.63
268	0604647A_Non_Line_of_Sight_Cannon		133.1	87	-46.1	-0.35
269	0602270A_Electronic_Warfare_Technology		25.6	20.1	-5.5	-0.22
270	0603506N_Surface_Ship_Torpedo_Defense		32.7	48.2	15.5	0.48
271	0603728A_Environmental_Quality_Technology_Demonstrations		14.6	16.8	2.2	0.15
272	0604234N_Advanced_Hawkeye		785.8	468	-317.8	-0.4
273	0604402N_Unmanned_Combat_Air_Vehicle_UCAV_Advanced_Component_and_Prototype_Development		153.9	266.5	112.5	0.73
274	0604216N_Multi_Mission_Helicopter_Upgrade_Development		74.2	67.9	-6.3	-0.09
275	0604746A_Automatic_Test_Equipment_Development		11.5	17	5.5	0.47

276	0603609N_Conventional_Munitions		7	6.4	-0.6	-0.09
277	0604300N_SC_21_Total_Ship_System_Engineering		622.8	506.8	-116	-0.19
278	0604329N_Small_Diameter_Bomb_SDB		11.3	18.9	7.7	0.68
279	0203735A_Combat_Vehicle_Improvement_Programs		42.8	139.1	96.3	2.25
280	0604270F_Electronic_Warfare_Development		76.2	66.3	-9.8	-0.13
281	0604269N_EA_18		269.4	115.7	-153.7	-0.57
282	0603653A_Advanced_Tank_Armament_System_ATAS		127.7	76.1	-51.6	-0.4
283	0604610N_Lightweight_Torpedo_Development		26.3	44.8	18.6	0.71
284	0901538F_Financial_Management_Information_Systems_Development		28.6	23	-5.6	-0.2
285	0604759N_Major_T_E_Investment		41.3	51.2	9.8	0.24
286	0604226F_B_1B		180.4	158.1	-22.4	-0.12
287	0604802A_Weapons_and_Munitions_SDD		63.4	101.8	38.4	0.61
288	0205632N_MK_48_ADCAP		19.7	26	6.3	0.32
289	0604329F_Small_Diameter_Bomb_SDB		147.6	122.6	-25	-0.17
290	0605712F_Initial_Operational_Test_Evaluation		30	29.1	-0.9	-0.03
291	0708611F_Support_Systems_Development		32.9	22.1	-10.8	-0.33
292	0303601F_MILSATCOM_Terminals		362.7	277.5	-85.2	-0.23
293	0204311N_Integrated_Surveillance_System		30.7	28.7	-2.1	-0.07
294	0604727N_Joint_Standoff_Weapon_Systems		28.8	21.8	-7	-0.24
295	0207601F_USAF_Modeling_and_Simulation		20.7	28.1	7.3	0.35
296	0604518N_Combat_Information_Center_Conversion		18.2	17.3	-0.8	-0.05
297	0603260F_Intelligence_Advanced_Development		5.9	6.6	0.7	0.12
298	0605863N_RDT_E_Ship_and_Aircraft_Support		178.7	172.5	-6.2	-0.03
299	0603851F_Intercontinental_Ballistic_Missile		26.1	58.9	32.9	1.26
300	0603729N_Warfighter_Protection_Advanced_Technology		50.7	52.7	2	0.04
301	0603606A_Landmine_Warfare_and_Barrier_Advanced_Technology		30	36.9	6.8	0.23
302	0604256F_Threat_Simulator_Development		35.9	34	-2	-0.05
303	0604742A_Constructive_Simulation_Systems_Development		30.7	25.1	-5.6	-0.18
304	0602307A_Advanced_Weapons_Technology		24.4	22.6	-1.7	-0.07
305	0603925N_Directed_Energy_and_Electric_Weapon_Systems		3.5	4.5	1.1	0.31
306	0305220F_Global_Hawk_UAV		274.7	279.2	4.4	0.02
307	0603755N_Ship_Self_Defense		10.6	9.8	-0.8	-0.08
308	0303131F_Minimum_Essential_Emergency_Communications_Network_MEECN		85.5	81.1	-4.4	-0.05
309	0207701F_Full_Combat_Mission_Training		60.2	77.4	17.2	0.29
310	0605702A_Meteorological_Support_to_RDT_E_Activities		8.2	8.1	0	0
311	0605450N_Joint_Air_to_Ground_Missile_JAGM		61.8	55	-6.8	-0.11
312	0604601A_Infantry_Support_Weapons		59.6	57.7	-1.9	-0.03

313	0305940F_Space_Situation_Awareness_Operations		38.7	15.6	-23.1	-0.6
314	0604735F_Combat_Training_Ranges		15.5	12.2	-3.3	-0.21
315	0605605A_DOD_High_Energy_Laser_Test_Facility		8.4	6.8	-1.6	-0.19
316	0603790A_NATO_Research_and_Development		4.8	4.9	0.1	0.02
317	0603430F_Advanced_EHF_MILSATCOM_SPACE		612.3	460.4	-152	-0.25
318	0601103N_University_Research_Initiatives		96.7	102.4	5.7	0.06
319	0604633A_Air_Traffic_Control		11.7	16.1	4.4	0.38
320	0305110F_Satellite_Control_Network_SPACE		23.5	54.5	31	1.32
321	0603801A_Aviation_Adv_Dev		8.9	7.2	-1.7	-0.19
322	0804758N_Service_Support_to_JFCOM_JNTC		4.9	5	0.1	0.01
323	0305178F_National_Polar_Orbiting_Operational_Environmental_Satellite_System_NPOESS		331	287.5	-43.4	-0.13
324	0401132F_C_130J_Program		62.1	25.2	-36.9	-0.59
325	0603790N_NATO_Research_and_Development		11	10.8	-0.2	-0.02
326	0305149N_COBRA_JUDY		131.8	100.8	-31	-0.24
327	0604220A_Armed_Deployable_OH_58D		176.1	63	-113.1	-0.64
328	0603308A_Army_Missile_Defense_Systems_Integration_Space		58.1	53.4	-4.7	-0.08
329	0603795N_Land_Attack_Technology		49.9	16	-34	-0.68
330	0603125A_Combating_Terrorism_Technology_Development		13.2	12.7	-0.6	-0.04
331	0401219F_KC_10s		13.5	3.8	-9.7	-0.72
332	0603854F_Wideband_Global_SATCOM_RDT_E_Space		21	29.5	8.5	0.41
333	0207446F_Bomber_Tactical_Data_Link		38.3	21.6	-16.7	-0.44
334	0605706A_Materiel_Systems_Analysis		16.9	17.5	0.5	0.03
335	0305099F_Global_Air_Traffic_Management_GATM		7.2	10.6	3.4	0.47
336	0702207N_Depot_Maintenance_Non_IF		20.9	9.8	-11.1	-0.53
337	0305114F_Air_Traffic_Control_Approach_and_Landing_System_ATCALS		6.4	8.8	2.4	0.38
338	0203758A_Digitization		10.4	7.8	-2.6	-0.25
339	0605011F_RDT_E_for_Aging_Aircraft		27	5.8	-21.2	-0.78
340	0605212N_CH_53K_RDTE		386.3	543.9	157.6	0.41
341	0207451F_Single_Integrated_Air_Picture_SIAP		4.7	49.6	44.8	9.49
342	0305111F_Weather_Service		39.8	45.9	6.1	0.15
343	0604311N_LPD_17_Class_Systems_Integration		4.2	1	-3.2	-0.77
344	0207163F_Advanced_Medium_Range_Air_to_Air_Missile_AMRAAM		36.4	43.6	7.2	0.2
345	0603564N_Ship_Preliminary_Design_Feasibility_Studies		25.6	22.9	-2.7	-0.11
346	0305182F_Spacelift_Range_System_SPACE		25.1	13.3	-11.8	-0.47
347	0401218F_KC_135s		7.8	11.9	4.1	0.52
348	0303141F_Global_Combat_Support_System		14.7	8.6	-6.1	-0.41
349	0605976F_Facilities_Restoration_and_Modernization_Test_and_Evaluation_Support		61.2	47.3	-13.9	-0.23

350	0604740F_Integrated_Command_Control_Applications_IC2A		27.8	9.7	-18.1	-0.65
351	0401130F_C_17_Aircraft_IF		166.2	182.8	16.5	0.1
352	0305164F_NAVSTAR_Global_Positioning_System_User_Equipment_SPACE		151	121.8	-29.2	-0.19
353	0604443F_Third_Generation_Infrared_Surveillance_3GIRS		75.4	1	-74.5	-0.99
354	0605301A_Army_Kwajalein_Atoll		180.8	169.4	-11.4	-0.06
355	0605716A_Army_Evaluation_Center		59.3	61.5	2.1	0.04
356	0901220F_Personnel_Administration		22.9	18.9	-4	-0.17
357	0603103A_Explosives_Demilitarization_Technology		20.9	17.2	-3.7	-0.18
358	0603651M_Joint_Non_Lethal_Weapons_Technology_Development		10.7	13.5	2.8	0.26
359	0305221F_Network_Centric_Collaborative_Targeting		12	8.8	-3.3	-0.27
360	0604221N_P_3_Modernization_Program		4.5	3.5	-1.1	-0.23
361	0305165F_NAVSTAR_Global_Positioning_System_Space_and_Control_Segments		110.2	86.6	-23.6	-0.21
362	0207438F_Theater_Battle_Management_TBM_C4I		12.1	18.8	6.8	0.56
363	0602785A_Manpower_Personnel_Training_Technology		15.8	16.1	0.3	0.02
364	0603619A_Landmine_Warfare_and_Barrier_Adv_Dev		19.1	13.8	-5.3	-0.28
365	0207268F_Aircraft_Engine_Component_Improvement_Program		158.6	146.4	-12.2	-0.08
366	0603850F_Integrated_Broadcast_Service		20.9	21	0.1	0.01
367	0308601N_Modeling_and_Simulation_Support		7.6	7.7	0.1	0.02
368	0101226N_Submarine_Acoustic_Warfare_Development		3.9	7.2	3.2	0.82
369	0207161F_Tactical_AIM_Missiles		7.7	5.6	-2.1	-0.27
370	0208058A_Joint_High_Speed_Vessel_JHSV		5	3	-2	-0.4
371	0603845F_Transformational_SATCOM_TSAT		776.5	428.6	-347.9	-0.45
372	0604421F_Counterspace_Systems		59.4	64.3	4.9	0.08
373	0207445F_Fighter_Tactical_Data_Link		57.4	55.1	-2.4	-0.04
374	0307207N_Aerial_Common_Sensor_ACS		8.2	34.2	26.1	3.19
375	0207590F_Seek_Eagle		22.7	21.4	-1.3	-0.06
376	0401318F_CV_22		23.4	18	-5.4	-0.23
377	0305173F_Space_and_Missile_Test_and_Evaluation_Center		5	1.9	-3.1	-0.61
378	0207253F_Compass_Call		13.5	4.5	-8.9	-0.66
379	0303150F_Global_Command_and_Control_System		3.2	3.1	0	-0.02
380	0604604A_Medium_Tactical_Vehicles		4.6	2.2	-2.5	-0.53
381	0305205N_Endurance_Unmanned_Aerial_Vehicles		111.3	424	312.7	2.81
382	0401839F_Air_Mobility_Tactical_Data_Link		4.3	7.7	3.4	0.79
383	0605606A_Aircraft_Certification		4.6	5	0.4	0.08
384	0604750F_Intelligence_Equipment		5	2.3	-2.8	-0.55
385	0708610F_Logistics_Information_Technology_LOGIT		104.8	144.9	40	0.38
386	0602622A_Chemical_Smoke_and_Equipment_Defeating_Technology		10.2	8.9	-1.4	-0.13

387	0603607A_Joint_Service_Small_Arms_Program		16.4	8.6	-7.8	-0.48
388	0604706F_Life_Support_Systems		13.2	14.9	1.7	0.13
389	0207448F_C2ISR_Tactical_Data_Link		1.7	1.7	-0.1	-0.04
390	0603105A_Military_HIV_Research		14.5	14.9	0.4	0.03
391	0602651M_Joint_Non_Lethal_Weapons_Applied_Research		6	4.8	-1.2	-0.2
392	0604280N_Joint_Tactical_Radio_System_Navy_JTRS_Navy		830.8	824.2	-6.6	-0.01
393	0603006A_Command_Control_Communications_Advanced_Technology		11.8	11.3	-0.5	-0.04
394	0204413N_Amphibious_Tactical_Support_Units_Displacement_Craft		1.8	2.3	0.5	0.27
395	0101122F_Air_Launched_Cruise_Missile_ALCM		4.5	0.4	-4.1	-0.91
396	0305204A_Tactical_Unmanned_Aerial_Vehicles		188.3	100.5	-87.8	-0.47
397	0603860F_Joint_Precision_Approach_and_Landing_Systems		6.2	7.2	0.9	0.15
398	0305116F_Aerial_Targets		5.7	11	5.3	0.93
399	0305207F_Manned_Reconnaissance_Systems		24.3	17.8	-6.5	-0.27
400	0602623A_Joint_Service_Small_Arms_Program		6.8	9.2	2.4	0.35
401	0604429F_Airborne_Electronic_Attack		23.2	42.2	19	0.82
402	0307141F_Information_Operations_Technology_Integration_Tool_Development		21.3	18	-3.3	-0.15
403	0604227N_HARPOON_Modifications		42.5	44.4	1.9	0.04
404	0605024F_Anti_Tamper_Technology_Executive_Agency		12.4	20.4	8	0.65
405	0603432F_Polar_MILSATCOM_SPACE		171.8	221.1	49.3	0.29
406	0207136F_Manned_Destructive_Suppression		0.5	5.4	4.9	9.83
407	0207418F_Tactical_Airborne_Control_Systems		3.4	1.5	-1.9	-0.56
408	0605978F_Facilities_Sustainment_Test_and_Evaluation_Support		33.8	29.6	-4.2	-0.12
409	0305887F_Intelligence_Support_to_Information_Warfare		5.2	5.3	0.1	0.02
410	0303158F_Joint_Command_and_Control_Program_JC2		5.6	3.1	-2.4	-0.44
411	0901212F_Service_Wide_Support_Not_Otherwise_Accounted_For		6.5	3.6	-2.8	-0.43
412	0204574N_Cryptologic_Direct_Support		1.4	1.4	0	0
413	0603889N_Counterdrug_RDT_E_Projects		65.2	62.4	-2.7	-0.04
414	0401138F_Joint_Cargo_Aircraft_JCA		20.3	16.3	-4	-0.2
415	0604654N_Joint_Service_Explosive_Ordnance_Development		9.8	10.8	1	0.1
416	0207161N_Tactical_AIM_Missiles		4.8	8.4	3.6	0.75
417	0207605F_Wargaming_and_Simulation_Centers		6.2	3.8	-2.4	-0.39
418	0804757F_Joint_National_Training_Center		3	3.1	0.1	0.03
419	0207423F_Advanced_Communications_Systems		30.2	28.2	-2	-0.07
420	0604827A_Soldier_Systems_Warrior_Dem_Val		1.5	20.1	18.5	12
421	0605861N_RDT_E_Science_and_Technology_Management		68.2	70.1	1.9	0.03
422	0604761N_Intelligence_Engineering		10.4	23.7	13.3	1.29
423	0308699F_Shared_Early_Warning_SEW		3	3.1	0	0.01

424	0603859F_Pollution_Prevention		10.7	13.6	2.9	0.27
425	0208053A_Joint_Tactical_Ground_System		23.3	1.9	-21.4	-0.92
426	0305924F_National_Security_Space_Office		15.1	7.5	-7.6	-0.5
427	0207247F_AF_TENCAP		11.5	11.5	0.1	0.01
428	0702207F_Depot_Maintenance_Non_IF		1.5	1.5	0	0.02
429	0603327A_Air_and_Missile_Defense_Systems_Engineering		155.7	115.6	-40.1	-0.26
430	0605101F_RAND_Project_Air_Force		40.5	37.7	-2.8	-0.07
431	0203761F_Warfighter_Rapid_Acquisition_Process_WRAP_Rapid_Transition_Fund		21.8	29.9	8.2	0.38
432	0303150A_WWMCCS_Global_Command_and_Control_System		24.2	12.6	-11.6	-0.48
433	0602234N_Materials_Electronics_and_Computer_Technology		1.9	7.3	5.3	2.77
434	0901202F_Joint_Personnel_Recovery_Agency		5.2	5.6	0.4	0.08
435	0605867N_SEW_Surveillance_Reconnaissance_Support		23.9	25.2	1.3	0.05
436	0305193F_Intelligence_Support_to_Information_Operations_IO		8.3	3.6	-4.7	-0.56
437	0305174F_Space_Warfare_Center		1.6	2.9	1.3	0.78
438	0208058N_Joint_High_Speed_Vessel_JHSV		18.4	11.6	-6.8	-0.37
439	0605860F_Rocket_Systems_Launch_Program_SPACE		23.8	16.9	-7	-0.29
440	0207697F_Distributed_Training_and_Exercises		6.8	6.9	0.1	0.02
441	0603627A_Smoke_Obscurant_and_Target_Defeating_Sys_Adv_Dev		9.1	3.7	-5.4	-0.59
442	0305885N_Tactical_Cryptologic_Activities		1.5	2	0.5	0.33
443	0605864F_Space_Test_Program_STP		50	44.7	-5.3	-0.11
444	0901218F_Civilian_Compensation_Program		13.3	14.6	1.3	0.1
445	0604609A_Smoke_Obscurant_and_Target_Defeating_Sys_SDD		1.3	5.4	4.1	3.17
446	0303158M_Joint_Command_and_Control_Program_JC2		1.2	1.8	0.6	0.49
447	0603827A_Soldier_Systems_Advanced_Development		26.2	41.6	15.4	0.59
448	0808716F_Other_Personnel_Activities		0.1	1.1	1	8.76
449	0603305A_Army_Missile_Defense_Systems_Integration_Non_Space		128.8	90.6	-38.2	-0.3
450	0603774A_Night_Vision_Systems_Advanced_Development		2.5	2.5	0	0

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2003 - 2010 Sponsored Research Topics

Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the 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-term 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
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

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