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Return on Investment of Network Design Exchange (NDEX)

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December 2005

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13. ABSTRACT *(maximum 200 words)* This project will examine the differences between a new ship alteration design process termed NDEX and the current system being utilized. Costs associated with the implementation and use of NDEX will be contrasted to costs of the status quo design process and a computation of the return on investment (ROI) of NDEX will be computed.			
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RETURN ON INVESTMENT OF NETWORK DESIGN EXCHANGE (NDEX)

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December 2005

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RETURN ON INVESTMENT OF NETWORK DESIGN EXCHANGE (NDEX)

ABSTRACT

The purpose of this MBA Project was to investigate and provide a calculated Return on Investment of a new ship alteration design process termed Network Design Exchange (NDEX). The project evaluated the differences between NDEX and the current system being utilized. Costs associated with the implementation and use of NDEX were contrasted to costs of the status quo design process to determine cost savings and benefits and compute the return on investment (ROI) of NDEX.

NDEX changes the way C4I equipment is configured for installation onboard United States Navy ships. It is being beta tested on several different classes of ships.

The current design process although effective, is highly inefficient. It is an antiquated system that is labor intensive and uses manual drawings to design compartment utilization and ensure the proposed equipment to be installed will fit in the correct space allotted. The current process also takes a considerable amount of time, upwards of 18 months from start to finish, and requires many unnecessary steps to accomplish.

The proposed system, NDEX, is based on commercially available software that will allow the creation of ship's drawings on laptops using computer aided design (CAD) applications and class design baseline (CDB) drawings that show how a ship was configured at construction. With NDEX, design cycle time can be shortened to weeks if time criticality is necessary. NDEX allows a considerable amount of time to be saved by eliminating a lot of the redundant efforts in the current process. With NDEX, a laptop computer is brought to the site visit and drawings are made during the visit based on the class design baseline (CDB) drawings. A library of components are available that are click and paste which can be used to add equipment that is in the space but not shown on the CDB drawings. The value-added, or notional benefit, and the avoided cost realized by the investment in this new NDEX process is the focus of this ROI measurement.

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I. INTRODUCTION

A. PURPOSE

This report modifies and applies the Jones-Bigham-Goudreau notional return on investment (JBG NROI) formula to a design process system known as Network Design Exchange (NDEX) for Program Executive Office Command, Control, Communication, Computers, and Intelligence and Space New Ship Construction (PEO C4I SC) at Space and Naval Warfare Systems Command (SPAWAR). Specifically, the data used in the NROI formula is applied to the management of design processes inherent in ship alterations and upgrades of radio control suite (RCS) equipment. This report provides a detailed analysis of the application of one approach to ROI in the public sector, with specific emphasis on modifying and applying previous work performed cooperatively by Naval Postgraduate School students and members of the staff with consultants to the SPAWAR PEO C4I Space Command to an existing management decision.

B. BACKGROUND

Representatives from SPAWAR, San Diego approached Dr. Lawrence R. Jones, RADM George R. A. Wagner SPAWAR PEO C4I Space Professor of Public Management, Graduate School of Business and Public Policy at the Naval Postgraduate School (NPS) regarding this project in hope of determining a return on investment in support of developing NDEX. In February 2005, LCDR Douglas W. Harold and LCDR Aaron S. Traver (the authors) volunteered for this project for their Student MBA Project with an anticipated completion date of November 2005. Since February, three teleconferences have been held with SPAWAR and Northrop Grumman representatives, including Mr. Tom Underwood, Mr. Ken Okamura, Mr. Jay Johnson, and Mr. Edward Dalton. On March 11th, LCDR Traver also had the privilege to discuss the project concept with RADM Ken Slaght (SPAWAR) following a brief at NPS. RADM Slaght offered several useful insights specifically concerning the direction of the project and the potential benefit to the Navy. In addition, several sources of information were provided by SPAWAR and Northrop Grumman to initiate understanding of both the current and alternative NDEX design processes. Finally, one teleconference was held with Mrs. Susan Senese (Co-Chairperson, PEO-C4I & Space) and Mr. Bob Buckley (SPAWAR 04R3).

The NDEX project calls for a change in the way C4I equipment is configured for installation onboard United States Navy ships. The following explanation of NDEX is provided by Mr. Dalton in a working paper (White Paper):

> NDEX (Network Design Exchange) is a series of products and processes designed to fully integrate, standardize, automate, control, disseminate, and manage all levels of design. From inception (Development of ICD's) to installation (SID's), NDEX uses a combination of existing commercially successful programs, a web-based document management system, and mobile CAD/Engineer teams to significantly improve the entire spectrum of design products and processes. (Dalton 1)

NDEX provides the ability for designers to input the characteristics of a new design directly into a class design baseline database and ensure the design will fit in the ship's configuration. It may reveal that certain ship infrastructure changes need to be considered prior to further design to make the system cost effective. NDEX is a tool to help designers plan installations while potentially avoiding several long and costly steps in the current process.

NDEX meets the design requirements imposed upon the Navy in the 21st-century and achieves the visions set for the 21st-century Navy. These requirements and the vision NDEX supports are covered in detail in Chapter II.

C. RESEARCH OBJECTIVES

The immediate objective of this effort is to develop a workable NROI formula for use within the SPAWAR organization, specifically for the NDEX project. However, the underlying objective is to validate an approach to developing NROI formulae for use in the public sector, and specifically in the Department of Defense. The further development and application of the JBG NROI formula is reported in this report to provide the reader with a road map to follow in future applications.

D. RESEARCH METHODOLOGY

At the end of 2004, Dr. Jones and two NPS students, LT Joshua Bigham and LT Thomas Goudreau, completed another Return on Investment project which analyzed SPAWAR PEO C4I Space Command's return on new ship construction (for radio control suite rooms). This research and the final report focused on prior efforts to use ROI in the public sector and the theoretical development of the JBG NROI formula, stated below (Bigham 33):

$$\text{NROI} = \frac{\text{PM}*0.1 + \text{ENG}*0.4 + \text{SM}*0.15 + \text{PR}*0.4 + \text{INST}*0.3 + \text{SS}*0.2 + \text{MM}*0.1 + \text{Avoidance Costs}}{\text{Radio Control Suite Program Costs}}$$

As stated in their project, this formula has limitations in applicability, specifically it is relevant only to the specific platforms for which it was developed, but the methodology "of defining how an organization adds value via its products and services" (Bigham 55) provided a foundation from which our current research proceeded from without retracing their steps. Therefore, proceeding from this methodological foundation, with the clear understanding that it had to be modified and supported with additional theory as necessary during our progression, we have arrived at an ROI calculation for NDEX. Chapter III details the evolution of the calculation and its final derivation. Chapter IV details the application of the methodology to the management decision relating to implementing NDEX.

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II. CONTEXTUAL BACKGROUND CONSIDERATIONS & REQUIREMENTS AND VISIONS ACHIEVED BY NDEX

A. DEFINING THE NDEX SYSTEM

The Network Design Exchange, or NDEX, system is designed to change the way C4I equipment is configured for installation onboard United States Navy ships. There are several known components in this system and in the design process that in the inception stage we have called "NDEX." These include AutoCAD, Web-based collaboration software, and on-site laptop data entry processes.

NDEX is based on commercially available software that will allow the creation of ship's drawings and designs on laptop computers using Computer Aided Design (CAD) applications and Class Design Baseline (CDB) drawings that show how a ship was configured at construction. With NDEX, design time can be shortened to weeks if time criticality is necessary. NDEX allows a considerable amount of time to be saved by eliminating a lot of the middle-man features. For example, the current process requires that a site visit is conducted and sketches are made for equipment layout. The sketches are brought back to an office where they are given to an individual who makes drawings based on information gathered during the site visit. Often, mistakes are made based on translation issues. With NDEX, a laptop computer is brought to the site visit and drawings are made during the visit based on the class design baseline (CDB) drawings. A library of components, known as Installation Control Drawings (ICDs), will be maintained and available to click and paste when adding equipment that is in the space but not shown on the CDB drawings.

NDEX will change the way C4I equipment is configured for installation onboard ships. The following explanation of NDEX is provided by Mr. Dalton in a working paper (White Paper):

> NDEX (Network Design Exchange) is a series of products and processes designed to fully integrate, standardize, automate, control, disseminate, and manage all levels of design. From inception (Development of ICD's) to installation (SID's), NDEX uses a combination of existing commercially successful programs, a web-based document management

> system, and mobile CAD/Engineer teams to significantly improve the entire spectrum of design products and processes. (Dalton 1)

NDEX is in its conceptual stage, with component systems in all stages of development, from being unfunded and not initiated to having already been used to support both new installations and back-fits. A significant potential advantage of the system is the avoidance of redundant effort and inefficient labor practices used during each design process step. Time and labor savings provide a decent return on investment, but NDEX also yields significant improvements related to mission readiness as well as knowledge capture. These benefits are all considered as a part of the return on investment equation.

NDEX improves design time to a matter of weeks vice months. NDEX saves a considerable amount of time by merging the data gathering and drawing steps of the current process into a single process step. The current process requires that a site visit is conducted and the engineer conducting the visit sketches the existing configuration and the proposed equipment installation layout. The sketches are brought from the ship back to the office where they are given to a draftsman (or CAD operator) who makes drawings based on information gathered during the engineer's site visit. Often, mistakes are made based on translation issues where the CAD operator may misinterpret the intent of the engineer. With NDEX, a laptop computer is brought to the site visit by the engineer and his or her supporting CAD operator. During the site visit, initial drawings or changes are made to establish or update the Class Design Baseline (CDB) drawings. A library of Installation Control Drawings (ICD's) contains component data that allows for a point-and-click pasting for automatic integration; or, detailed drawing and component data for efficient facilitated integration of component additions into the existing system being altered. This on-site process allows for highly efficient spatial planning for the new components and accounts for equipment in the space but not shown on the existing CDB drawings. This work, which creates what is known as a Ship Change Document (SCD), can be transmitted and approved while still on the site visit if necessary to facilitate installations. This could have significant benefits to ships overseas, especially those subject to "Sea Swap" that will remain overseas for significant periods of time and be supported by rotating crews.

Although the current design process presently remains effective, it is highly inefficient, costly, and error-prone. It is an antiquated system that is labor intensive and uses manual drawings to design compartment utilization and ensure the proposed equipment to be installed will fit in the correct space allotted. The current process also takes a considerable amount of time, upwards of 18 months from start to finish, and requires many unnecessary steps to accomplish the design. These steps are also subject to requiring rework to achieve any level of accuracy. Furthermore, due to the extended time lag with the current process, it may be possible for projects in the same physical shipboard compartment to overlap and have the same equipment or ancillary equipment, such as power sources, earmarked for more than one installation. Some past installations were completed without SCD's completed due to the level of effort required and the abundant inefficiencies in the process. All these inefficiencies are captured in the current budgeting process as well, increasing the overall cost of design funding at SPAWAR.

In addition, the current process is very slow in adapting to change. During the shipcheck and SCD creation process, when ICD's change or when new technology becomes available and desired, the result is a return to the initial steps of design. Thus, the process starts all over again. This leads to numerous delays and a great amount of retracing steps in order to complete the installation. In the meantime, because of all of the delays, it is likely that the final installation will be antiquated technologically before the end-users even begin to use the product. This directly impacts the capabilities in the fleet.

Another feature NDEX provides that is currently unavailable is the ability for designers to input the characteristics of a new design directly in to the class design baseline database and see if the design will even be a fit. It may reveal that certain ship infrastructure changes need to be considered prior to further design to make the system cost effective. It is not unheard of for planners to find that their new equipment will not work correctly due to inadequate electrical power sources and air conditioning, therefore requiring further changes. With this in mind, major changes to the electrical and HVAC systems will need to be performed at considerable costs that were yet unidentified, therefore driving the install cost substantially above the initial planning figures. Simply stated, this tool will help designers plan installations while potentially savings tremendous amounts of money

While the impact of the NDEX design process will also impact installation costs and rework, we have limited the measurement of installation effects to include only design-related installation Change Order Request Notifications (CORNs). In addition, our perspective for computing benefits is from that of SPAWAR, so our measures are of SPAWAR's benefit, not that of other stakeholders (customers, planning yards, etc.). However, we understand that NDEX will impact these stakeholders, and even improve the value they add to the designs, and these effects are measured. So, in summary, for the purposes of our research, NDEX encompasses all hardware, software, manpower, and process changes in the design system that impact design costing and design-related installation CORNs. Therefore, we attempt to measure the benefits and value to SPAWAR of the design process only, not the installation process.

B. 21ST-CENTURY REQUIREMENTS AND VISION SUPPORTED BY NDEX

Several current business trends and resulting initiatives taking place in government, the Department of Defense, and the Navy impact or are supported by NDEX. It is important that these be understood, and that NDEX be considered in the context of all the changes going on around it vice considering NDEX in a vacuum. Some of these include ROI measurement, CNO initiatives, Fleet Readiness Plan (FRP), FORCEnet, Spiral Acquisition, and Next-Generation Manufacturing Technology Initiative (NGMTI), to name a few. A brief initial analysis of these contextual matters and the implications of these to NDEX are provided below.

First, there are several examples of the Navy being criticized for its inability to accurately assess a return on investment related to its programming in order to justify its budget. In a June 2003 report, the Government Accountability Office (GAO) stated, "Without information that links funding to readiness, the Navy's budget package does not provide Congress the return on readiness investment information it may need to make resource decisions" (GAO).

The GAO has also been critical of the evaluation criteria used in procurement, as the Navy has misapplied ROI formulas to business decisions:

> Because of the long-term nature of these investments, they typically do not yield savings in the early years while initial costs are being incurred. According to the Navy's most recent assessment, 62 approved aviation projects yielded about $2 million in net savings from fiscal year 1997 through fiscal year 2002. These projects, along with 11 forthcoming ones, are expected to generate additional savings of approximately $785 million from fiscal year 2003 to fiscal year 2010.[Footnote 26] In addition, Navy officials noted that unmeasured savings may accrue through cost avoidance resulting from reduced maintenance, processing, and transportation of broken or defective items. Navy officials told us that the service is reviewing plans to facilitate project approval by relaxing current return on investment criteria. Management attention to the investment criteria could expand the number of eligible parts, help mitigate spare parts shortages, and increase the readiness return on investment. (GAO)

As these GAO statements show, ROI is important in making budget claims, but can be misleading if we are not careful to ensure analysis over the life-cycle of the project in question. These are just two of many ROI-related issues that GAO or others have called into question concerning the DOD's and, in particular, the Navy's business practices. It is evident that the Navy must link investments to outcomes and determine the value of those outcomes in order to quantify ROI and present justification upon request at any moment throughout the program life cycle. Therefore, NDEX must be considered in light of this framework, and analyzed over the long-term for value. The resulting ROI analysis may then be used in the Planning, Programming, Budgeting, and Execution System (PPBES) if necessary in order to justify and fully fund NDEX.

Current guidance from the Office of Management and Budget (OMB) relating to NDEX that supports this project is provided in CIRCULAR NO. A-130, Revised, (Transmittal Memorandum No. 4). In this memorandum, OMB requests that agencies and executive departments determine ROI for all Federal Information Resources. Specifically, the memorandum requests that agencies:

> (v) Demonstrate a projected return on the investment that is clearly equal to or better than alternative uses of available public resources. The return may include improved mission performance in accordance with GPRA

> measures, reduced cost, increased quality, speed, or flexibility; as well as increased customer and employee satisfaction. The return should reflect such risk factors as the project's technical complexity, the agency's management capacity, the likelihood of cost overruns, and the consequences of under- or non-performance. Return on investment should, where appropriate, reflect actual returns observed through pilot projects and prototypes;
>
> (vi) Prepare and update a benefit-cost analysis (BCA) for each information system throughout its life cycle. A BCA will provide a level of detail proportionate to the size of the investment, rely on systematic measures of mission performance, and be consistent with the methodology described in OMB Circular No. A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs; (OMB)

OMB's ROI guidance follows the President's lead on measuring performance, both anticipated performance prior to investing and metrics that measure performance over the life of an agency or program. In addition, MID-913 changes to the PPBES seek to focus efforts more on execution. Therefore, our effort to measure ROI for NDEX can be viewed as an effort to both comply with current guidance and to further develop the Navy's ROI measuring process.

Within the Navy, the former Chief of Naval Operations, Admiral Vernon Clark, had long been a proponent of capturing the ROI inherent in our business practices. In his latest direction to the Navy, the "2005 CNO Guidance", ROI considerations were a recurring theme, appearing six times:

- Ensure ***savings are harvested and returned*** to the leadership for reallocation against other Navy priorities.
- We established the Assistant CNO for Information Technology (ACNO-IT) to promote Navy-wide alignment between warfighting and business information technologies, and to ensure IT investments and resources are targeted for highest value efforts and ***return on investment***.
- Conduct an Expeditionary Strike Group Sea Swap experiment in FY05. While awaiting live testing, conduct computer modeling simulation to provide initial assessments of feasibility and ***return on investment***. (CFFC by Jun 05)
- Review ship (preventative/routine/intermediate/depot) maintenance practices and ***quantify corresponding return on investment***. Report on

innovative ways to support FRP readiness while preserving safe and effective operations. (CFFC lead, NAVSEA, TYCOMs, by May 05)

- [Develop] an analytical process for warfighting "wholeness" and a methodology by which modernization plans can be evaluated for ***return on investment*** (e.g., platform life cycle cost), overall value to warfighting and risk. (OPNAV N6/N7)
- Facilitate business process transformation and foster a culture of productivity and continuous improvement enterprise-wide. Develop and advocate high potential, cross-functional enterprise initiatives and ensure enhanced performance and organizational efficiencies are not lost in the "white space." ***Ensure savings are harvested and returned*** to the corporation for reallocation against other corporate Navy priorities. (Boldface added for our emphasis) (Clark, 2005)

NDEX meets the spirit of all of the above criteria as outlined by the CNO. It will likely harvest and return savings to SPAWAR and the Navy by automating, updating, and streamlining the design process. In addition, it specifically supports the fourth item, to "review ship maintenance practices and quantify corresponding return on investment" (Clark 2005). However, the ability to greatly improve support the Fleet Readiness Plan (FRP) may be the greatest advantage of NDEX.

NDEX achieves the CNO's goal of being an "innovative way to support FRP readiness while preserving safe and effective operations" (Clark 2005). This is a very important value-added consideration, as the current design process is apparently struggling to meet the challenges presented by FRP. FRP shortens the turnaround process for ships, requiring compressed maintenance availability and training periods in order to ensure the fleet maintains a higher state of readiness. Previously, ships would go through cycles of readiness which would peak on deployment or just prior to a deployment. The cycles were detrimental to readiness and created periods where if called upon, ships might not have been ready for an assigned mission. FRP has attempted to eliminate the cyclical trends and focus on a steady state of readiness. NDEX will mesh into the goal of FRP by providing shortened installation times and overall greater fleet readiness.

NDEX will also possibly lead to savings in the platform life cycle costs, returning value to the warfighter. The CNO's interest items should continue to be monitored and

NDEX "fit" into the overall objectives of the Navy. As summarized above, this "fit" should be natural and advantageous in selling the advantages of NDEX. How these advantages will impact our ROI calculation should also be considered vigorously as we proceed.

As might be expected, NDEX supports SPAWAR's "Enterprise Strategic Plan 2005-2010." The plan's "Framework for Information Systems" challenges the organization to leverage cost savings toward FORCEnet, or toward the warfighting capability in the fleet. "We must leverage business information technology investments, strategies, and efficiencies to reduce costs associated with FORCEnet delivery and deployment while ensuring alignment with business information technology governance policies and procedures of ACNO IT and PEO IT." (SPAWAR 12) While improving delivery, NDEX leverages already established technologies to reduce costs inherent in the current process. Achieving this change in process will contribute significantly to SPAWAR meeting its strategic goal over the coming years.

In recent years, Spiral Acquisition methods have been considered a key component of future acquisition plans. In order to support spiral acquisition, in which new technologies continue to be delivered as they are developed, close coordination and readily available technical information are critical. NDEX provides this coordination and ready information. The Program Executive Officer/ Systems Command (PEO/SYSCOM) Commanders' Conference is "one of the longest running forums to review progress in achieving DoD's acquisition reform objectives. Nearly 500 representatives of the DoD acquisition community … exchange success stories and lessons learned" (Reed 10). At the ninth conference in this continuing series, Dr. Jacques S. Gansler, Under Secretary of Defense (Acquisition, Technology, and Logistics), noted that changes in technology and the threat environment dictate dramatic changes in the way DoD and industry operate: "We need to change the way we buy and field new systems. We need to follow a spiral requirements process, where we put things in the field and then improve them. In addition, unless we get ways to dramatically reduce the costs of these systems, we won't be able to afford them" (Reed 11). If the advantage of spiral acquisition is to be realized, the supporting design system must support quick decisions and delivery of “plug and play” components in the mission architecture. In order to facilitate this, NDEX’s database will provide the information necessary for spiral acquisition, and its interface will allow coordination and efficiency in the process of spiral delivery of new technology.

Another initiative which NDEX will support is SHIPMAIN. SHIPMAIN seeks to provide “a common planning process for surface ship maintenance and alterations” and “increase the efficiency of the process without compromising its effectiveness” (SHIPMAIN 3). SHIPMAIN integrates the ship’s Commanding Officer, the Port Engineer, and the SUPSHIP Manager at the shipyard in a maintenance team that coordinates the work required at a Planning Board for Maintenance. One goal is to complete installations and work whenever possible, vice waiting for a lengthier availability period. In this effort, NDEX will provide the backbone for design support that can be leveraged toward better definition of the C4I task to ensure it can be completed on-schedule to support the ship’s schedule and operations. SHIPMAIN, in its support for the FRP, also seeks to ensure surge capability. Again, NDEX will be more responsive and will better handle this need than the current process.

Two lesser known initiatives should be kept in mind while NDEX is developed. In fact, one such DOD initiative, the Next-Generation Manufacturing Technology Initiative (NGMTI) may be a source of support for NDEX. NGMTI’s objective is to:

> …develop a national manufacturing technology investment strategy to accelerate the transformation of the U.S. industrial base. NGMTI seeks to energize a national consensus for investing in high- leverage, high- impact manufacturing technologies that enable faster delivery of affordable systems for defense while at the same time improving the global competitiveness of U.S. manufacturers. (Graves 1)

NDEX, in enabling faster delivery, may support the objectives of NGMTI and thus qualify as of interest. NGMTI General Manager Gerry Graves of the Advanced Technology Institute (ATI) stated, "Our objective is to radically enhance the nation's return on its manufacturing technology investments. We want to reestablish U.S. leadership in manufacturing science and technology by delivering a plan to double the nation's manufacturing technology investments and increase the return on those investments by a factor of ten" (Graves 1). NDEX, while not in the private sector, is interesting when related to NGMTI, because it offers DOD an internal improvement that may deliver the same results sought by NGMTI. "For the defense community, this means shortening the time and cost to move new weapons from concept to delivery" (Graves 1), said Richard Neal of IMTI, the NGMTI Technical Director. NDEX is SPAWAR’s tool which will improve this delivery process for C4I systems.

Worth noting as it relates to NDEX is the Information Lifecycle Management (ILM) system. ILM is a “strategy that uses people, processes and technology to store and tap critical agency data throughout its lifespan of value. For many agencies, smart use of information has become a differentiator, particularly as technology provides information access within and among agencies who need to collaborate” (Information Lifecycle Management 1). NDEX may be seen as similar to an ILM system, and thus more research should be done on ILM. In addition, ILM addresses several concerns in the current process, including rising costs of technology, increased labor to support back-fits, and aging technical experts that will soon be retiring, leaving a void in corporate knowledge. If ILM can deliver as advertised, it is an important source of comparison with NDEX: “ILM is a strategy that provides a ***return*** on ***investment*** that frees resources to sustain operations with fewer resources. ILM is being discovered as a unique weapon against flat information technology budgets, increasing labor costs and an aging workforce” (Information Lifecycle Management 2). The same could be said about NDEX.

C. ANALOGOUS IMPLEMENTATIONS OF CAD MANAGEMENT SYSTEMS

In a Congressional Research Service (CRS) updated report to Congress on June 23, 2005, entitled “Navy Ship Acquisition: Options for Lower-Cost Ship Designs—Issues for Congress,” the Government Accounting Office’s (GAO) February 28,2005 report is cited, in which numerous problems in the Navy’s ship cost estimating process were noted. Of note, one conclusion drawn was that “contract prices were negotiated and budgets established without making full use of design knowledge and construction experience” (O’Rourke, CRS-31). In addition, the CRS report recommended one option for reducing design costs is to “improve the operating efficiency of yards building Navy ships by incorporating more advanced design and production processes and equipment" (O'Rourke, CRS-34). In light of this pressing current need, NDEX delivers an advanced alternative for C4I configuration design process reengineering. However, SPAWAR is not alone in its attempt to transform the way in which design work is performed.

Several private and public industry initiatives parallel the NDEX program. Most are defined as collaborative engineering, online collaboration, or product lifecycle management initiatives. A few of these initiatives will be covered here for the point of comparison with NDEX.

In China, Wuchang Shipyard announced in June of 2005 that it had implemented Product Development Company's Shipbuilding Solution which comprises several software, hardware, and process innovations "which will be used as a production design management platform… to bring about revolutionary changes in Wuchang Shipyard's business processes, particularly in the way product data is managed" (www.businesswire.com). Wuchang Shipyard was founded in 1934 and is one of China's largest shipyards, with the most modern design, build, and repair facilities in China for civil, military, and tourist ships used in China and exported around the world. Wuchang Shipyard expects that this "collaborative tool for the R&D, manufacturing and production departments, [will enable] concurrent engineering, shortening product design lead-time and accelerating time-to-market" (www.businesswire.com). The benefits of this initiative are not yet known.

Design collaboration, while challenging, provides a significant return. Gartner research director, Mark Halpern, estimates that "design-collaboration tools help companies cut the time it takes to finish a design, typically by about 30%... that's very significant in a marketplace where getting a new product to market before the competition is a key competitive advantage" (Gonsalves 2). In the DOD, this competitive advantage has been a mantra for years, and design collaboration will ensure that our advantage of being on the leading edge of defense technology can be maintained, or even accelerated.

Several U.S. and worldwide companies have reported the results of establishing online collaboration tools. DaimlerChrysler reported that “Compared with the old means of couriers, faxes, and face-to-face design meetings, [it] has cut 60% to 90% of the time it takes to communicate design changes to a supplier and get required changes back” (Gonsalves 2). Karenann Terrell, director of its E-business operation, E-connect stated, “Any change to a design is immediately communicated to everyone, and the impact on their piece of the design is known right away” (Gonsalves 2). Similarly, Lockheed Martin used “proprietary collaborative design technology, a blend of web-based tools that use enterprise data management software and simulation technology to reduce design cycles by an astounding 40% to 80%” (Krouse 1). In addition, Babcock Power in Worcester, Massachusetts, a maker of “scrubbing” systems for power plants realized a 90% reduction in search time for project information (Krouse 5). How did Babcock Power accomplish this? “Communication about drawings and other documents is now done online” (Krouse 5). Finally, Gamesa, a Spanish aircraft and helicopter assemblies manufacturer used “EDS Solutions Teamcenter to reduce design errors by a whopping 88%” (Krouse 5).

One effort to compute ROI as it relates to CAD software is of interest. In a recent White Paper, AutoCAD 2000 was evaluated to determine the performance and productivity ROI of upgrading from a previous version of CAD software, R14. Measured from the perspective of a sole user as the stakeholder, the ROI was measured at 347% (www.cadresource.com/r2000). While not completely analogous, it is expected that NDEX can achieve similar efficiency and productivity enhancements for those responsible for creating and maintaining Navy ships’ drawings.

In summary, the use of online collaborative design tools has yielded the reported effects summarized in Table 1.

Table 1. Combined Effects of CAD and Collaboration Technology Improvement Initiatives In Private Industry

Design CAD/Collaborative Technologies Combined Effects	
1.	30% overall reduction in time to finish design
2.	60% to 90% reduction in time to communicate design changes to supplier and get back
3.	40% to 80% reduction in design cycle time
4.	90% reduction in search time for project information
5.	88% reduction in design errors
6.	347% ROI on sole CAD user's performance & productivity

These effects must be viewed as potential results of not only implementing the new technology, but also reengineering the processes that this technology will support in order to harvest these benefits. NDEX may achieve results similar to many of these.

In addition to these initiatives, Table 2, compiled by Dr. Peter Capell of the Carnegie Mellon Software Engineering Institute, outlines the type of results that have been achieved by process improvement efforts related to acquisition, software, and design. Dr. Capell cites three recurring themes. First, he states that process improvement aims at "eliminating errors in the process upstream." (Capell, v) NDEX certainly aims to achieve this goal, eliminating costly Change Order Request Notifications (CORNs) and rework in the design process. One case study in this body of research found that 30% of errors found at integration were eliminated.

The second recurring theme in Dr. Capell's research is that "while improvement efforts are typically driven by cost and measured by return on investment, quality attributes… are often of more value to the success of the overall project." (Capell, v) The value of these additional quality attributes is difficult to quantitatively measure. However, some of these quality attributes are explained in the Abrams project, for example, capturing the "knowledge and expertise of current PM Abrams personnel for future employees" (Capell, 5). This same quality attribute holds true for NDEX. By capturing data, future design professionals will have a tool that not only enables them to perform more quickly, but also refer to existing drawings quickly when needed to enhance their understanding of an existing problem.

The third recurring theme presented by Dr. Capell is that "most improvement efforts will yield benefits as long as those efforts follow general rules and use appropriate methods." (Capell, v) In implementing NDEX, establishing these rules and methods for collaboration and design will lead to beneficial results, leading to the question— how much? It is important that consideration be given to new paradigms relating to the acquisition and generation of designs as well as the provision of design support services that capture the full benefits of working in a collaborative environment.

Table 2. Program benefits related to Acquisition, Design, and Software Improvements (Capell 5-6)

Organization	Result
Abrams Project Manager (PM)	• Empowered the PM Abrams organization and facilitated M1A2 SEP development • "Leveled the playing" field with the contractor by providing a common language and set of standards • Captured the knowledge and expertise of current PM Abrams personnel for future employees • Paved way for transitioning the PM Abrams to support organizations through documented policies, procedures, and practices
Accenture	Reported 5:1 benefit as a ratio of hours spent on Capability Maturity Model Integration (CMMI) process activities
Air Force Institute of Technology	Cost Performance Index (CPI): The multiple comparison test showed significant differences between CMM Levels 1 and 2 and between CMM Levels 1 and 3. As the organization increased in CMM maturity, its CPI general approaches 1.00 with generally decreasing variation. Schedule Performance Index (SPI): At all CMM rating levels, the SPI remains close to 1.00. However for projects less than 80% complete, the performance of Level 1 organizations was consistently below an SPI of 1.00. As the institute exceeded the 80% completed milestone, it increased its SPI to meet the required 1.00
Boeing Australia	• Decreased cost to correct a defect (measured over 18 months) 33% • Decreased time to deliver releases 50 % • Reduced preparation, conduct, and rework from pre-test and post-test audits 60% (resulting in audits passed with few or no outstanding actions).
General Motors	• Increased the percentage of milestones met from approximately 50% to approximately 95% • Decreased the average of milestones days late from approximately 50 to fewer than 10
Hughes Aircraft	Saved $2 million dollars annually Other improvements include certain quality of life attributes such as: • Fewer overtime hours • Lower employee turnover • Better organizational image
Jet Propulsion Laboratory	Reduced defect identification and correction time from as much as 17 hours to less than 2 hours
JP Morgan - Chase	• Reduced post-release defects • Reduced severity of post-release defects • Improved predictability of scheduled deliveries
Litton Data Systems	Reduced the number of errors found during systems integration 30%

Lockheed Martin MD & S	• Reduced overhead rate 4.5% • Increased software productivity 30%
Motorola Government Electronics Division	Achieved an ROI of 6.77 to 1 for a typical 100,000 Software Lines of Code (SLOC) project. Such a project would span 18 months and require 20 software engineers. In dollar amounts, Motorola saved $611,200 after investing $90,180 in a typical project.
NASA Goddard	• Reduced cost of software development by 55% • Decreased cycle time by 40% • Reduced post-release defect rate by 75%
Northrop Grumman Electronics Systems	Moving from Level 3 to Level 4 resulted in 20% annual gains in productivity for the 5-year reporting period. This represented a 10% gain over their previous annual improvement achievement. The acceleration resulted in a $25 million annual cost avoidance over the 5-year time span.
Northrop Grumman IT	• Achieved 13:1 ROI calculated as defects avoided per hour spent in training and defect prevention • Met milestones 25 times in a row (with high quality and customer satisfaction) • Increased focus on quality over "firefighting" • Earned rating of "exceptional" in every applicable category on its Contractor Performance Evaluation Survey
Oklahoma City Air Logistics Center	• Saved $11.3 million over 8 years • Reduced defects 90% from baseline project to second project • Reduced average cost of a TPS maintenance action 20% over the last two years • Achieved 10X increase in productivity based on source code produced from baseline to most recent project due to technology as well as CMM improvements
Raytheon Northeast Software Engineering Center	• Reduced Cost-Performance Index variability by 36% • Reduced Schedule Performance Index variability by 70% • Reported productivity gains in the following percentages: – 1997-1999: 30% – 2000: 9% – 2001: 11% – 2002: 6%
Sanchez Computer Associates, Inc.	• Saved $2 million in first 6 months due to early detection and removal of defects • Created a robust training program • Applied process improvement activities to functions other than programming
Schlumberger	• Reduced validation cycles 54% • Improved productivity 100% • Increased on-time delivery of software from 51% to 94% • Reduced post-release defects from 25% to 10%
Thales TT&S	Decreased cost and schedule variances as process maturity levels increased

We can deduce from this table that the process improvements achieved had significant effects within the organization, saving time and money. Numbers ranging from 10% to over 1300% are reported for the various “returns” of these efforts. In addition, many of these process improvements were not expensive to implement in comparison to the net effect. Finally, as stated before, not all effects were monetized, but each was valuable to the organization and improved the process for both the organization’s employees and customers. Even if NDEX were to fall short of realizing the significant cost avoidances expected, it would likely prove its value many times over to both the customer and the employees currently tasked in design processes by improving the efficiency and ease of managing and communicating design data.

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III. DEVELOPMENT OF THE METHODOLOGY

A. OVERVIEW OF THE JBG NROI MODEL

As stated, the JBG NROI formula was the starting point for arriving at a measure of ROI for NDEX. The original formula is restated below.

$$NROI = \frac{PM*0.1 + ENG*0.4 + SM*0.15 + PR*0.4 + INST*0.3 + SS*0.2 + MM*0.1 + Avoidance\ Costs}{Radio\ Control\ Suite\ Program\ Costs}$$

The need for businesses to capture return on investment (ROI) has been an industry standard for many years and is one metric many businesses use to gauge financial performance. It is a very challenging task to compute ROI for the public sector since the normally applied formula numerator of profit or net operating income is difficult to capture in DoD applications.

There have been numerous attempts to calculate ROI in the public sector but all have met mixed results. The prior Chief of Naval Operations, ADM Vernon Clark placed much emphasis on capturing ROI in November of 2003 in an Echelon II visit feedback memo:

> This is an area where we are struggling the most. We need to know that we are making the right type and level of investment. We have made some progress in understanding what we are investing in and have even made progress in understanding the output of our processes. However, we are struggling to link the two (investment to output). We need to model how increases or decreases in investments (people, dollars, and technology) will change the output. (Clark, 2003)

Traditional ROI computation cannot be used in the public sector as freely as private enterprise. The reasoning is that public sector organizations do not produce profits or generate revenues as their outputs, as do private organizations. It is difficult to measure how much benefit or value is derived from producing a new ship class or aircraft type. While vitally important to national security, it is hard to determine how much return is generated on that investment.

There have been many attempts to quantify ROI in the public sector both by international governments as well as domestic organizations. The Australian government attempted to quantify ROI on government purchases in an attempt to show its citizens that it is making proper use of funds. The effort resulted in criticism: "There is a widespread dissatisfaction with Defence's Performance [regarding the Australian Defence…use of funds]…In essence we have a credibility problem" (Bigham 16).

The Royal New Zealand Navy initiated ROI measures on a program used to control attrition of their marine engineers by providing better pay and bonuses. Essentially, the ROI study was initiated to validate the cost of the program of increasing the compensation of the marine engineers in comparison to retention rates after the program's implementation (Bigham 16).

The United States Postal Service (USPS) attempted to measure ROI by using an Economic Value Added (EVA) approach which measured the efficient use of assets. The EVA effort was discarded in 2002. Of note is that the USPS is one of the few public organizations that realize a profit and can use traditional ROI computations in determining financial performance (Bigham 20). In addition, the Navy Dental Corps used several iterations of an ROI formula in an attempt to quantify their performance output with mixed success (Bigham 22).

The basis for our formula is patterned after the Jones-Bigham-Goudreau notional ROI formula (JBG NROI) derived in an attempt to measure ROI of Radio Control Suites (RCS) on the new T-AKE class of ship (Bigham 33). The JBG NROI formula was derived over a period of 10 months and had a total of four iterations. Early iterations attempted to capture weighted vital components of the program. It wasn't until the third iteration that the numerator of the final product eventually evolved into what was termed Work Breakdown Structure (WBS) categories and applied weights to each category. The fourth and final iteration fine-tuned the numerator of the formula to compensate for rework costs and to model the formula after a traditional ROI formula.

The seven WBS categories that were settled upon were Program Management, Engineering, Supportability Management, Production (integration), Installation, Shipyard Support, and Material Management.

Weights, or value-added factors (VAFs), of each WBS category were settled upon after consulting with several Program managers and RCS experts from both the T-AKE and other classes of ships and the final product was delivered. An example of the weighting settled upon is that for every dollar spent in Program Management, $1.10 is returned.

B. ADAPTATIONS TO THE JBG NROI MODEL

In conversations held with Mr. Ed Dalton and Mr. Jay Johnson, we agreed that NDEX added value to the existing processes in addition to avoiding costs. First, we believed that knowledge capture was a significant benefit derived from NDEX that was not in the original formula, and that this knowledge would be leveraged toward the existing process to deliver better design support in the ship installation and alteration processes. Second, we felt that customer support and responsiveness was greatly improved and added value to the process. Finally, we saw acquisition alternatives would increase and be more accurate due to the information available in NDEX. Much later in the process, we realized the current process delivers the same benefits, but that NDEX as a tool leverages these efforts and improves the resulting impact of current efforts.

After several struggles with application, we realized that investment effects from investing in NDEX did not behave in the same manner as direct investment in a program, such as the Radio Control Suite Program originally measured with the JBG NROI formula. The investment in NDEX is leveraged toward all programs supported by designs. Thus, the investment in NDEX indirectly results in improved existing processes in program management and processes leading to installation and operation of the system supported.

In returning to analyze the original JBG NROI variables, supporting the Work Breakdown Structure (WBS) utilized in the installation process was important for both consistency of application and ease of tracking. However, how to account for the benefit a tool like NDEX provided to the existing WBS expense model was not directly evident. We determined that what NDEX does as a tool is provide better information and design data throughout the process, benefiting other work on a scale related to the funding flowing into NDEX. For example, funding NDEX at a $10M value to employ enough CAD operators to complete CDBs for over 100 ships in one year would yield a benefit to the entire WBS process(es) on scale with the $10M invested into NDEX. We then determined what value NDEX would provide and tied it to NDEX funding. It is important to note that in terms of notional benefit the benefit may not be seen in the bottom line of these processes. However, as detailed above, the benefits of NDEX are not completely measurable. For example, what is the value of time-to-market in a warfare environment? The answer must be dependent on the scenario, however the benefit of a time-to-market (to install and operate in this case) advantage surely exists. These benefits at a lower magnitude are provided inherently in the current WBS processes. The value-added by NDEX is thus the multiplied effect it has on the WBS value to the organization. Even if this benefit is realized by the end-user, it results in goodwill benefit for the organization (in this case, SPAWAR). Thus, we captured through a NDEX "Invested Multiplier" the benefit that funding NDEX will create in the ship design and installation process as reflected in WBS format.

We were left with choosing to apply NDEX to all programs supported, a daunting task, or to measure the notional benefits derived by NDEX as a whole. In the interest of time, we chose to factor the "Invested Multiplier" to measure the expected whole. Application and measurement of the formula as it relates to an individual project or program would be of interest in follow-on research and would perhaps refine or verify the "Invested Multiplier" factors.

The benefits of NDEX will likely be realized and increase with acceptance and growth of the system; however, an implementation period is expected in which benefits are not realized immediately. A "learning curve" effect will likely be encountered while users and customers adapt to the capabilities of the new system. Therefore, we conservatively lagged benefit one year behind funding as immediate benefit is not likely, and then increased benefits by adjusting the Invested Multiplier up over time.

C. FINAL NOTIONAL ROI FORMULA

The resulting revised JBG NROI formula is presented below as it relates to a program that acts as a tool that can be leveraged in support of other programs:

$$JBG\ NROI = \frac{\text{PMIM} * 0.2 + \text{ENGIM} * 0.4 + \text{SMIM} * 0.15 + \text{PRIM} * 0.4 + \text{INSTIM} * 0.3 + \text{SSIM} * 0.2 + \text{MMIM} * 0.1 + \text{Avoidance}\ Costs}{\text{Pr}\,ogram\ Costs}$$

Note that this formula's numerator reflects the notional return on investment of each WBS element's improved effect overall (across all work supported) plus the avoidance costs generated, and does not depend on the WBS element's funding per program. This measure is very subjective, but is indeed based on the knowledge of many experts. In reality, the notional benefit realized ultimately depends on the world environment, workload, and specific value-adding opportunities presented in a given year. However, as a first approximation of value-added, or net benefit, the Invested Multiplier can be estimated based on the investment in the tool being leveraged.

The Invested Multiplier for each WBS category is derived for insertion into the JBG NROI formula. Each Invested Multiplier is determined as follows:

$$WBS\ Category\ Invested\ Multiplier = Supporting\ Tool\ Investment * Invested\ \text{Im}\,pact\ Factor$$

Objectively, we can determine the Program Investment, which is also used in the denominator as Program Costs. Subjectively, we must determine the expected leveraged impact and construct an associated factor. For example, for every dollar invested in NDEX, if we expect that fifty-cents ($0.50) of resulting benefit to program management at SPAWAR exists, a factor of 0.5 would result. This would encompass benefits such as time invested in managing, better informed decision-making and better acquisition decisions. In application, we chose to be conservative, but given the amount of dollars invested in program management at SPAWAR, the value of having NDEX to a particular decision could be as much as 20 times the investment, or more. However, to project such a realized return would be haphazard and insulting at best. Therefore, in application, we recommend applying the factors on scale with the investment to yield no more than a 1.0

return to any WBS element if greater benefit cannot be supported empirically (which we did). In measuring the impact over time once a program is implemented, however, the factor may be empirically supported to be much greater than the magnitude of the investment.

IV. APPLICATION OF THE METHODOLOGY

A. ESTIMATING THE COST OF IMPLEMENTING NDEX

NDEX will not be a very expensive project for the Navy to implement. The majority of the equipment that is used by NDEX is commercial off the shelf (COTS), subsequently; items are readily available from commercial sources and will not require further development.

The majority of the costs associated with NDEX are with hiring new people to perform the functions of NDEX. As it stands, NDEX will have offices on both the East Coast and West Coast in large fleet concentration areas in order to handle the bulk of ships. It is initially proposed to have five CAD operators on each coast to work with the ICD and class design baseline drawings. Furthermore, it will be required to hire two programmers and two engineers for each coast to perform work with network analysis and CADIT programming. The total anticipated cost of all combined labor is expected to be $2.5M.

Bringing NDEX to fruition will require the purchase of computer hardware, software, ancillary support equipment needed for everyday use, training, and travel. Costs as described below were contractor provided and are assumed accurate for implementation.

Hardware is comprised of all computer support to include laptop computers for personnel utilizing NDEX. Software includes AutoCAD and the necessary collaborative web-based tools. NDEX will require special equipment to include servers and a T1 internet line. Of note is that all hardware and software is based on a two year life cycle. If equipment malfunctions or becomes obsolete earlier than the anticipated two year life cycle, costs will likely increase.

There are many everyday consumable items that will be required for sustained use. These include items such as printers, print cartridges, laptop stands, thumb drives, and other items necessary to carry out the day to day operations. These items have a life cycle that varies from one to four years.

Since NDEX is a new system which incorporates new ideas and a new approach to design work, professional training will need to be conducted. Training is offered through Autodesk, the developer of AutoCAD and is currently scheduled every two years as either a refresh for existing employees or initial training for new hires.

Travel is listed as an expense but is truly a negligible expense due to the fact that travel will be necessary whether NDEX is implemented or the current system is utilized. There will still need to be site visits and ship check regardless of the system in place. For the sake of this project, travel expenses were factored in to the NROI equation as they will occur as part of the implementation of NDEX. Furthermore, travel expenses are expected to reduce as fewer trips will need to be made and fewer people will be required to travel due to the efficiencies of NDEX. Of note is that if NDEX expands beyond the C4I suite applications and into complete ship design, additional travel will be necessary but costs savings will increase even more dramatically. Travel as it currently stands is expected to range from approximately $53,000 during NDEX's first year of operation and will grow by about $3,000 per year as NDEX expands. (Dalton, spreadsheet)

Table 3 shows expected start up expenses for NDEX starting in fiscal year 2006 and going through fiscal year 2010. Other direct costs (ODC) include all hardware, software, and peripheral support equipment.

Table 3. NDEX Start-up costs per fiscal year

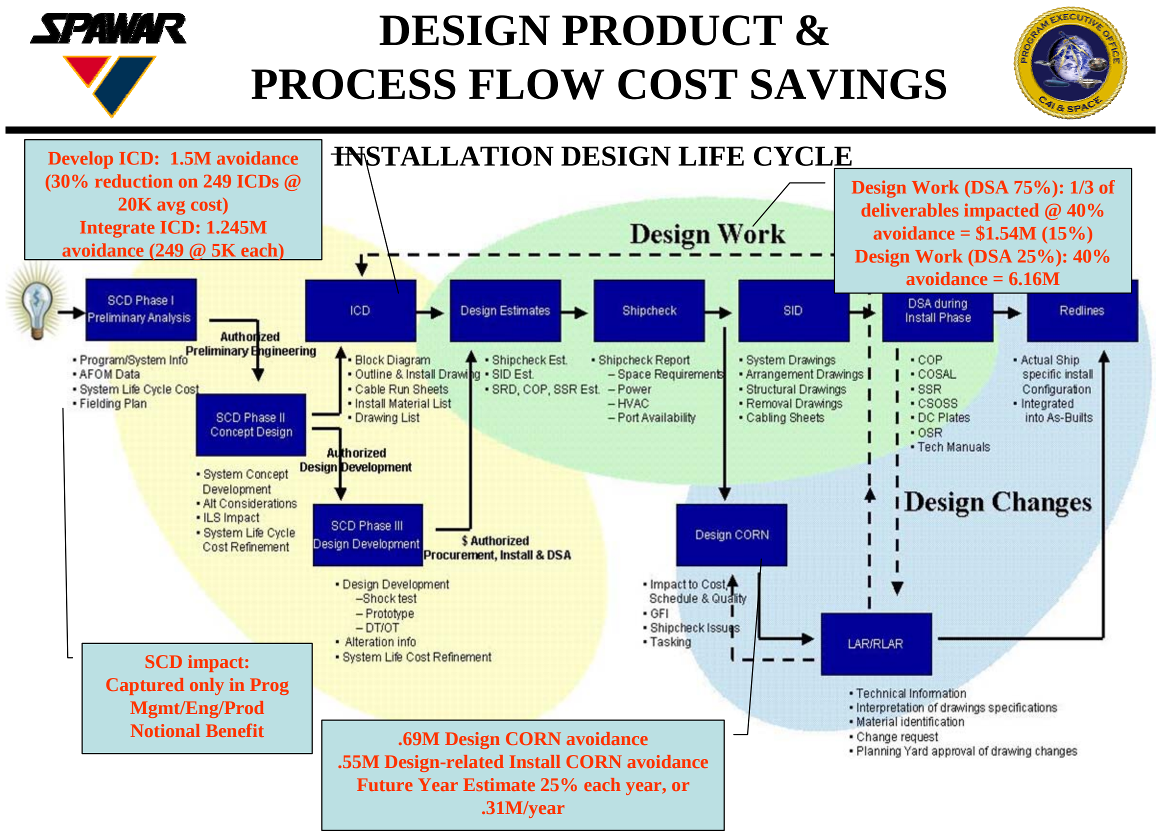
	FY06	FY07	FY08	FY09	FY10
TOTAL LABOR	$2,530,258	$2,656,771	$2,789,609	$2,929,090	$3,075,544
TOTAL TRAVEL	$53,314	$55,980	$58,779	$61,718	$64,804
TOTAL ODC	$43,529	$45,705	$47,991	$50,390	$52,910
TOTAL ANNUAL COST	$2,627,101	$2,758,456	$2,896,379	$3,041,198	$3,193,258

B. ESTIMATING THE BENEFITS OF IMPLEMENTING NDEX

There are many potential benefits that may result from establishing NDEX as a Navy standard for coordinating the design efforts related to ship installations. These include but are not limited to cost reductions, technological advance, data-sharing, and three delivery benefits: end-user value, worldwide availability, and contingency capability.

Significant cost reductions are expected due to several work processes changing and a decrease in time required for completing installations. With laptops and CAD operators on-site with the engineer, the design teams will be more streamlined and effective in integrating ICD's and completing SID packages. Duplication of effort will be nearly eliminated. Information will be readily available to interested parties; thereby decreasing the amount of time spent drafting redundant drawings. In addition, management decisions can be made more quickly based on a single available network of information servers which will save time throughout the installation and in numerous subordinate or supporting processes such as shipyard bidding and engineering redesigns. Finally, design and design-related installation Change Order Request Notifications (CORNs) will be reduced and changes made will be less expensive to process. Figure 1 summarizes the expected cost avoidances as they relate to the current design process. The authors assume that NDEX will be phased in and therefore do not take all avoidances at once. In addition, avoidances once taken, are not repeatedly taken, thus a diminishing return of avoidances persists in the model. The avoidances are taken over a five year period based on an assumed schedule that reflects both the phase-in of NDEX effects and the diminishing availability of avoidances for harvesting. The assumed percentages for years two through six are set at 15%, 25%, 35%, 15%, and 10%. These should be adjusted in future models should further data become available concerning the phase-in of NDEX. Finally, we assume 25% of CORNs avoidance will recur each year due to the nature of designing new systems (these are not avoidable altogether), and the resulting value of $0.31M represents decreased costs associated with making or supporting the required changes that occur similarly each year.

Figure 1. Cost Avoidances Generated by NDEX Reflected in the Current Process (Chart adapted from original SPAWAR briefing slide)



As outlined previously, several initiatives in our business environment dictate that we become more and more network-centric and time efficient in our processes. NDEX aligns the installation process with other 21st century business, technology, and defense processes. This will improve speed, reliability and coordination through utilizing network-centric technology which will automate, eliminate redundancies, and enable NDEX to support and integrate with other modern systems.

A single network for data-sharing will also prove beneficial in at least two ways. First, data-sharing will create value through increased corporate knowledge. In the shipbuilding industry, where expertise is growing short, the movement toward utilizing a reliable database system will likely capture and protect the knowledge developed over many years and hopefully integrate automated skills and knowledge which may be in short supply in the future. Second, data-sharing will level the playing field in the contracting and bidding process, hopefully returning value to the Navy and contractors by providing a greater amount of precise specifications needed for cost estimation. This should drive contract prices down.

Finally, and perhaps most significantly, NDEX is expected to improve delivery of technology to the fleet and vastly improve the capability of the design process to respond if necessary to any contingency requirement. While delivering this technology, the NDEX process should be far less imposing on the end-user. This convenience should not be underestimated, as it reduces the ships' own investment of time and resources in the process. These savings can be leveraged at improving training, maintenance, or any number of other value-adding activities.

The ability to handle multiple installations in a short timeframe provides needed capability to install urgent and routine system requirements fleet-wide if necessary. In addition, design can be conducted worldwide and managed through the network for approval, allowing installations to be done even while underway if necessary. As stated, NDEX will allow the Ship Change Document (SCD) to be transmitted and approved while still on the site-visit if necessary to facilitate installations. Therefore, ships overseas, especially those subject to "Sea Swap" that will remain overseas for significant periods of time and be supported by rotating crews, will be equally supported without multiple travel requirements or a return to CONUS. This allows greater flexibility and support of the fleet during the design and installation process.

How are these benefits included and measured in the formula? They are captured in the Invested Multipliers. As previously stated, NDEX impacts the current work processes by providing better data and efficient support. The WBS structure captures program costs for processes that add value to the end product. NDEX improves these values across all affected programs.

WBS categories and their associated value added factors (VAFs) were derived by experts and reported in the JBG NROI original paper (Bigham 30). The NDEX Invested Multipliers for each category are derived from the authors' expected value added to these processes through the use of NDEX, and are phased in as NDEX matures at the following subjective rates corresponding to years of maturity: 10%, 25%, 50%, 75%, 100%. For example, an Invested Multiplier of 0.5 at full maturity would provide 0.05 times the NDEX investment in return in the first benefit year. The resulting dollar value would then be multiplied by the WBS category's VAF to determine the overall WBS category's benefit resulting from NDEX in that year. These results are summarized in Table 4.

The following explanations are provided for each WBS category's Invested Multiplier.

Program Management / Invested Multiplier (PMIM): A weighting factor of 0.1 was applied to program management in the JBG NROI model, based on the agreed amount of value added to dollars spent within this category (Bigham 33). Program managers were perceived to have the education and experience necessary for analyzing decisions within their programs, and benefit from discussing and sharing issues with each other in a collaborative environment. A number of project management tools are used by program management to add value to their programs. NDEX will improve the design process and support collaboration, decreasing the time and effort required for acquiring design data critical to program decisions, and adding value by shortening the design cycle time, enabling program managers to deliver end-products quicker. The NDEX Program Management Invested Multiplier (PMIM) at NDEX's full maturity is 0.2, meaning for every dollar spend on NDEX, the NDEX tool will return a total value of 20 cents to supported program management decisions.

Engineering (ENG): A weighting factor of 0.4 was applied to engineering in the JBG NROI model, based on the agreed amount of value added to dollars spent within this category (Bigham 33). Harvesting past experience in developing engineering products for a number of deployed systems is the primary value-adding process in Engineering. NDEX will provide better knowledge capture related to completed designs, improve the ability to leverage engineering products from one hull to the next, and provide Class Design Baseline management to vastly improve efficiency for integrating Installation Control Designs (ICDs), enabling faster integration of technology in the fleet. The NDEX

Engineering Invested Multiplier (ENGIM) at NDEX's full maturity is 0.4, meaning for every dollar spend on NDEX, the NDEX tool will return a total value of 40 cents to supported Engineering products.

For example, once a specific ICD drawing is developed for a given communication system (i.e., HF system, VHF/UHF system, etc), it becomes the automated design starting point for follow-on system installs on other platforms. NDEX's CDBs provide follow-on platform requirements. NDEX then can be used to provide automated integration of drawings from one platform to the next. Leveraged across multiple hulls, the ICDs, cable run sheets, and "As Built" drawings are captured and remain available for future designers and installers. Improved technologies can thus be employed faster in the fleet and the feedback loop closed very quickly on engineering changes or design modifications required.

Material Management (MM): A weighting factor of 0.1 was applied to material management in the JBG NROI model based on the agreed amount of value added to dollars spent within this category (Bigham 33). NDEX improves the capacity of support for spiral acquisition products and the time-to-market delivery of material by providing design-related information sooner. NDEX may also improve work practices by easing access to needed data. Life cycle costs of material support may be reduced as well by the improvement of the initial design and supported decisions related to spares. The NDEX Material Management Invested Multiplier (MMIM) at NDEX's full maturity is 0.1, meaning for every dollar spend on NDEX, the NDEX tool will return a total value of 10 cents to supported Material Management decisions.

Supportability Management (SM): A weighting factor of 0.15 was applied to supportability management in the JBG NROI model based on the agreed amount of value added to dollars spent within this category (Bigham 33). Time available for crew familiarization and maintenance training will increase for any specific platform due to an improved design cycle time. Development of supporting documents and classroom packages will improve as rework is reduced by reducing drastic design changes and work stoppages. Changes to existing training programs will be easier to complete with readily available design data. Sharing of lessons learned across multiple platforms may also be incorporated into future designs in a very quick feedback loop. The NDEX Supportability Management Invested Multiplier (MMIM) at NDEX's full maturity is 0.3, meaning for every dollar spend on NDEX, the NDEX tool will return a total value of 30 cents to supported Supportability Management decisions.

Production/Integration (PR): A weighting factor of 0.4 was applied to production/integration in the JBG NROI model based on the agreed amount of value added to dollars spent within this category (Bigham 33). There is significant "value added" in the integration and testing that NDEX supports. NDEX allows for automated integration of tested components with existing ICDs into the CDB within hours. Production efforts like providing the cables, connectors, back shells and other systems not sponsored by hardware providers but required for delivery of the product can be planned, scheduled, and completed with the use of readily available and timely design data. Interoperability with other new and legacy systems in the design process can be checked prior to installation. A full design "mock up" of the shipboard spaces enables validation of the proposed design configurations, providing improved value to the end user who avoids delays in delivery. The NDEX Production/Integration Invested Multiplier (PRIM) at NDEX's full maturity is 0.5, meaning for every dollar spent on NDEX, the NDEX tool will return a total value of 50 cents to supported Production and Integration processes.

Installation (INST): A weighting factor of 0.3 was applied to installation in the JBG NROI model based on the agreed amount of value added to dollars spent within this category (Bigham 33). NDEX can improve the installation and testing time needed by validating the design of the ICD to the CDB much quicker than the current process. This greatly reduces the install time as well as the confusion and troubleshooting related to installations within the industrial environment at the shipyard. This also enables delivery of systems that are closer to "state of the art" at delivery. Additional benefits of these improvements include capturing lessons learned quickly and incorporating them into future installs, as well as improved customer satisfaction with the installation process.

The NDEX Installation Invested Multiplier (INSTIM) at NDEX's full maturity is 0.6, meaning for every dollar spent on NDEX, the NDEX tool will return a total value of 60 cents to supported Installation processes.

Shipyard Support (SS): A weighting factor of 0.2 was applied to shipyard support in the JBG NROI model based on the agreed amount of value added to dollars spent within this category (Bigham 33). Civil service and contractor personnel interface daily with the shipbuilder and planning yards. NDEX improves communication between PEO/SPAWAR and these collaborators, allowing for quicker identification and resolution of issues and concerns. Design-related issues leading to stopped work orders can be extremely expensive. By improving the design-related communications between all parties in a collaborative data environment for the sharing of information, NDEX will reduce the circumstances that often lead to stopped work. In addition, oversight will be improved with the accessibility and control of design information. Feedback loops will be improved as well. The NDEX Installation Invested Multiplier (INSTIM) at NDEX's full maturity is 0.3, meaning for every dollar spent on NDEX, the NDEX tool will return a total value of 30 cents to supported Installation processes.

C. ESTIMATING THE JBG NROI FOR NDEX

To complete the estimation of the JBG NROI for the NDEX system, a spreadsheet model (Table 4) of cost and benefit data was developed for a five-year period using the factors developed. Benefits are assumed to lag one year later than NDEX funding, or be realized in the Fiscal Year following funding. In addition, cost avoidances are only reported in the year they are projected to be realized, not in subsequent years. Thus, the cost avoidances in aggregate are a measure of real better-off-"ness" in terms of budget expense at the end of the period. One limitation of this analysis is that the phasing-in of NDEX must be assumed- therefore subjective percentages are based simply on a reasonable impact schedule, rather than an available schedule or data. As stated above, the percentages chosen for phase-in of notional benefits by year were 10% (second year), 25% (third year), 50% (fourth year), 75% (fifth year), and 100% (sixth year). The percentages chosen for phase-in of avoidances by year were 15% (second year), 25% (third year), 35% (fourth year), 15% (fifth year), and 10% (sixth year).

NDEX, as measured, returned a 195.94% JBG NROI. Two required calculations are demonstrated below for understanding. In addition to the calculations made below, the net present values of future year Total Benefits were computed and the cumulative result used as the numerator in the JBG NROI formula. The denominator is simply the first year investment in NDEX. While the numbers produced by the spreadsheet model imply significance to the penny, it should not be viewed with such precision. The numbers are provided for review as calculated, but should be rounded appropriately should the answer provided be used in further reporting (the JBG NROI is about 200% would be a better stated approximation).

The following is the computation of the Program Management Invested Multiplier (Year 2):

$$\text{Pr}\,ogram\ Management\ (PM)\ Invested\ Multiplier(Year\ 2) = NDEX\ \ Investment\ Year\ 1 * PM\ \ Investment\ \text{Im}\,pact\ Factor\ Year\ 2$$

PMIM = $2,627,101 * 0.02 = $52,542.02

The following is the computation of the Program Management Notional Benefit from NDEX (Year 2):

$$PM\ \ Notional\ \ Benefit\ (Year\ 2) = PMIM\ \ (Year\ 2) * PM\ Value\ Added\ Factor\ (VAF)$$

PM Notional Benefit (Year 2) = $52,542.02 * 0.1 = $5,254.20

After calculating the notional benefit for each WBS category in each of the 5 benefit years (years two through six), the sum of the benefits in all WBS categories for each year is calculated. We arrive at our numerator by then adding the total avoided costs to the notional benefits in each benefit year and subtracting any new investment in NDEX.

Then, each year's total benefit is valued at Net Present Value and summed to arrive at the numerator value of $5,147,508.22. The final calculation of the JBG NROI (modified for NDEX) is

$$JBG\ NROI = \frac{\text{PMIM} * 0.2 + \text{ENGIM} * 0.4 + \text{SMIM} * 0.15 + \text{PRIM} * 0.4 + \text{INSTIM} * 0.3 + \text{SSIM} * 0.2 + \text{MMIM} * 0.1 + \text{Avoidance}\ Costs}{\text{Pr}\ ogram\ Costs}$$

$$\text{JBG NROI} = \frac{\text{\$5,147,508.22 (Summation of all five years at NPV)}}{\text{\$2,627,101.00 (First year investment in NDEX)}} = 195.94\%\ or\ 200\%$$

NDEX PROJECTED INVESTMENT	FY		PROGRAM MANAGEMENT	ENGINEERING	SUPPORT MANAGEMENT	PRODUCTION	INSTALLATION	SHIPYARD SUPPORT	MATERIAL MANAGEMENT	TRAVEL	C/S FEE	MATERIAL
$2,627,101.00	1	INVESTMENT IMPACT FACTOR (Improvement impact of every NDEX $)										
$2,758,456.00	2		0.02	0.04	0.03	0.05	0.06	0.03	0.01			
$2,896,379.00	3		0.05	0.1	0.075	0.125	0.15	0.075	0.025			
$3,041,198.00	4		0.1	0.2	0.15	0.25	0.3	0.15	0.05			
$3,192,258.00	5		0.15	0.3	0.225	0.375	0.45	0.225	0.075			
	6		0.2	0.4	0.3	0.5	0.6	0.3	0.1			
	2	PROJECTED INVESTED MULTIPLIER (Impact Factor * Projected Investment in Prior Year)	$52,542.02	$105,084.04	$78,813.03	$131,355.05	$157,626.06	$78,813.03	$26,271.01			
	3		$137,922.80	$275,845.60	$206,884.20	$344,807.00	$413,768.40	$206,884.20	$68,961.40			
	4		$289,637.90	$579,275.80	$434,456.85	$724,094.75	$868,913.70	$434,456.85	$144,818.95			
	5		$456,179.70	$912,359.40	$684,269.55	$1,140,449.25	$1,368,539.10	$684,269.55	$228,089.85			
	6		$638,451.60	$1,276,903.20	$957,677.40	$1,596,129.00	$1,915,354.80	$957,677.40	$319,225.80			
		JBG Program Factor	0.1	0.4	0.15	0.4	0.3	0.2	0.1			
(P.I.M.'s * JBG Program Factors)	2	Notional Benefit from Prior Year NDEX Funding (Factor* Proj.	$5,254.20	$42,033.62	$11,821.95	$52,542.02	$47,287.82	$15,762.61	$2,627.10			
	3		$13,792.28	$110,338.24	$31,032.63	$137,922.80	$124,130.52	$41,376.84	$6,896.14			
	4		$28,963.79	$231,710.32	$65,168.53	$289,637.90	$260,674.11	$86,891.37	$14,481.90			
	5		$45,617.97	$364,943.76	$102,640.43	$456,179.70	$410,561.73	$136,853.91	$22,808.99			
	6		$63,845.16	$510,761.28	$143,651.61	$638,451.60	$574,606.44	$191,535.48	$31,922.58			

Total Notional Benefit	(+) Avoided Cost	(-) NDEX Investment	(=) Total Benefit	FY
$0.00	$0.00	-$2,627,101.00	$0.00	1
$177,329.32	$1,937,563.65	-$2,758,456.00	-$643,563.03	2
$465,489.45	$3,229,272.75	-$2,896,379.00	$798,383.20	3
$977,527.91	$4,520,981.85	-$3,041,198.00	$2,457,311.76	4
$1,539,606.49	$1,937,563.65	-$3,192,258.00	$284,912.14	5
$2,154,774.15	$1,291,709.10	$0.00	$3,446,483.25	6

TOTAL NDEX Cost (Investment):	$14,515,392.00	NPV of Total Benefit	$5,147,508.22
Less TOTAL Avoided Cost:	$12,917,091.00	Base	$2,627,101.00
Net Budget Impact:	-$1,598,301.00	JBG NROI	195.94%

ASSUMPTIONS:

1. Impact of NDEX is lagging ONE FY behind funding of NDEX.
2. Cost Avoidance may only be counted once. Once the Avoidance has been achieved, it cannot be "avoided" again in future years. Avoidance Base is figured from FY04 data, then phased in (15%, 25%, 35%, 15%, 10%) over 5 FYs to account for implementation.
3. Notional Benefits are realized at the end of each FY (impact of prior year NDEX funding), and are based on both the value-adding capability of each WBS element and the investment in NDEX.

Avoidance Base	$12,917,091.00	
Avoidance Breakdown:		
DSA Design Work	$1,536,439.00	(40% of FY04 cost for 1/3 of processes related to 75% work)
DSA 25% avoided	$6,155,652.00	(40% of FY04 cost)
ICD Development	$1,500,000.00	(30% of 249 ICDs @ 20K estimated average cost)
ICD Integration	$1,245,000.00	(249* 5K simple ICD cost avoided)
CORNs Avoided	$1,240,000.00	(CORNs analyzed and deemed avoidable in 1 FY)
CORNs Avoided Future Years	$1,240,000.00	(25% of 1st Year Avoidance * 4 Years)

Figure 2. NDEX NROI Computation

V. CONCLUSIONS AND RECOMMENDATIONS DRAWN FROM APPLICATION

The purpose of this project was to provide an ROI computation for NDEX. With much thought and after carefully studying all public sector ROI computations, it was determined that the best course of action in applying the JBG NROI formula to this application was by valuing the notional benefits and avoidances created by the investment in NDEX based on the Work Breakdown Structure of SPAWAR programs in order to determine the benefit NDEX generates when infused into the current process. The resulting JBG NROI (modified) of 195.94% (or about 200% rounded), represents a significant opportunity for investment. This investment would, if completed, provide excellent return and modernize the design process SPAWAR currently utilizes.

Based on the information provided in this document, it appears that implementing NDEX would provide substantial cost avoidance in addition to added benefit over many years. Even with the initial startup costs associated with bringing a new process online, the savings over time would be tremendous. Calculations based on the modified JBG NROI computation for NDEX show that in a short time the budget could absorb NDEX funding completely and realize additional savings and benefits. However, in reality, the result depends on solid implementation and the ability to break existing paradigms in order to maximize efficiency, effectiveness, and savings.

Implementing NDEX will not be an easy task. It will require substantial buy-in from all levels ranging from the planning yards to program managers to NDEX operators, and all the way to the ships the process supports. It will also require the organizations who deal with ship design applications to perhaps modify their modus operandi. Additionally, there may be cultural resistance from those who were doing the job the old way. They may feel that the current system is not broken and therefore should continue unaltered. Therefore, it is again recommended that existing paradigms be carefully considered and challenged in order to realize the potential benefits NDEX might provide.

Limitations do exist, however. First, the Invested Multipliers used to determine the added value NDEX provides to programs must be refined and verified by program experts. Prototyping utilization of NDEX will provide data related to existing programs that may be used to enhance the model provided. This may also require a survey and research beyond the scope of this project. Additionally, the Invested Multiplier concept can only be applied toward a tool or program that impacts other programs. Finally, the factors used for calculating the Invested Multiplier are subjective and hard to estimate. However, we do believe that when the tool investment is substantially less than the program investments affected, as in the case of NDEX, that reasonable notional benefits based on the tool investment and a reasonable approximation of factors which produce Invested Multipliers will provide a very good first approximation of the value of the tool which may be used for evaluating the tool's notional return on investment. The resulting notional return on investment may then be used in the decision process as one of many data points in a go/no-go decision to implement the tool.

Several benefits of this research have been realized. One benefit of the model is that the scale may be modified through the adjustment of the factors to value a tool like NDEX to one or many programs. The model is also adaptable as more data becomes available. This flexibility enables the model to be used for evaluating numerous investments. In addition, there is great utility in the concept of valuing a process such as NDEX based on its ability to improve the value a program or many programs may deliver to the end-user as it relates to the Work Breakdown Structure. This method puts notional benefits in a language common to the Department of Defense, and enables capture of both potential benefit of the new process or product and realized benefit based on current program capabilities to deliver value in the first place. The model ultimately measures NROI from the perspective of the stakeholder's improved capability of delivering end-user value.

Finally, the authors realize the value of a notional return on investment calculation should never be fully authoritative or prohibitive in making decisions. In the case of NDEX, it is important to realize that recent business trends internationally and in the public sector support the decision to implement, as does technological awareness which demands design process improvement. It appears obvious, based on our research of analogous projects and in our conversations with all parties, to implement design process improvement throughout the Department of the Navy. This is necessary for driving cost behavior and valuable to existing programs, and a return is virtually assured. Furthermore, as a first mover, SPAWAR could realize a significant return on its own investment in design process modernization if the friction encountered in modernizing can be overcome. Ultimately, implementation and the ability to reengineer current processes will be the key to NDEX's success or failure.

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