Optimized Manning Case Studies

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Key Findings	**Implications for Crew Reduction**
It is important to find **leverage points—** changes with high payoffs.	A combination of strategies is needed to identify leverage points. An understanding of current operations must be combined with a top-down analysis of function allocation that is not constrained by current operations.
Iteration is a constant theme of successful re-engineering efforts. New configurations of people and physical space, new procedures, and new technology cannot be expected to work perfectly the first time they are tested.	Schedules and budgets must accommodate iterative design, testing, and modification.
A **clearly stated goal** is needed to establish the rationale behind new procedures and new technologies.	If the primary goal is crew reduction, then all new technology must be evaluated against this goal.
Training is a key issue for crew reduction. In smaller crews, there is less opportunity for individuals to learn from more senior personnel on the job.	The Navy must find ways to train skills currently learned from on-the-job apprenticeship and mentoring.
Reduced crew size has implications across **multiple modes of operation**. It may not be possible to provide optimal staffing in all situations and modes of operation.	There is a tradeoff between costs and risks. Reduced crew size means that fewer people will be available to handle unusual situations. Analysis must be conducted for multiple possible scenarios and conditions, not just for the most likely scenarios.
Changes must take the larger **world context** into account. Many failures have been caused by designing equipment to operate in contexts that never materialized, or changed drastically after design.	Crew reductions must be based on an accurate forecast of future missions.

Managing the **implementation of changes** is critical. Failures during implementation lead to resentment and skepticism.	People at all levels of an organization must understand the changes that will affect them. Informal networks as well as formal organizational structures must be considered.
Across different types of organizations, the technologies that best support reductions in staffing levels fall into three categories: • Tools to build and maintain **situation awareness**. • Technology to support the use of **remote specialists**. • **Central monitoring** systems that allow fewer, centralized humans to monitor a larger area.	These three technology areas have the most potential to support crew reduction.
Across different types of organizations, certain **measures can provide design criteria** for optimized manning: • Ratio of decision makers to overall staff • Percent time spent on overhead and information management tasks • Concentration of expertise • Message tracing • Gridlocks on information flow • Ratio of handoffs to transactions • Ratio of information received to information sought • Value of message outputs for cells in organization • Degrees of separation between decision makers and raw data	Organizational design and team modeling efforts for optimized manning should use these measures to assess design success.

Table of Contents

Optimized Manning Case Studies

Executive Summary

This project is one component of the SC-21 Manning Affordability Initiative sponsored by the Office of Naval Research to develop a suite of methodologies and tools that will allow designers to anticipate the role of the human operator in platforms of the future. There are a number of issues under study within the program, including the application of new and developing technologies to traditional shipboard staffing and organization of work. Critical to the success of these design efforts is the ability of designers to identify leverage points or areas of potential change with high payoff, and to envision and implement an effective re-engineering strategy.

The goal of the case studies effort has been to examine previous re-engineering efforts and extract lessons learned and recommendations for the U.S. Navy in its efforts to design future ships to operate with dramatically fewer people. This has been accomplished via interviews using Cognitive Task Analysis (CTA) methods and a review of the literature. Approximately 20 case accounts were gathered from interviews with Subject Matter Experts[1] and from the existing literature.

This paper presents an important study of re-engineering. It goes beyond previous compilations of case studies in focus. Specifically, the cases investigated here involve organizations that have undergone dramatic personnel reduction and introduced new technology. Previous case studies have focused predominantly on proceduralized tasks. We have emphasized command and control settings and tasks that require considerable teamwork. Furthermore, our analysis includes an in-depth examination of what steps organizations have taken and steps that have been avoided. We have gone beyond recommendations that are little more than slogans found in similar efforts, to a level of specificity that provides a view of *how* previous efforts were accomplished.

Primary accomplishments include:

- two examples of highly successful manning reduction efforts,
- a set of leverage points that can be used to identify areas in which personnel reduction is likely to pay off,
- lessons learned from previous re-engineering efforts,
- guidelines and recommendations for achieving successful manning reduction, and
- a proposed set of tools that can help the design community achieve dramatic reductions in staffing.

[1]For purposes of this project, Subject Matter Expert was defined as someone who had first-hand knowledge of the re-engineering project.

Section 1: Introduction

This project is one component of the SC-21 Manning Affordability Initiative sponsored by the Office of Naval Research to develop a suite of methodologies and tools that will allow designers to anticipate the role of the human operator in platforms of the future. There are a number of issues under study within the program, including the application of new and developing technologies to traditional shipboard staffing and organization of work. Critical to the success of these design efforts is the ability of designers to identify leverage points or areas of potential change with high payoff, and to envision and implement an effective re-engineering strategy.

In previous work with individuals and teams, Cognitive Task Analysis (CTA) methods for extracting cognitive elements of expertise and skilled performance, based on real or simulated incidents, were developed (Calderwood, Crandall, & Klein, 1987; Hoffman, Crandall, & Shadbolt, 1998; Klein, 1998; Militello & Hutton, in press). In the hands of skilled CTA practitioners, case or incident-based methods provide access to a wide range of cognitive and perceptual events. One reason to ask people to describe real-world events is that the specific, detailed information gained from a single incident can be compared, contrasted, and catalogued across similar incidents to reveal critical themes and dimensions. Evidence accumulated over the specifics of incidents reveals themes and dimensions that never come to light when people talk in the abstract, or talk in generalities about “how to do the job.”

It seemed likely that an incident-based approach to personnel reduction would offer a view of major elements, interactions, opportunities, leverage points, hazards and contextual factors that was not available in general models of organizational change or high-level descriptions of “how to” or “how not to” downsize. By examining a range of examples of (reduction) downsizing within and beyond the Navy, we hoped to make available important lessons learned, that would provide guidance for Navy programs.

Furthermore, a subset of the cases examined focus specifically on command and control environments. Re-engineering of the Command Information Center (CIC) of a Navy ship is a particularly challenging issue given the cognitive complexity of individual roles, the information demands of the environment, and the high level of team coordination required. Most of the published case studies focus on procedural tasks. By focusing on command and control environments, our goal was to extract guidelines and recommendations that would be particularly relevant to the Navy.

This project has addressed the questions of how to affect change, how to monitor the impact of change and tweak a system over time, and how to re-engineer a system so that it best supports the overall mission and goals. Via a review of relevant literature and a series of interviews with people who have played an instrumental role in previous re-engineering efforts, we have gathered lessons learned from 20 different re-engineering efforts.

The objective of this effort was to compile and analyze a set of case studies that involve re-engineering and personnel reduction. We identified and documented:

- two examples of highly successful manning reduction efforts,
- a set of leverage points that can be used to identify areas in which personnel reduction is likely to pay off,
- lessons learned from previous re-engineering efforts,
- guidelines and recommendations for achieving successful manning reduction,
- a proposed set of tools that can help the design community achieve dramatic reductions in staffing.

The body of this report describes methods as well as findings that are particularly relevant for the Navy Affordability effort. This report is organized into eight sections. Following this *Introduction* is the *Section 2: Methods* section describing the methods used to select cases for study and the means by which the cases were gathered. *Section 3: Cases* contains a brief description of the all the cases studied in this effort. *Section 4: What Does Successful Re-engineering Look Like?* present examples of two highly successful re-engineering efforts. *Section 5: Re-engineering Process* examines the stages of re-engineering and provides and in-depth discussion of leverage points that can be used to identify areas for potential change with high payoff. *Section 6: Lessons Learned* contains a summary of the important lessons learned from previous re-engineering efforts that have relevance for the Navy Affordability project. *Section 7: Recommendations*, summarizes our recommendations for the Navy in building ships to operate with dramatically fewer people. Finally, *Section 8: Conclusions* sums up the major accomplishments and conclusions of this project.

Section 2: Methods

The case study research team collected a case base of approximately 20 case accounts from interviews with Subject Matter Experts[2] and from the existing literature. Due to the diversity of the data collected, we started with a broad approach to the case studies and eventually narrowed down to a few in-depth case studies.

A literature search was conducted to extract what information exists pertaining to personnel reduction, re-engineering, reductions in force, redesign, etc. Psychology and business abstracts were reviewed. We selected approximately 32 articles to read (a full bibliography is included in Appendix A). Some articles contained case studies, while others contained general outlines of downsizing lessons learned. The articles and case studies were comprised of various aspects of human factors and operations research in both the commercial and military worlds. Several of the articles included incident accounts from companies going through a restructuring process.

Early in the project, the case study research team contacted representatives in potential domains in order to collect initial information and gain an understanding of the manning reduction used within these organizations. Based on these preliminary interviews with participants in previous re-engineering efforts, a set of criteria was developed to bound the project.

Selection Criteria

The first criterion concerned the **goal of the reduction effort**. We were particularly interested in cases where the goal of reduction was to gain greater efficiency. Many personnel reduction efforts have occurred because of financial crises and budget cuts. We talked to representatives from companies where this was the case and realized this type of input would be less useful as the re-organizations tended to consist of large-scale reductions with little strategy or planning behind them. We also ruled out companies that were going through a redesign effort but not necessarily downsizing.

The second criteria was **dramatic reduction**. Personnel reduction involving a dramatic reduction and realignment of functions across the remaining work force seemed the most likely to be relevant to the Navy because an actual re-engineering of functions occurs. We were interested in cases where there was a frame-breaking change. Of less interest were reductions that involved cutting a few people from each of a number of departments with the idea that remaining workers would absorb the extra work.

The third criterion addressed **new technologies**. Reductions that involved the introduction of new technologies or redistribution of functions across the human-technology span were of particular relevance. We were interested in unintended consequences of these new technologies, both positive and negative.

[2] For purposes of this project, Subject Matter Expert was defined as someone who had first-hand knowledge of the re-engineering project.

For those cases we planned to learn about via interviews, availability of participants who had been involved in the re-engineering process was an important criteria. Our plan was to focus on **key decision makers** in the personnel reduction effort.

The last two criteria were not strictly upheld across all cases included in this report. However, we attempted to identify as many cases as possible that included a **CIC-type environment**, such as a command post, a control room, or a management team. These settings include functions such as planning, decision making, and command and control. We also focused on domains that have a **team focus** rather than a modular work setting. We were less interested in mechanistic repetitive settings such as an assembly line, than in domains with more complex tasks and interactions, and more cognitive elements.

<u>Cases Studied</u>

A list of each of the cases investigated and the source of information is included in Table 1. The cases are grouped by domain.

Table 1: Cases Investigated

<u>Navies</u>	
FFG7 and LHA	An interview was conducted with a representative from NAVSEA who had recently completed a study of the design, development, and use of the FFG7 and the LHA.
USS Princeton	An interview was conducted with Ted Hontz, previous captain of the Princeton. An article describing the incident in which the Princeton struck a mine was also reviewed (Gregory, 1998).
USS Samuel B. Roberts	An interview was conducted with Paul Rinn, previous captain of the Samuel B. Roberts. An article describing the incident in which the Samuel B. Roberts struck a mine was also reviewed (Mussi, 1988).
USS Yorktown	USS Yorktown. Interviews were conducted with five representatives from NAVSEA who participated in the Smart Ship project from Washington DC. We also toured the Yorktown and interviewed ten people who served on the Yorktown during the Smart Ship project including the captain of the ship, the Training Officer, the Combat Systems Officer, the Assistant Training Officer, the Main Propulsion Assistant and the Chief Engineering Assistant, the Engineering Training Officer, a Gas Turbine System Mechanic Chief, a Sonar Supervisor, and a Gas Turbine Systems Technician. We also reviewed several reports and articles describing the Smart Ship project including the Smart Ship Report containing a summary of the review conducted by Navy Manpower Authority (NAVMAC) and Operation Test and Evaluation (OPTEVFOR) on file at the Smart Ship Office.

USS Rushmore	We toured the Rushmore and interviewed four of the key players involved in transitioning the Rushmore to a Smart Ship including the System Administrator for the new computer systems, the Training Officer, the LCPO of machinery division, and the Smart Ship Publicity Officer.
British Royal Navy	An interview was conducted with an officer of the British Royal Navy concerning lessons learned from efforts to reduce personnel and operate ships more efficiently by Britain.
United States Marine Corps (USMC)	
USMC Regimental Command Post	Interviews were conducted with a team of researchers who studied the Regimental Command Post to make recommendations for re-engineering. A follow-up interview was conducted with the commander of the regiment to find out which recommendations had been implemented and whether the re-engineering had been successful.
USMC Marine Air Ground Task Force	An interview was conducted with researchers who observed exercises, interviewed participants, and made recommendations for streamlining and improving the command and control structure.
Nuclear Power Industry	
Nuclear Power Plant in Southeast US	Interviews were conducted with the station manager, the site vice president, and the head of the human resources department at a nuclear power plant in the Southeast U.S. about ongoing downsizing efforts for the plant as a whole.
Technical Support Center I	An interview was conducted with researchers who studied the Technical Support Center at the Southeastern U.S. nuclear power plant to make recommendations for re-engineering (Klinger & Klein, in press).
Technical Support Center II	An interview was conducted with researchers who studied the Technical Support Center at a Midwestern nuclear power plant and made recommendations for re-engineering.
Petrochemical Industry	
Beville Engineering	Two interviews were conducted with human factors engineers from Beville Engineering. Two separate cases were explored in which they conducted studies and made recommendations for re-engineering efforts in the petrochemical industry. In addition, a report documenting their work in one of the two cases was reviewed.

Automobile Industry	
General Motors	An interview with a former General Motors (GM) employee and a written report describing the major reorganizations at GM over the last 15 years (Debbink, 1996) were used to gather information about re-engineering in the automobile industry.
Health Care Industry	
The Health Care Advisory Board	An interview was conducted with two representatives from the Health Care Advisory Board, a company that publishes lessons learned from reorganization efforts and new technologies in the health care sector. One of their publications was reviewed (Health Care Advisory Board, 1992).
Telemedicine	To investigate the success of recent telemedicine efforts, interviews were conducted with Dr. Clement McDonald of the Regenstrief Institute and with Dr. Frederick Pearce of the University of Alaska. In addition, correspondence with Kimberly Lain about telemedicine projects in Arizona and Colorado was conducted (Lain, 1998).
Leicester General Hospital	An article describing a case study of a reorganization effort of a British Hospital System was reviewed (Buchanan, 1997)
Communications Industry	
Bell Atlantic	A published case study of re-engineering at Bell Atlantic (Hammer & Champy, 1993) was reviewed.

Interview Methods

Interviews were tailored in each domain depending upon the role each interviewee played in the re-engineering effort, his/her experience with the organization prior to re-engineering, and the current stage of the re-engineering project. However, whenever possible, each of the following topics were addressed in each interview: the motivation for the re-engineering effort, the leverage points used to determine where to reduce the number of people or introduce technology, the strategies used to re-engineer, the lessons learned from the implementation, measures of success, the role each interview played in the past, and the interviewee’s current role. Interviews lasted from 30 minutes to two hours, depending upon the availability of participants.

Section 3: Cases

This section of the report contains a brief summary of each of the cases studied over the course of the project. No attempt was made to study each case in equal depth. Those that were most relevant to the Navy's Affordability project are considered in more detail and more context is provided. Each case is listed here with a short description of the most interesting findings from each. Cases are organized according to domain. More general findings gleaned from analyses across cases are included in subsequent sections.

Navies

An interview was conducted with a representative from NAVSEA who had recently conducted a study of the FFG7 (Fast Frigate). This ship was designed based on WWII scenarios where frigates were used only for short missions, so all maintenance could be done ashore. However, the FFG7 was built post World War II, and the scenario upon which its design was based no longer occurs. The FFG7 has always been used for missions that are long enough to require maintenance. As a result the FFG7 consistently operates with more personnel than it was designed for in order to accommodate the people needed to handle maintenance. The designers of the FFG7 failed to take into account the current state of the world and the types of missions for which the FFG7 would likely be used. Thus the ship has always operated in an overcrowded state because of a design based on the past rather than the future.

In the same interview, we learned about the evolution of the LHA, a large deck, amphibious ship. This ship was designed specifically to reduce manning by introducing an automated boiler control system. The goal was to have unmanned engine spaces that could be monitored from a central location. This design had received a lot of publicity and several dignitaries had arranged to participate in the sea trial. Unfortunately at the time of the sea trial, the shipbuilders had not worked out all the of the bugs in the software. The ship was dead in the water with all the dignitaries aboard. Even though the contractors were able to fix the software soon thereafter, the concept of operating with unmanned engine spaces was viewed as a failure and policy was set that the engine spaces would be manned. This case illustrates the common mistake of believing that the first-fielded version of a system is the only version. It is critical in both re-engineering efforts and in the design of entirely new systems, that a period of test and evaluation is planned so that the system may be revised and adjusted to accommodate unexpected environmental factors and unanticipated difficulties in implementation. It is impossible to anticipate every important eventuality <u>before</u> implementation.

In order to understand the types of severe challenges Navy ships have faced in the past and will likely face in the future, interviews were conducted with Ted Hontz, previous captain of the USS Princeton, and Paul Rinn, previous captain of the USS Samuel B. Roberts. Both interviews provided compelling examples of the likelihood of multiple problems occurring at once (e.g., fire, flooding, weapons systems down, injured personnel, damaged helicopter), as a result of striking a mine. Although less-serious damage control situations may be handled with a limited number of people interacting with computerized damage control monitoring systems and sensors, in the event of a serious damage control situation, it is important to consider the number of people needed to address multiple problems occurring at once.

The Smart Ship project was considered an important case for examination because it represents a major redesign and personnel reduction demonstration by the Navy. The Smart Ship project was commissioned by the Chief of Naval Operations, Admiral Boorda, after a briefing by the Naval Research and Analysis Center indicated that technology was available that could be used to reduce the crew size needed to run warships. Furthermore the briefing indicated that the biggest barriers to reducing crew size on ships were culture and tradition. Admiral Boorda directed that the technology be found, a test ship be identified, and a ship run with dramatically fewer people be created. The Commander of the Naval Surface Fleet Atlantic, Vice Admiral Katz, was given permission to challenge Navy policy, doctrine, or rules that might impede improved efficiency. The challenge given was that if everything tried on the Smart Ship project worked, the project was not going far enough.

The USS Yorktown is a Ticonderoga (AEGIS) class cruiser that served as the first Smart Ship. Before introducing new technologies, the captain of the Yorktown, CDR Rushton, implemented a policy in which every person on the ship was instructed to think about ways to work smarter and more efficiently. This was a clear deviation from Navy culture. Suggestions by everyone on the ship were reviewed and many implemented to evaluate the impact of the suggested change. Even before new technology was introduced to the Yorktown, the three section watchbill was reduced from 69 to 27 people, a reduction of 61%. New technologies allowed for further reductions and better quality of life for the sailors. Because of the overwhelming success of this project, it is discussed in greater detail in Section 4.

The USS Rushmore was identified to be the second Smart Ship to determine which of the new policies and technologies implemented on the Yorktown were transferable to a larger vessel. The Rushmore is a Dock Landing Ship (LSD) that typically carries 340 people in the ship's company and an additional 450 troops. Interviews were conducted before the Rushmore had an opportunity to deploy as a Smart Ship. Although many of the changes had been implemented and tested in drills, the sailors interviewed indicated an eagerness to see whether the changes would be sustainable in a real-world setting. The timing of our interview on the Rushmore allowed us to gather lessons learned about the implementation phase of a re-engineering effort. The personnel on the Rushmore were in the throes of change. They were dealing with new policies, new technologies, the need for additional training, and changes in Navy culture. Although the end of the Yorktown story was clearly a success, our interviews with personnel on the Rushmore provide a clearer picture of the pitfalls to be avoided in implementing large-scale change.

Interviewees emphasized the importance of managing the re-organization process. At times it was unclear which changes would be implemented when, which led to disruptions in work and frustration on the part of the crew. Furthermore, a sense of disorganization during the implementation can lead to skepticism and resistance to the re-organization itself. Interviewees on the Rushmore also pointed out the importance of creating means for user input to new technologies. One interviewee spent his own time researching network systems so that he would be better able to communicate with and advise contractors. Another interviewee actually designed screenfaces at the contractor facility. In this case it seems that the need for user input was underestimated until the implementation phase. It was only when these systems began to appear on the ship and crew members stepped forward with concerns about safety that user input was incorporated into the design.

An additional case that falls into the Navies category was gathered via an interview conducted with an officer of the British Royal Navy. While the U.S. Navy is currently experiencing pressures to reduce costs, particularly in the form of personnel reduction, many of the European Navies faced similar economic drivers as far back as the late 1940s. The officer described several strategies the Royal Navy has used to reduce the number of people needed to run ships. One strategy to reduce training costs has been to require more specialization for officers. There are three branches in the Royal Navy: weapons engineering, marine engineering, and the executive branch. An officer chooses a branch upon entering the Royal Navy and gains expertise within that branch throughout his/her career. This is quite different from the U.S. Navy in which one may have a position in weapons, followed by engineering, and later command a ship. By focusing on one branch, each position a Royal Navy officer fills builds directly on his/her previous position, leveraging previous experiences.

On the other hand, the Royal Navy encourages more generalized skills for enlisted personnel. Rather than having specialized operators and specialized technicians, the Royal Navy crosstrains personnel so that operators may also maintain their own equipment. Furthermore, the Royal Navy has begun to investigate whether it is possible to have one electronics specialist who has multiple tasks including sonar and radar.

A third strategy the Royal Navy has used to reduce personnel is to employ contract cleaners and painters. Although ship staff are still needed to supervise, most of the work is contracted out. Other functions such as laundry, tailor, and cobbler service have been accomplished by contractors in the past with considerable success.

United States Marine Corps (USMC)

In 1995, a team of researchers was asked to observe exercises involving the USMC Regimental Combat Operations Center and to conduct interviews with key personnel to make recommendations that would help the team operate more smoothly (Klein, Schmitt, McCloskey, Heaton, Klinger, & Wolf (1996). Incidents were gathered that illustrated key decisions and different types of uncertainty. Based on analyses of these data, the researchers made several recommendations. One of these recommendations was to sharply reduce the number of people in the Regimental Combat Operations Center. Because there were too many people, the command post was unnecessarily congested and the staff needed to make many unnecessary handoffs of messages. If the staff size was reduced, the size of the Combat Operations Center could also be reduced, making it more mobile. This, in turn, could increase security because the Combat Operations Center could be moved more frequently. One suggested approach to cutting staff size was to encourage the decision makers to engage in more direct communications with decision makers in other command posts, rather than passing messages through intermediaries. This would allow better communications and would also permit the regiment to reduce the number of radio operators. Other recommendations included a redesign of the workspace so that the different maps could be compared more readily (which would increase shared situation awareness).

In 1998, follow-up interviews were conducted with the commander of the regiment to find out whether our recommendations had been put in place, and how the Regimental Combat Operations Center had fared under the reorganization. Dramatic reductions had in fact been made, reducing the number of people from 50 to 24. Recommendations made by the research team had been adapted, incorporating the perspective of the current commander. The commander reported that the reduced number of people did, in fact, result in more smoother operations and increased mobility. A reduction in the number of intervening radio operators allowed decision makers to get more accurate information and actually hear the inflection and level of certainty (or uncertainty) in the deliverer’s voice. The use of centralized maps to improve shared situation awareness was eagerly embraced by personnel in the Regimental Command Operations Center.

A second case involving the USMC involves the Marine Air Ground Task Force (MAGTF). The USMC has established a program called Sea Dragon aimed at improving the command and control function by pulling distributed command centers back into one centralized command center. The centralized command operations center has been restructured with regard to individual billets and their associated tasks, and has capitalized on advanced technologies to support operations. The approach used in this multi-phase effort has been to schedule a series of both high- and low-fidelity exercises to test different organizational schemes and technologies.

A team of researchers has participated in this effort as observers of the exercises, identifying leverage points for change and making recommendations for more efficient operations (McCloskey, Pliske, Klein, Heaton, & Knight, 1997). Recommendations were then further refined and adapted by USMC personnel and tested in the next exercise.

For example, in initial exercises, MAGTF included a cell for future operations made up of planners, and a cell for current operations made up of implementers. The researchers noted the discontinuity between these two cells as plans were thrown over the wall from the future operations cell to the current operations cell. This created unnecessary confusion and duplication of effort. A recommendation was made to create a Mission Manager who would take responsibility for a mission from its planning through the close of its execution. The USMC decided to expand this recommendation to implement a Mission Team, a group of people who would follow the plan from one cell to the next. After trying this in an exercise, the Mission Team was abandoned and replaced by an even better solution. The principles (heads of major cells and key staff members of the battalion and the MAGTF) now do high level planning, which is then fleshed out by more junior personnel. The principles are then involved in the implementation of the plan, where again they provide high level guidance and are supported by more junior personnel.

This iterative approach to re-engineering has several benefits as illustrated here, on the USS Yorktown, and in the Atlantic Bell example described later in this section. The iterative approach is more realistic in that it does not assume an initial design will work the first time it is introduced. It allows for experimentation and revision before an organization-wide change is introduced.

Nuclear Power Industry

In anticipation of deregulation, a nuclear power plant in the Southeast United States has been looking for ways to downsize and run more efficiently for approximately 10 years. The organization recognized that it had simply grown too large and was populated predominantly with employees who had worked in the nuclear power industry for 20+ years. The threat of impending deregulation made the board begin to look for ways to operate more efficiently and the demographics of the workforce began to raise worries about the loss of skills and corporate knowledge as the current employees began to approach retirement age. Researchers interviewed three key decision makers in the ongoing re-engineering effort at the plant.

In 1991, the plant had 2200 employees; there are 1250 employees now. Several downsizing strategies have been used including early retirement packages, the use of on-call consultants rather than employee specialists, restructuring to more decentralized control, and laying off those with the least seniority during low-workload periods. The company is still making efforts to downsize and run more efficiently. No end state was articulated, so it is difficult to know when they will have achieved its goal. One drawback of this multi-year, we'll-know-when-we-get-there strategy is that employee morale, motivation, and loyalty to the organization has greatly decreased. Employees do not understand the rationale behind the continuing changes, and live with a constant level of anxiety about their own job security. The result has been the loss of valuable, highly productive, experienced employees who prefer to work in a more secure work environment.

A separate case focuses on the Technical Support Center at this same Southeastern nuclear power plant. A team of consultants were asked to make recommendations for improving the effectiveness of the Technical Support Center, a key player in the Emergency Response Team which is activated during a nuclear crisis (Klinger & Klein, in press). The team had been struggling during Nuclear Regulatory Commission exercises and, as a result, the power plant had been charged hefty fines. Observations and interviews with personnel to determine who were the key decision makers and what was needed to support them resulted in a reduction from 80 people to 35 people. Subsequent evaluations by the Nuclear Regulatory Commission were positive. Because this case provides such a powerful example of successful re-engineering, it is discussed in more depth in the Section 3 of this report.

Another case focuses on a large Midwestern nuclear power plant that provides power for parts of three states. A team of researchers worked with the Technical Support Center (one division of the Emergency Response Team) of this plant to determine means by which to operate more effectively in crisis situations. In this case recommendations were made to add staff to increase the emergency coordinator's efficiency. In contrast to the Southeastern plant which started with 80 people in the Technical Support Center, the Midwestern plant (a much larger plant) started with 48 people in the Technical Support Center. Computer operations people were added to provide accurate information more quickly to the Emergency Response team. Maintenance workers were also added to ensure that the computers were working, the status board was updated, and to deal with equipment failures. The solution here was to increase the number of people in the Technical Support Center in order to operate more efficiently. An interesting point to note here is that although these changes were quite successful in the Technical Support Center, when management implemented the same changes in a different department (the Emergency Operations Facility), the very same recommendations were a failure. The problem was that the two organizations have very different functions and goals. No one had taken that into account in trying to transition the recommendations wholesale from one organization to another.

Petrochemical Industry

Beville Engineering is a human factors engineering firm located in Dayton, Ohio that works exclusively in the petrochemical industry. Approximately 1/3 of their business involves analysis and recommendations for improving personnel utilization. Over the past decade, they have performed over 80 projects of this type. Approximately 50 of these have involved analysis of maintenance and external plant operations and another 30 have focused on control room operations. They have developed methods for assessing staffing needs, efficiencies and redundancies, along with metrics and qualitative indices that provide a basis for evaluation. They also have developed techniques, in particular the use of scenarios, to help their clients consider (envision) a range of potential staff reduction organizational changes designed to increase operational efficiency. Beville has developed a large database of tasks, functions, and staffing levels that provide normative standards for staffing and personnel utilization within this industry.

Researchers conducted interviews with two Beville engineers. Both are long-term employees of Beville and highly experienced in this aspect of their work. The interviews covered a wide range of topics related to their work in the petrochemical industry, and included specific examples. One example was an oil refinery that had been downrated in a key industry-based publication because of overstaffing. Staffing levels are monitored by industry watchdogs and used as an index of financial health and efficient operation of individual companies. To be downrated had financial and investment consequences for the organization and they were highly motivated to reduce staffing and recover their previous high rating. Based on an extensive analysis of workload, risk associated with decreased staffing for various functions, and operational/infrastructure constraints, Beville presented the plant with several options. The most dramatic staffing reduction recommendations involved cutting 52 staff positions, based on parallel improvements in control room interfaces, alarm systems, and consolidation of maintenance and inspection functions, an overall decrease of 30%.

The interviews with Beville personnel offered several important insights. First, they offered an approach for analyzing staffing needs under differing contexts or conditions – in this case, “steady state” and “upset” conditions within a plant. Second, Beville personnel underscore the importance of clear goals: the staffing levels and organizational redesign options they offer may differ depending on what management is attempting to achieve. They reported to us that a major part of their work with organizations often involves working with plant management to help them nail down what it is they are trying to accomplish (e.g., greater efficiency vs. increased safety vs. greater profit). Third, their work indicates the usefulness of scenarios and simulations for analyzing multiple influences, and the interplay of complex factors and dependencies. Scenarios allow Beville to present options in context, and to expose Management to various impacts (positive and negative) of staffing changes under various conditions (e.g. steady state vs. upset; with and without major changes in automation) as well as different ways to achieve the same set of goals. Third, they alerted us to the subtlety of many of the judgments and assessments involved in assessing staffing needs, and analyzing tasks and functions. Beville personnel typically build a profile of each operator’s task and the overall plant function. But they note there is no set, or “correct,” way to build these profiles. One can cut through the data many different ways. Finally, they echoed our own belief that it’s important to assess the value of the activity, but also to assess the value to the organization of having a person available to do that activity, and to perform multiple tasks. At least within the range of technologies available in the petrochemical industry, automation rarely has the ability to function with the same degree of flexibility that one gains with a human operator. Their data suggest that the assumption that automation is always cheaper is not well-founded, and that it is often difficult for plant managers to grasp what they give up as well as what they gain when they automate.

Automobile Industry

GM is an important case to study in part because it is a large, bureaucratic organization with a strong tradition of success, much like the U.S. Navy. It is important to try to understand the difficulties GM has faced over the last several decades in their attempts to re-engineer. Our analysis is based on Debbink’s (1996) write-up and interviews with a former GM employee.

From after World War II until the early 1970s, General Motors was the undisputed leader in the automobile industry. GM made the rules and set the prices. During this period of steady market growth, Americans wanted ever-larger, more powerful cars. GM was certain there was no money to be made in smaller cars. In the early 1970s, this started to change. People were more concerned about gas mileage, the environment, and safety. The energy crisis and increasing federal safety and emissions regulations made GM cars less appealing to the American public. Meanwhile the culture within GM was very risk averse. Success was defined as supporting one’s boss and not bringing up any problems. GM was completely out of touch with the consumer. This lack of consideration of the changing world and the needs of users (consumers) resulted in significant losses for GM.

It was not until 1980 that GM started to take the changes going on in the world seriously. In 1980, GM introduced smaller, more efficient front-wheel drive cars. However, the existing manufacturing structure was set up so that one group built all the chassis, engines, and transmissions while another group built bodies. To create a dramatically new design required change across the entire organization.

To make the production of newer designs more efficient, GM implemented a major re-organization. Two major groups were created: one to build larger cars (Buick, Olds, and Cadillac) and one to focus on smaller midsize vehicles (Chevrolet, Pontiac, and GM of Canada). Although this seemed like a reasonable solution to the problem, the reorganization was a failure. The GM bureaucracy was impenetrable. The only managers who could get things done were the ones who knew how to circumvent the system. The reorganization made it impossible for these managers to use their informal networks to get things done. The organization got completely reshuffled and no one knew who to contact to get things done. GM was paralyzed for 18 months while people rebuilt information networks.

In 1991, a second massive re-engineering effort took place. Decision making was centralized by creating a 14-person strategy board to make all important decisions. Cultural changes were introduced, including a move away from the old risk-averse, good-news culture. Benchmarking was promoted as a process to compare GM's products and costs with other manufacturers to identify places for improvement. Purchasing functions were centralized in order to leverage GM's volume with its suppliers. In order to simplify confused and overlapping product lines, the number of vehicle platforms was reduced from twelve to five.

In spite of more than a decade of organizational change and two massive reorganization efforts, GM continues to be the high-cost producer in the industry. They still suffer costly delays in launching new cars because of manufacturing and quality problems. This is in part due to GM's late realization that user input is important. Other factors that contribute to GM's troubles include a failure to recognize the importance of informal networks in the 1980s re-organization, a culture that discouraged risk-taking or even recognition of the changing conditions of the world, and simply waiting too long to introduce much needed changes to improve efficiency.

Health Care Industry

The Health Care Advisory Board is a membership-based research organization that conducts efficiency studies of hospitals and other health care organizations and publishes lessons-learned reports for member organizations. Researchers interviewed two representatives from the Health Care Advisory Board and studied a report published by the organization (Health Care Advisory Board, 1992). The Health Care Advisory Board's strategy is to study health care organizations that have introduced new technologies or implemented new procedures that dramatically change the way in which work is accomplished, and to publish lessons learned and recommendations for other health care organizations.

Of the successful strategies for increasing efficiency reviewed by the Health Care Advisory Board, the concept of crosstraining “generalists” seems particularly relevant for the Navy. Most hospitals employ “specialists” dispatched from central ancillary departments to perform bedside services such as phlebotomy, IV therapy, respiratory therapy, and physical therapy. The use of specialists creates a need for significant scheduling of care and additional time must be spend documenting care delivery because so many people are involved in the care of a single patient. A growing number of hospitals are crosstraining caregivers in these “bedside” ancillaries. By having one caregiver who spends more time with the patient, the need for coordination between ancillary departments is reduced. A similar strategy of crosstraining technical specialists on a Navy ship is being used by the British Royal Navy (i.e., one electronics specialist who maintains both radar and sonar equipment). This strategy may be useful for the U.S. Navy in that it may allow for fewer technicians and more efficient equipment maintenance as each technician would have a better sense of the big picture.

Other relevant strategies reviewed by the Health Care Advisory Board focus on moving resources and technology closer to the people who use them. For example, in a hospital setting, obtaining simple x-rays is an enormous undertaking. Dozens of people are involved in coordinating a long, drawn-out process of transporting the patient from his/her room to a centralized radiology department where specialists take x-rays. In an attempt to simplify this process, a handful of hospitals have built radiology suites on nursing units. These radiology suites handle simple diagnostic x-rays that can be performed by crosstrained nurses on the unit or a dedicated radiology technician. Physicians have almost instant access to the film. Patients are sent to the central radiology department for only the most complex procedures (e.g., CT scan, MRI).

This example illustrates how technology can create a legacy system. In the early days of x-ray technology, the expense of the x-ray machine required a centralized machine to which everyone would be transported to use. This set up continued long after the original need disappeared. Even though portable x-ray machines have been available and economical for several years, it is only recently that hospitals have begun to restructure operations to decentralize the x-ray function.

Another example of moving resources closer to those who need them is the use of “automated teller machines” to dispense commonly used drugs and supplies on nursing units. These systems are intended to eliminate nurse time spent tracking down drugs and supplies, and to eliminate time spent documenting drug and supply use. A nurse uses a menu-driven screen to select an appropriate medication or supply. The machine automatically dispenses the item, documents each transaction, and captures the charges for patient billing.

Other lessons learned in the health care industry can be taken from telemedicine projects. Telemedicine is the use of medical information exchanged from one site to another via electronic communications for the health and education of the patient or health care provider, and for the purpose of improving patient care. Interviews with Dr. Clement McDonald of the Regenstrief Institute and with Dr. Frederick Pearce of the University of Alaska, as well as correspondence with Kimberly Lain, allowed us to explore the lessons learned from recent telemedicine efforts. Telemedicine efforts have been extremely successful in terms of saving health care dollars, reducing transportation costs, and improving patient access to quality care. The change in culture required for such systems to work, more so than the development of technology, has been the primary challenge faced by proponents of telemedicine.

A third source of lessons learned in the health care industry is an article documenting efforts to re-organize the operating theaters of Leicester General Hospital in Leicester, England (Buchanan, 1997). The article describes a twelve-month effort in which the steering committee struggled to determine whether a problem actually existed and, if so, what the nature of the problem actually was. Efforts were made to map the current path a patient follows from reception to surgery to recovery to discharge. Although the hospital used a computer system which was supposed to be used to capture information such as the time spent in each part of the process and any delays or disruptions along with their causes, the system was believed to be inaccurate. Via a series of interviews and questionnaires, the committee determined that there were so many exceptions to the typical patient path, that no typical patient path existed.

This is a striking example of an organization's failure to understand its own existing processes. In many cases, different sections of an organization create a simplified version of reality. These myths about how operations actually occur can be very robust and resistant to reality. In this case, the hospital was eventually closed.

Communications Industry

A case taken from the literature is a study of the re-engineering efforts at Bell Atlantic (Hammers & Champy, 1993). Before re-engineering efforts, Bell Atlantic had a hierarchical structure of management. Employees performed single functions without knowledge of the entire system. Many did not know what happened to their work once it was passed off. Bell Atlantic determined that a change in culture was needed in order for the company to continue to be competitive. The goal was to give employees a better sense of what the corporation was trying to achieve and how to achieve it. In addition to cultural change, Atlantic Bell wanted to implement organizational changes. In order to accomplish widespread organizational change, two re-engineering teams were created. One would come up with the ideas; the other would test and refine these ideas in the real world, but only in an isolated division of the company. Thus, the re-engineering process was iterative. Nothing was introduced company-wide until it had been tested in a real-world setting by a division within the company. As a result of re-engineering efforts they were able to improve their service and save money.

Section 4: What Does Successful Re-engineering Look Like?

Hammer and Champy (1993) estimated that between 50 and 70 percent of organizations that re-engineer do not achieve breakthrough performance. Most people in the U.S. have some experience with failed or less-than-successful re-engineering efforts resulting in bitter employees and fractured companies, as friends, family members, or neighbors have been downsized. One reason for the many examples of failed re-engineering efforts is that it is so difficult to define success. In some cases success may simply be staying financially viable for another few years. In other cases, the successful introduction of technology which allows for fewer human operators may be the criteria for success. Success can be measured by the downsizing rate, the financial benefit of the re-engineering effort, improvements (or at least lack of decrement) in efficiency and quality, etc. However, none of these elements are easily measured as the organization continues to operate and exist in a changing world. Although an organization may make gains on one or two measures of success, in many cases the tradeoffs on other measures are costly.

In the cases studied as part of this project, two stand out as powerful examples of successful re-engineering. In both cases, careful analysis of the existing organization indicated that reducing the number of people would actually result in smoother, more effective teams. Recommendations were evaluated in near real-world conditions and solutions adapted based on information gathered in the evaluation. Interview data gathered after re-engineering in each case indicates the organizations are running as well or better, with fewer people. One example, the transformation of the USS Yorktown into a Smart Ship, was carried out within the U.S. Navy. The second example, the re-engineering of a Technical Support Center at a nuclear power plant, comes from the commercial sector. Each of these examples is described in detail below.

USS Yorktown: The First Smart Ship

The first example we will consider is the USS Yorktown, the first ship to be outfitted as a Smart Ship. As indicated in the *Cases Section*, the direction to create a Smart Ship came from the CNO at the time, Admiral Boorda. Driving this direction was the continuing need to cut costs in the military, combined with findings from an NRACS report indicating that the barriers to reducing personnel on Navy ships stemmed from culture and tradition rather than limitations in technology. From the NRACS briefing in October 1995 to end of June 1997 when the Yorktown had completed its first five-month deployment in the Caribbean and a one-month carrier operation with the USS George Washington battle group, tremendous change occurred about the Yorktown.

Change At All Levels. One of the most striking things about the re-engineering effort on the Yorktown was that changes were made at all levels of the organization. For example, a typical AEGIS cruiser has 15-20 people on the Bridge at any time other than when the ship is in port. These people are responsible for navigating, watchstanding, charting, and communicating with other parts of the ship. During normal operations, the Yorktown Bridge is now staffed by *two* people. This reduction was accomplished in part by the introduction of new technology. However, the bulk of the changes on the bridge were accomplished by looking at how important each person was to the basic goal of "driving the ship safely." Based on that evaluation, changes were made to the number of watchstanders, how charting was done, and how communication with the rest of the ship happened, *before* the new technology was implemented.

Other, more mundane but equally important aspects of running a ship were also subject to scrutiny. We had an opportunity to meet the Chief Petty Officer in charge of supply. He told us there are traditionally five to six servers in the Officers mess, who serve each person individually. They tried serving meals buffet style, but found it too disruptive to have people moving up and down so much in a small space. Their current system is to serve meals family style, with two servers at each meal. Laundry is another area that has been greatly streamlined on the Yorktown. One crew member told us the standard procedure for laundry was that each person would make out an inventory of his/her dirty clothes, seal them in a mesh bag, and send them to the laundry service. The people in the laundry service would take everything out of the bag, check each item in the inventory, reseal the mesh bag, and wash it. The inventory system has been eliminated. Each person seals his/her own clothes in a mesh bag. The laundry workers, wash the bag of clothes intact, and other than a few stray socks, nothing ever gets lost.

More sweeping changes came in the form of reducing the number of instructions. There are four official documents every ship uses: Standard Operating Regulation Manual from the CNO, Combat Systems Doctrine from SURFLANT, Engineering Operations from SURFLANT, and Repair Party (includes damage control) which is ship specific. Generally, on a ship, many of the procedures in these documents are tailored or adapted in the form of Instructions for that specific ship. Often a ship will have more than 100 of these Instructions. Personnel are required to track, update, and document changes in Instructions. The captain of the Yorktown canceled all Instructions except to follow the procedures contained in the four documents listed above. If it became important to adapt something in one of those documents, it was noted on blue paper which was pasted into the original document. This greatly reduced the administrative load on the ship and the constant confusion over which was the most recent instruction.

<u>Work Smarter, Not Harder</u>. Although the order from Admiral Boorda was to create a ship that could run with greatly reduced manning, the Smart Ship office in Washington DC translated that to reducing workload on the ship. This framing of the Smart Ship effort around the concept of reduced workload and "work smarter, not harder" was a major driver for the ship's crew. There are myriad changes that they described in how work and work teams are organized, scheduled, and carried out, and the upshot has been that they have more regular and predictable schedules, they are not expected to multi-task when it can be easily avoided (e.g., stand watch and do maintenance) and they get more sleep, are better rested, and believe they are doing as good or better quality work as they were before.

It was in the context of decreasing workload and improving quality of life for the ships' crew that massive changes in technology were introduced. The Smart Ship program got underway in December 1995 and CDR Rushton began asking for input from the crew and making organizational changes immediately. For example, engineering dropped its shifts from 11 people to 7, before any changes in technology were introduced (once the new systems were in place, they reduced from 7 to 4). In this context, the technology was viewed as one more support to making the ship work smarter, not harder. We have heard of so many examples of technology shoved down the pipeline, inserted as The Fix into an ongoing system. Here, the hardware/software were part of a more-overall set of changes to meet the goal of reduced workload.

<u>Technology: What Did It Buy Them? Where Did It Fail Them?</u> The introduction of technology onto the Yorktown allowed for even greater reductions than those accomplished by questioning Navy tradition and culture. In most cases, the systems introduced were accepted by the users and welcomed as a means to work smarter, not harder. Contractors worked closely with the crew to both train the crew in the use and maintenance of the new technology, and to make final adaptations to the technology for use on the Yorktown. The new technologies allowed for more flexible operations on the ship as they shifted from dedicated, hardwired computer systems to networked PCs that could be programmed to run an array of different software programs. Increased sensors linked to software allowed for better situation assessment about the status of the ship's engineering components and damage control elements. The use of HYDRA, a wireless hand held radio system, allowed for more efficient and accurate communication throughout the ship.

One priority of the Smart Ship project was fast implementation. The goal was to build a Smart Ship now. This meant they had to work with technology that was currently under development, nearly ready to go. They were willing to tweak the technology online rather than wait for a five to ten year Research and Development cycle to finish. This rationale was made clear to the crew, so that their expectations for the contractors were realistic.

The crew did not expect everything to work. They understood they were serving as a testbed and that it was their job to try to find a way to make the new technology work within the new, work smarter, not harder paradigm. This meant that they were comfortable, not frustrated or exasperated, when things didn't work right off the bat. One illustration of this is the Ship's Machinery Control System (SMCS). The SMCS was installed via an aggressive installation plan in the fall of 1996. Preliminary dockside testing resulted in a series of "communications buffer overfills" which led to main engine shutdowns. These incidents were seen as part of the learning curve and important lessons in learning how to recover from a system crash. During sea trials and once early in the first deployment, similar incidents occurred. The incidents were not seen as catastrophic. Each time the crew was able to bring the systems back on-line in less than an hour. By the time the crew completed the five-month deployment, the system was fully functional 99.9 percent of the time. Rather than abandoning the technology at the first indicators of trouble, they invested resources in learning the system and tweaking the software.

It is also important to note that they didn't accept every new technology introduced to the ship. For example, the Yorktown had a tagout system in which they would hang red tags on systems that weren't working. The tag was a clear indicator that something needed to be repaired and also contained notes about the problem with the equipment. During the Smart Ship project, a computerized tagout system was introduced. People interacting with the computerized system found that it simply duplicated the paper system. It was a bad idea. It increased the workload and was redundant with the existing and more efficient paper system. They tried it for six months and finally got it off the ship.

Change in Training. The shift to operating with fewer people meant that people had to come up to speed more quickly on the Yorktown. With reduced redundancy, every person counts. In recognition of this need, changes were made in the way training happened on the Yorktown. A dedicated training officer position was introduced. On most ships, training is one of many other duties, and often becomes a low priority as other more urgent responsibilities pull for each person's time. The introduction of a dedicated training officer increased the chances that personnel would receive training and come up to speed quickly. An expanded indoctrination program was introduced, providing more standardization and a more thorough introduction to the ship.

In addition to the direct changes in roles and functions regarding training mentioned above, process changes on the ship impacted training effectiveness. One striking example is the use of a Command Inspection Team. On most ships the period prior to an official inspection is very stressful. People get into a frantic mode preparing for the inspection, making sure they have the most up-to-date Instructions and that they are following them all correctly. Operating from an old version of Instructions is seen as a serious problem to the inspectors. However, on many ships keeping track of the most recent version turns out to be a challenge. This difficulty was greatly reduced on the Yorktown when, as described above, Rushton eliminated all instructions except for the basic four documents found on every Navy ship.

To further reduce the stress and added workload that comes with inspections, a Command Inspection Team was created to conduct an inspection of some portion of the ship every week, rotating across functions so that there was a regular inspection cycle for the whole ship.[3] This eliminated the franticness generally associated with official inspections. This is possible because the procedures themselves have been simplified so that it is possible to follow them at all times. The implication here is that they have introduced a constant check on their ability to function. If it becomes a strain to prepare for inspections, this is an indicator that they need to rethink staffing and/or procedures.

Core Flex Battle Bill. The core flex battle bill is one of the most innovative things on the Smart Ship. It goes against much of Navy tradition, reduces the workload on individual sailors, and allows more people to sleep at night and work during the day.

Four essential ship operations have been identified: drive the ship, maintain engines, track and identify air/surface contacts, and shipboard self-defense. These functions are

[3]This is not specifically a Smart Ship initiative and variants have been used on other ships under the name "Division in the spotlight." It is included here because the crew considered it a part of the frame-breaking changes that occurred on the Yorktown.

staffed 24 hours a day. Other functions that have been identified as critical and potentially needed for extended periods of time are assigned a sustained flex team. The sustained flex teams are ready to be called into action at any point in time and maintained. A third set of critical functions have been identified that do not require sustained staffing. These unique flex teams are also ready to be called into action at any point in time, but cannot be staffed for a sustained period of time. It is possible for one person to be on more than one flex team, but only if it is not anticipated that the flex teams will be needed at the same time.

Under the traditional system, nearly all of these functions were staffed 24 hours a day. People would generally work from 11:30 am to 5:30 pm, have some dinner and sleep, and then work from 11:30 pm to 6:00 am. That is six hours on and six hours off in a continuous cycle.

Under the current system, most of the maintenance that used to be conducted at all times of the night and day is conducted during the day shifts. More people are able to sleep at night, which is easier on the body and there are more people around to supervise the maintenance. The Main Propulsion Assistant and Assistant Chief Engineer reported that he believes the systems on the Yorktown are better maintained under this new system. In addition, by moving the maintenance function off the watch station, senior enlisted people have been removed from the watch altogether. This means the senior enlisted people can spend their time training and troubleshooting, where their experience is most needed.

The Role of the Captain. One important question about the Smart Ship project on the Yorktown concerns the key role CDR Rushton played. The authors of this report believe his background and his leadership style contributed much to the success of the project. CDR Rushton had previously worked in the office of the Secretary of the Navy, trying to characterize the types of situations and missions the U.S. Navy will be facing 20-30 years out, as part of the Surface Combatant Force Level Study (SC21, now DD21). When CDR Rushton took command of the Yorktown, he had already spent a significant amount of time thinking about the challenges the Navy would face in the future and generating ideas to meet those challenges.

Furthermore, CDR Rushton has a very pragmatic leadership style. He knew that in order for this project to be a success he needed buy-in, not just from the CNO and other officials in Washington DC, but also from the crew of the ship. In presenting the Smart Ship project to the crew of the Yorktown, he made it clear that every person was expected to participate and generate ideas for how to work smarter and reduce workload. In spite of these efforts, crew members told us they didn’t believe it at first. For some it took nearly a year before they realized that it was alright to question procedures and policies that seemed central to Navy culture. CDR Rushton sent a clear and consistent message that first year, that participation from every single person was expected for this project, and that participation required them to question things that seemed counterproductive. Everyone on the crew knew that they could make suggestions to the Captain of the ship or anyone else in the chain of command and that the suggestions would be heard.

All involved in the project acknowledge that it takes a talented and devoted group of people to develop and work out the details of a new vision[4]. Most point toward Rushton as a driving force. As the Navy faces future re-engineering efforts, it will be important to choose an effective leader and project team.

So They're Better Rested, But Can They Fight A Battle? Considering the stories of the Samuel B. Roberts and the Princeton, one simply must ask whether the Yorktown operating with fewer people, using the core flex battle bill is really ready to face battle and other crisis situations. The official answer is yes. Inspections by OPTEVFOR and NAVMAC, as well as self-evaluations, indicate that the Yorktown can fulfill all of its duties and functions, and can sustain this level of operation long term.

We were also curious about whether the crew of the Yorktown felt confident in its abilities to operate with fewer people and new technology. People were very clear that they believe they are fully prepared to deal with the full range of scenarios — perhaps better prepared given that the crew is decently rested and not dual tasking unnecessarily. When we posed the question of "readiness" their response was that they have been evaluated, inspected, and reevaluated and have passed every assessment. To the crew of the Yorktown this seemed to support what they already believed: that the Yorktown is just as effective as any other Navy ship.

In spite of the confidence of those who have served on the Yorktown and the extensive testing and evaluation the Yorktown has undergone, there are those who continue to question its effectiveness. The crew of the Yorktown believe they have been tested in every way possible short of taking the ship into battle and sustaining casualties. However, when an actual combat situation arises, they believe they will be as capable as any other U.S. Navy ship.

How Did This Really Happen? To the crew of the Yorktown, there was still a sense of disbelief that the Smart Ship project had been allowed to happen. There was clearly a sense that what had happened over the last three years went against much of what they believed they Navy was. One person told us that his understanding of the Navy culture is that to be successful, you must stay in the middle and take no risks. You do your job

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[4]Interviewees are quick to point out that now that the Smart Ship concept has been instantiated, implemented, and tested, anyone should be able implement the concepts successfully. Regarding the future of the Smart Ship concept, there are competing forces at work. For those captains who have excelled under the existing systems and who have not had exposure to studies such as SC-21, the Smart Ship project may appear to present unnecessary risks to those who serve in the Navy and to our country. For years the Navy has viewed redundancy on ships as a necessary means of running ships effectively in the many unanticipated situations they are placed, and as a means to train new crew members. On the other hand, the success of the Yorktown is a powerful testament to the validity of the Smart Ship concept. Efforts such as the Rushmore and the Destroyer Squadron Eighteen have begun to generalize the Smart Ship concepts to other platforms.

by the book, nothing less, nothing more. The Smart Ship project went against culture in a dramatic way. The crew of the Yorktown told us that the Smart Ship project was a chance to do more, to take some risks, to try to make things better.

Key factors that we believe stand out as contributors to the success of the Yorktown include:

- Both a top-down and a bottom-up approach. Although the directive to create the Smart Ship came from the CNO and the project had much support in Washington DC, the crew of the Yorktown felt every bit as much responsibility for the success of the project as the Smart Ship team in Washington DC. Suggestions for reducing workload were generated at all levels.

- Clear guiding principle: Reduce workload. This guideline had different benefits for different communities. For the Smart Ship team in Washington DC, reducing workload was a means to run the ship with fewer people and reduce costs for the Navy. For the crew of the Yorktown, reducing workload translated into working smarter, doing the job better, and having a better quality of life for sailors. However, for both communities the concept of reducing workload was a goal that made sense, and was concrete enough to drive the project.

- Strong leadership. Clearly CDR Rushton's vision and leadership were strong contributors to the success of the Smart Ship project on the Yorktown. CDR Rushton was able to communicate his vision equally well to the team in Washington DC and the crew of the Yorktown.

- Focused approach to introducing technology. The Smart Ship team in Washington DC culled through many suggestions for technologies that could be used on the Yorktown. A guiding principle in choosing which would be placed on the Yorktown was whether the technology would work toward the goal of reducing workload and running things more efficiently.

- Iterative approach to change. No one expected to be able to redesign the ship a priori, determining which functions would be accomplished by technology and which would assigned to humans. The Yorktown was viewed as a testbed. This was a place to test new technologies and new procedures. With that frame, the crew was willing and eager to try new things and critically evaluate feasibility and progress toward the goal of reduced workload. There was not a sense of frustration and failure if things didn't work the first time.

<u>Technical Support Center</u>

The second example we will examine here is the reorganization of the Technical Support Center at a Southeastern nuclear power plant. The Technical Support Center is one division of the Emergency Response Organization (ERO) that is activated when a crisis or accident occurs in the plant. The ERO at this plant had a long history of passing test scores with the Nuclear Regulatory Commission, but had struggled during recent drills. Lower scores resulted in an increase in the number of drills required and monetary fines.

In an effort to improve performance of the ERO, the Manager of Emergency Planning arranged researches to analyze the situation and make recommendations to improve team performance (Klinger & Klein, in press). This example is described from the perspective of the consultants rather than the people involved with the re-engineering project within the organization.

The Technical Support Center was identified as a key area of focus because this is where most of the difficult decisions are made. The Technical Support Center is made up of managers of various areas within the plant (i.e., maintenance, operations, engineering). Each member of the Technical Support Center is highly experienced within his/her area of the plant and possesses the expertise necessary for solving novel problems, making decisions to help stabilize the plant, and determining the emergency level (or criticality) of the event. Most members of the Technical Support Center have worked at the plant since it was constructed.

Approach. Initial visits to the plant were made to become familiar with the environment. After observing an emergency drill, the research team conducted interviews with individual participants in the Technical Support Center. The goal of the team was to determine what types of difficult decisions the Technical Support Center faced, and who were the primary decision makers.

In order to identify the key decisions, the researchers began by focusing on the four primary decision makers identified by the plant manager. However, based on observations and interviews, it became clear that only one of the four identified as decision makers actually made any decisions. Interviews with key personnel in the Technical Support Center revealed that they did not know who the decision makers were.

The next step was to examine decision loops, including the cycle from the identification of a problem to the decision, to its implementation. In examining these cycles, the researchers found a large number of handoffs. It was common practice to let everyone in the room see data before anyone reacted to it. This caused visible bottlenecks that were obvious to observers. Interviews revealed that information was sometimes held up by someone who did not have a need to see it. It turned out that the person who made a decision was often sitting next to the person who would initiate the action associated with the decision. However, the information traveled through the entire room before it got to the person who was to initiate action. What could have easily been a handoff from one person sitting next to another became a long, involved information dissemination task.

The fact that information was shared with everyone in the room whether it was needed or not, led to gridlock conditions. People waited in line to talk to the crisis manager, tying up the decision maker's time and putting those in line out of action while they simply waited their turn to talk. An assistant was used to help keep track of information for the decision maker by writing it on post-it notes which could be read and discarded.

Interviews also revealed that people did not have a clear understanding of everyone's roles and functions. To further confuse things, people often did not understand the intent behind the tasks they were asked to complete. Observers reported that the Technical Support Center was not displaying the metacognitive activity seen in more successful teams. The Center team members were not particularly aware of how well the team was functioning. Often, some members would be described by others as having very high workload. Observations, however, indicated that many of those reported by colleagues as having high workload appeared to have low workload. In follow-up interviews, one member identified as having a particularly high workload revealed that he actually had nothing to do. He wanted to be moved to another part of the organization where he would be able to have an impact.

<u>Interventions</u>. The primary recommendation was to reduce the number of people in the Technical Support Center. The rationale was that the confusion about roles and functions was caused by too many people with ill-defined jobs. This led to the "social loafing" phenomenon in which team members begin to identify their roles more narrowly and to assume others will handle new tasks. In addition, the effectiveness of the key people in the room was diminished by the extra people milling about.

In order to determine which positions should be eliminated, they started with observers, people who didn't seem to have a specific role. Next, assistants were eliminated to reduce the number of people through whom information would be filtered. One indicator that the assistants were contributing little is that neither the assistants nor their supervisors could clearly describe their responsibilities. To test these choices, a drill was run without observers and assistants. Performance was better with the smaller group.

The next reductions were made by consolidating positions. For purposes of coordination and communication, in some instances, the consultants predicted the efficiency would be improved by having a single person handle the entire task instead of forcing different people to coordinate with each other.

The final step was eliminating legacy positions. The Technical Support Center mirrored the organization of the plant, which had made sense earlier in the development of the Emergency Response Organization. However, in the current situation, there were many departments represented in the Technical Support Center for no reason. These personnel were shifted elsewhere in the plant where their expertise could be used more effectively.

This was an exercise in improving performance, not downsizing, so an additional person was added to be the expert in procedures by tracking the activities in the Technical Support Center in a procedures book. Recommendations were also made to revise the structure of the team to improve decision flow and to permit better coordination with outside organizations.

Recommendations to improve shared situation awareness included a revision of the Operations Net so that information was disseminated more effectively. The use of headsets was changed and a priority/status board was added so that team members could readily determine the current priority of goals along with the current actions.

Outcome

Implementation of these recommendations resulted in vastly improved performance. Observers of the reorganized Technical Support Center were surprised by the lack of noise and confusion. Participants in the first exercise following the reorganization thought that they had been given a particularly easy scenario to solve. Exercise controllers later revealed to the participants that they had presented one of their most difficult scenarios. Fewer people in the room and added situation awareness tools and procedures resulted in a much more streamlined, efficient process. As a large part of the team coordination task was eliminated by reducing the size of the team, key decision makers found themselves thinking ahead instead of reacting to problems. The noise level was down because there were fewer people asking questions.

Section 5: Re-engineering Process

The previous section illustrated two highly successful re-engineering efforts. In this section, we will take a macro view and examine the processes used for re-engineering across the case studies examined.

We will consider three stages of the re-engineering of organizations: a) the recognition and specification of need, b) the detection of leverage points as indicators of areas for potential change with high payoff, and c) the selection of the re-engineering strategy. Although the second stage is clearly critical to the success of any re-engineering project, it is the least-documented. For this reason, the detection of leverage points was a focus of our study of the cases. This section is primarily about the way skilled observers notice leverage points that enable re-engineering and personnel reductions. Nevertheless, we will briefly touch on the other two stages, to provide context.

Specification of the Need

The classical management literature identifies only two primary sources of change for organizations: situations in which organizations are threatened by changes in the environment and recognize the need to change (Hall, 1991; Manns & March, 1978), and situations in which change is motivated from within the organization itself (Porter, 1980). We find these to be too high-level to be useful, so in examining the case studies we looked for a finer grain and identified seven different motivations to attempt to dramatically reduce staffing. These are not mutually exclusive. Several of these motivations can, and do, blend for any given program. Nevertheless, the seven seem to be conceptually distinct. And the strategies that would emerge from each would differ.

The Desire To Cut Costs. This is the most common reason given, and the strongest motivation. It is also one of the least promising motivations. We did not find any successful examples of downsizing that were motivated purely, or even primarily, by cost considerations. Unless there are other reasons, and other opportunities, we believe that it is highly unlikely for a cost-cutting program to be effective.

The Desire To Demonstrate New Technology. With all the advances in information technology, managers often expect that the technology will enable them to make radical changes, and thus to reduce staff size. Part of these concerns are based on observations of how inefficient the older technologies are. More modern equipment would surely reduce life cycle costs in many ways. Therefore, modernizing the technology should result in the chance to cut staff. In our cases, we did not find any successful examples of this motivation. Typically, if the new technology reduced operational staff, they were replaced by technical support staff, often in the form of contractors maintaining the equipment, and often in greater numbers than the positions they replaced. This is not to say that technology cannot be useful in personnel reductions. The point is that technology can support the realization of other goals. Pure technology insertion does not appear to be an effective strategy.

The Desire To Shake Up An Organization By Setting Forth Stretch Goals. The goal to reduce staffing by 75% is a prime example of a stretch goal, forcing designers to think outside the box, break cultural barriers, and so forth. As such, we think that stretch goals are exciting and stimulating. However, none of the cases we reviewed were motivated by stretch goals.

The Desire To Improve Performance. This appeared to be the most powerful and effective motivation. In both the cases discussed at length in this report, the Smart Ship project and the nuclear power plant, the intent was to achieve greater levels of performance. In both cases, this was achieved by reducing staff. Both attempts were highly successful. This is disappointing, because it suggests that performance, not cost, is the key stimulus. But this is also reassuring, because it suggests that downsizing does not have to degrade performance levels and can even upgrade them.

The Lack Of Availability Of Skilled Personnel. None of the cases we studied or considered included this motivation. We present it here because it appears to be a potential issue in future systems, particularly as the military itself downsizes.

The Desire To Reduce Vulnerability. Smaller ships can mean a smaller radar profile. This is one of the reasons given by the Navy for studying ways to reduce personnel. None of the cases we reviewed included this rationale.

Detection of the Leverage Points

The case studies showed that successful downsizing efforts depended on skilled observers being able to size-up operations and spot opportunities for making significant changes. There are no recipes for spotting these leverage points. There are no techniques such as are used in re-engineering low-level functions (e.g., plot the steps taken with an insurance claim from start to finish, note the value added of each step and the time needed to accomplish it, etc.). For the cognitive demands of command and control functions, there are no simple products that can be monitored.

In reviewing the case studies, we made a discovery that some of the clearest successes occurred when an organization was able to cut staff in order to improve performance. This seemed paradoxical. Subtracting staff members should have increased the workload of the remaining staff, and prevented them from doing their jobs as well. The interpretation is therefore that the existing staff had gotten in their own way, and that by selectively cutting staff, the interference was reduced. We found this pattern for Smart Ship, for the nuclear power plant, and for the USMC regimental COC. In each case, the driving motivation had been to improve performance (rather than cutting costs or demonstrating new technologies). And in each case, a sharp reduction in staff (15% cuts for Smart Ship, reduction from 80 to 35 in the nuclear power plant Emergency Response Organization, a cut from 34 to 24 in the USMC forward command post) led to better performance.

Figure 1 describes the relationship between staff size and workload/performance. This hypothetical relationship was derived from the case studies we reviewed. The concept is that if just a single person was performing the entire task, adding more staff members will cut workload and improve performance. The addition of staff continues to improve performance, up to a point. After that point, the staff increases will add to workload and degrade performance. The reason is that at the left side of the curve, each new staff member makes a large reduction in workload. If one person does the entire job, then adding an assistant will reduce the first person's workload by almost half. However, the marginal improvement in workload diminishes the more staff members are added.

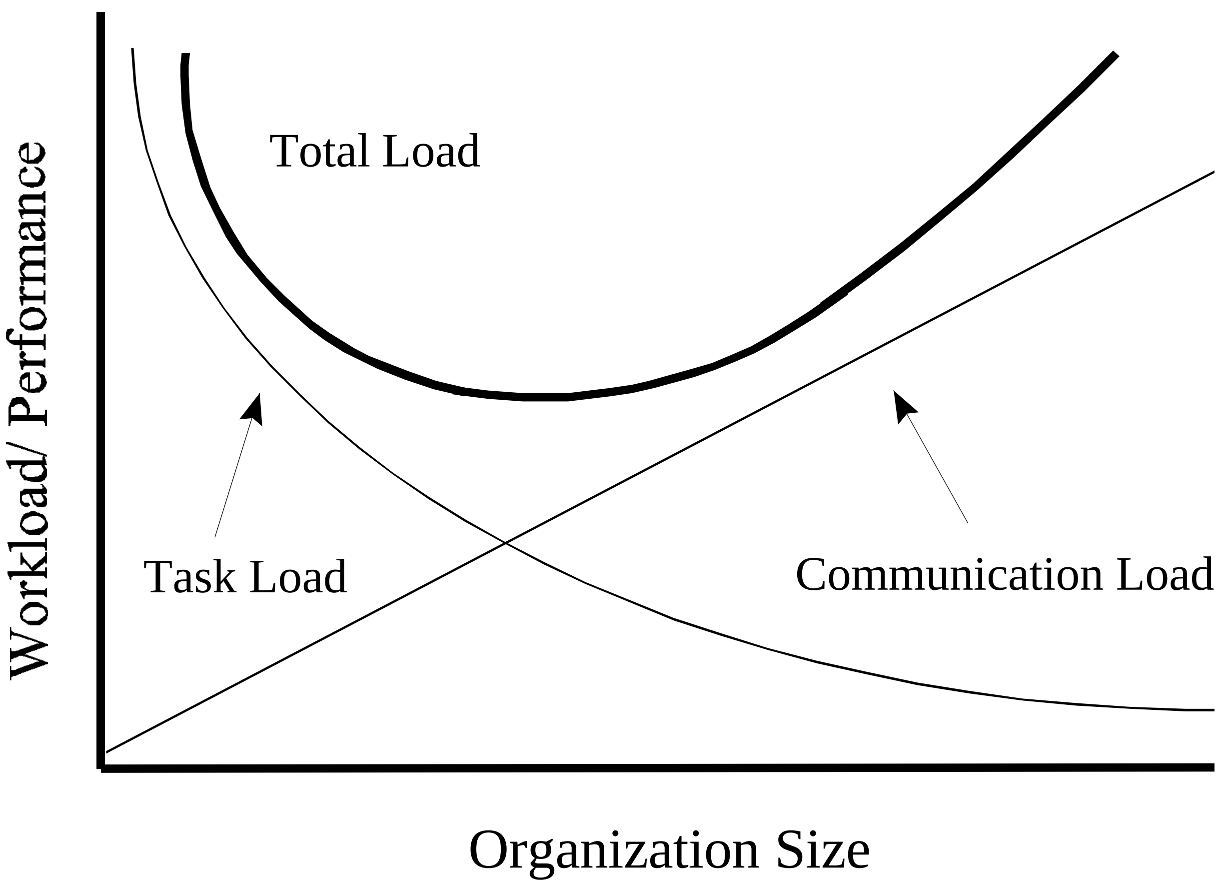

Figure 1. Relationship between staff size and workload/performance.

At the same time, the information management activities needed to coordinate staff members continue to grow at a constant rate. If the task used to be performed by one person, and a second is added, the first person has information management responsibilities to coordinate and inform the second person. A third person makes this worse, and so forth. At some point, people begin adding tasks and increasing the complexity of the work in order to make good use of people available. In time, new levels are established, hierarchies are formed, protocols are put into place, all for the purpose of managing the staff and distributing the information. As these burdens grow, and the marginal workload gain reduces, a point is reached where the additional staff members cost more than they contribute.

The paradox in Figure 1 is that adding more staff beyond the inflection point will result in an increase in workload, but most organizations only know one remedy for workload: to add additional staff. Thus, a positive feedback system is set into play.

Figure 1 suggests that teams and organizations face competing pressures. The pressures to add more staff include the desire to increase expertise, to speed up reaction time (by performing more tasks in parallel), to reduce workload, to monitor more input channels and offer more output channels, to operate a wider array of specialized systems, and to increase status. The counter-pressures to adding more staff include the information management costs (greater number of handoffs, etc.), greater inertia (e.g., it is harder to revise plans the more people have to be coordinated), greater confusion over roles and functions, and so forth. Unfortunately, the pressures to add staff, such as high workload or lack of expertise, are fairly visible, whereas the costs of those staff (such as information management and coordination) are much less visible, and may only become visible afterwards.

The challenge is to detect which side of the curve an organization has reached. Here the leverage points come into play, to suggest when an organization is over-staffed.

1. Signs that weak staff members are not contributing as much as they cost:

a) Large numbers of personnel cannot answer simple questions, such as the goals of the exercise and their rationale. Inability to answer these questions indicates that the staff members are performing context-limited tasks that could potentially be merged or eliminated. In the nuclear power plant, the assistants were usually uninformed about events during exercises. The plant claimed that it needed these assistants in case events became too chaotic and required a surge capability. However, during a surge period, the decision makers would have even less time to fill in their assistants about what was going on. And the incident commander admitted that during a surge period he preferred fewer people in the command post.

b) Anyone not on a primary communication link is suspect. In most settings, the staff members who count wind up on these links, and the ones who are not essential often wind up off them. This is not a firm rule, only the beginning of a suspicion.

The solution is not to require that support staff learn how to answer questions about goals, or gain access to the communications channels. These are just some of the indicators that the support staff may be dispensable, without degrading the operations.

c) The products of an individual or cell are not used. In one USMC exercise, a large cell of about 8-10 people worked hard to generate planning products, but the other cells rarely used these products or consulted this cell. This was a tip off that the cell was too large, and its function was not important. A general strategy here is to identify the most important planning and decision-making products in a command post and trace how these get generated, and how each individual and cell contributes. This can provide a good picture of the value added along the way, and of the weak links in the chain.

d) The nature of the tasks that are not getting done. No organization ever finishes all the tasks on its 'to-do' list. Sometimes, the tasks being left incomplete are important, and this suggests that the organization is understaffed. Other times, the remaining items are all trivial, and this indicates that there are too many staff members. In the nuclear power plant, low-level staff members were assigned jobs such as waiting in line to obtain and distribute soft drinks. This was a bad sign.

2. Signs that the organization is not getting sufficient benefit from its key decision makers.

a) Actuals never get to talk with actuals. Sometimes, the key decision makers do not talk to other key decision makers without going through several intermediaries. This results in delays, and reduces the quality of the communications. If actuals could talk to actuals, the time they spent would be the same as when they have to talk to their subordinates. After this was pointed out to a USMC regiment, they reduced the size of the forward command post from 34 down to 24 simply by removing the radio talkers. They estimated that it took less time to have actuals talk to actuals, and the quality of the interchanges was greatly improved.

b) The key decision makers cannot see the big picture. This was found in the USMC regimental COC. There was no central map or bank of maps where the commanding officer or the executive officer could learn the relationship between friendly movements, enemy movements, and artillery capabilities. Instead, for the regiment studied in most depth, these maps were placed in separate corners of the tent, with passage between them blocked. (After this was pointed out, the maps have been placed in direct proximity.) The implication for downsizing is that the organization usually requires unnecessary staff to maintain the different representations, as well as even more staff to combine them.

c) An organization doesn't know who are its key decision makers. One approach to re-organization is to find ways to support the primary decision makers. Often the organizational structure gets in the way of these decision makers. That is why reducing staff size can sometimes improve performance. In itself, the search for the actual decision makers can be enlightening. The example from the nuclear power plant showed that the organization itself did not know who was making the decisions in the Emergency Response Organization. This lack of self-awareness raises the likelihood that the organization has not been effective in supporting its decision makers, and that there should be changes that would boost performance even while cutting unnecessary staff members.

d) The key decision makers are passively receiving information rather than actively searching for it. In a number of settings, primarily military ones, rituals have developed for having the commander briefed. This is a tedious process and one that chews up a fair amount of resources. Another factor is the introduction of technology that reduces decision makers to a passive role, cycling through messages rather than seeking out key items from databases. These indicators suggest that inefficiencies exist, and that these can be overcome, possibly with a reduction of the staff needed to orchestrate the inefficient briefings or band-aid the technological gap.

e) The staff huddled together at times of crisis does not correspond to the assigned roles. Using a simple sociogram, it is possible to determine that the same 4-5 people are always found in the middle of a crisis, figuring out how to respond. Often they are not assigned the role of planner or decision maker. Yet, they are the actual core decision makers. The greater the deviation between the actual roles and the assigned ones, the more likely that people are filling ceremonial roles in the organization.

3. Signs that the organization does not have good insights into its own decision cycles. These are important because an organization that lacks self-awareness is not likely to be able to spot problems, diagnose them, and repair them.

a) Blind spot for problems. In a number of settings, the observers had seen problems during exercises, but the command post staff denied that the problem had ever arisen. Only by pointing out events along a timeline was it possible to even begin a discussion about what went wrong. If an organization is not watching itself to see how it is working and where it is having difficulty, there is a good chance that inefficiencies have gradually increased, and a good likelihood that staff members have been added because it was easier to handle needs that way than to rethink the practices. A team that lacks metacognition is probably not able to rethink its practices.

b) Lack of understanding about roles and functions. For teams that are on the right-hand side of Figure 1, observers notice that there is often confusion about who is supposed to be responsible for which task. One sign is the "bumblebee” pattern in which someone who needs a piece of information visits one person after another, like a bumblebee going from one flower to another. In this case, the intent is to find the missing datum, and the inefficient search pattern stems from a lack of understanding of roles and functions. A related pattern is the "shotgun” approach, when a person has an important message and doesn't know who needs to see it, and chooses to broadcast it widely just to be safe. This increases workload all around, and contributes to message overload. Yet another sign is the “grout” approach to staffing, in which new staff members are poured in to fill the cracks, adding more bodies to handle tasks rather than re-thinking the distribution of work.

One way that a ‘grouting' approach to staffing can affect an organization is when more people are requested than are needed, in order to increase the chances that at least a few of these will be proficient. This is a safe strategy, and it works in many settings. Unfortunately, it leads to over-staffing. If the organization had the self-awareness and self-discipline to eject the less-proficient staff, the damage could be minimized. However, a sunk cost type of logic usually requires that these unnecessary team members are retained. Attempts to remove them are often resisted because of the costs incurred in gathering them.

4. Signs that the team or organization is spending excessive time/effort on managing itself rather than performing its functions. These are additional indicators that a team is on the right-hand side of the curve in Figure 1.

a) Excessive links in the information chain. The hallmark of a team that is on the right-hand side of the curve in Figure 1 is that it is doing a poor job of managing information. Thus, at the nuclear power plant that was having difficulties, the observers found a very high number of handoffs per transaction. Sometimes a transaction would wind its way around the center, eventually landing at the desk next to the person who initiated it, with little or no value added along the way. For the observer, the ideal is a 1:1 ratio, with one handoff/transaction. Large departures from this ideal were the tripwire that something was wrong. In addition, there were numerous confusions about current status, priorities, and so forth. The addition of unnecessary staff had created its own confusion, increasing workload.

Yet another indicator is the appearance of gridlock. In the nuclear power plant, the observers found that a long line appeared in front of the incident commander's desk. These were staff members who had important information to share. Unfortunately, they had to wait in line, sometimes for 20 minutes or longer during a full-day exercise. While they were in line, they were losing situation awareness themselves. In a vain attempt to remedy the situation, another staff member was added, an assistant whose only job was to go up the line, have the people write down their issues on yellow stickies, and then place these in front of the incident commander on his desk. He would read these and throw them away when he was done. The inefficiency of this practice was explained away as the cost of doing business, and the team did not try to use it as a cue that they needed to re-think the way it was working.

Another sign is the emergence of cells. The advantage of a cell is that it is small enough to work effectively without requiring a great deal of coordination. However, as the number of cells increases, the problem of coordinating these cells becomes greater and greater, recapitulating the curve in Figure 1 but at a cellular rather than individual level. Now the organization has its members shuttling between cells, then spending additional time figuring out how to coordinate the cells. The appearance of integrators can be a signal that the cell structure has become too complex.

b) For the nuclear power plant, one of the signs was that there were too many assistants and non-decision makers. In a USMC exercise, a sign was that some staff officers complained that they spent the majority of each day preparing briefings, attending briefings, and preparing to disseminate the notes of briefings, rather than doing 'real' work. Thus, the ratio of planning/decision-making time to information management time was too low, indicating an inefficiency.

The more low-level staff in a center, the slower and less efficiently it will work. Although too many people at any level of the organization reduces the efficiency, overstaffing tends to occur at lower levels of the organization. This happens in part because of the prestige associated with having assistants. Furthermore, in some settings, junior people are brought in for training purposes, and then tasks are created to keep them busy. In organizations with too many low-level staff members, cutting staff can boost performance. In our work with the USMC regimental COC, we found that they were able to do a better job inside the forward command post with 24 than with 34. Moreover, the overall size of the command post dropped from 50 to 24 because they also cut the outside security forces and other technical support staff. The security forces increased their footprint, thus adding more to their vulnerability than to their protection. With a smaller staff, they could move more quickly than before. And with a smaller staff, they could eliminate about five generic support personnel needed for set up and breakdown of the tents. With smaller and lighter tents, these personnel were unnecessary.

c) The requirement for staff members to answer the mail. In many cases, outside organizations drive staff size. If a regiment has to coordinate with a division, and the division is overstaffed, and continues to send requests for information, the regiment's workload will be increased and it will legitimately need to add more staff. A better solution is to study the connection between regiment and division to determine the value added of the division's requests for information. It is likely that the division could improve its performance by cutting staff, and that this would trickle down to help the performance of the regiment.

This concludes the discussion of issues surrounding Figure 1. The last three leverage points address different aspects of team functioning that skilled observers were able to use to spot problems and identify ways to cut staff without degrading performance levels.

5. Staff size is driven by inefficient features of the equipment.

a) Expertise is centered around operating systems, not achieving outcomes. In a number of exercises, observers have noted that stovepipes created a situation where each workstation was staffed by a different specialist. Furthermore, the specialists differed with regard to their ability to operate and calibrate and repair the workstations, and not with regard to their mastery of the functions performed by the system. Often, domain knowledge was fairly low. The opportunities are to cut staff by using better designed systems and human-computer interfaces. If a specialist on one system could achieve, say, 80% competence on a second system, then the benefits of merging these might outweigh the loss of expertise.

b) Legacy systems and staff members predominate. Over time, new systems and specialists are brought into command posts to work alongside existing ones. But no one has tried to re-think the relationships, or the need for the previous systems/specialists. Or, more likely, the organizational difficulty of phasing out legacy systems is too great, so they have become embedded in a command post. At the nuclear power plant, each of the functions associated with normal operations of the plant was re-created in the Emergency Response Organization. However, many of these functions were not relevant to emergency responses, and the representatives were just getting in the way. Yet, without good metacognition, no one had the big picture to see this difficulty, and no one inside the organization was realizing how much could be gained by removing these irrelevant representatives.

6. False boundaries are maintained. This is similar to the preservation of legacy functions. If historical precedent has generated different specialty areas, and if a training structure has grown to support those areas, it may be very difficult to even realize that the functions can be merged. Thus, in one USMC exercise, we noted how often the operations officer (S-3) was doing the same job as the intelligence officer (S-2), namely, trying to locate the position of enemy forces on a map. Perhaps at higher levels (e.g., division and above) it would make sense to divide the specialties, but at the regimental level and below, the division just created one more handoff. The Marine Corps is aware of this as a potentially false boundary, and continues to discuss the costs and benefits of maintaining it. The indicators of a false boundary appear to be that the coordination

between specialists is extensive, and that one specialist is prepared to perform the job of the other.

In many cases, existing technologies create false boundaries. For example, in interviews with the crew of the Yorktown, people indicated that significantly reducing the number of people in the CIC would be impossible with current technologies. Systems in the CIC are hardwired and can display only a single function, thus requiring at least one person to monitor and operate each system. With more flexible technologies those boundaries will disappear and it will be possible to combine functions on a single console so that one person may be able to accomplish what are now considered to be distinct functions.

7. Lack of standards for routine functions. In many settings, there are historical guidelines about the number of personnel needed to perform routine functions. Thus, in petrochemical plants, it may be clear that two people are needed to close a certain type of large valve. Then, if one plant has assigned four people to this job, questions can be raised. There may be answers, but the standards have served the function of raising the issue. These standards permit benchmarking (identifying best practices), and also help to generate guidelines about the breakpoints for adding more staff.

<u>Selection/Implementation of the Strategy</u>

We found a number of different strategies used to achieve downsizing. The methods in this list can be used in combination, even though they are conceptually distinct. One difficulty facing all of these strategies is the lack of absolute standards. An organization can argue that although its size has been increasing by 5% a year, the range of tasks it performs has been growing faster than that, so it has really been downsizing, and the whole issue becomes muddled. Using an analogy, automobiles cost much more than they did forty years ago. At that time it was possible to purchase a new car for $2,000. However, that car would not have had the features we see today, or the quality. And some features, such as airbags and anti-lock brakes, were not even feasible. Thus, today’s command and control center may be the same size as the ones in place forty years ago, but the volume of messages and the span of control may be much larger. The counter-argument is that the increases in message traffic do not add to increases in performance, and with this turn the comparisons become murkier still. The point is that a strategy for downsizing must take into account the changes in mission and the quality of performance and the unintended consequences. If a function used to be performed by six people, and now is performed by two, but those two require enormous amounts of training and the end result is an increase in personnel costs rather than a decrease, then the exercise may be counterproductive. This ties back to the earlier discussion of the reasons for trying to downsize.

<u>Bottom-up Strategy</u>. This relies on opportunities and suggestions from within the organization. Thus, the Smart Ship project used a suggestion box for the crew members of the Yorktown, and the captain of the ship retrieved notes he had made on

inefficiencies that had troubled him during his career in the Navy. The opportunities suggested by leverage points also would fit into this category.

Top-down Strategy. In the purest form, this is a zero-based design that seeks to completely rethink the command and control functions. Instead of trying to uncover places to cut in the existing system, a top-down strategy would start over, using knowledge and technology. In this way, there is no need to fight through legacy systems and existing practices. It is an approach for making bold changes, as opposed to incremental ones. The disadvantage is the difficulty of the "envisioned world" problem. Schemes that seem reasonable on paper usually turn out to be impractical. In a less extreme form, a top-down strategy would combine a plan or architectural concept with other strategies such as opportunities that were noticed for making cuts.

One way to achieve a top-down strategy is to use a decision-centered design — focus on the decision makers. This would begin with the key decision makers and seeing how to support them, and building out from there.

Fiat. Rather than developing a strategy, one approach is to demand change and expect the staff to figure out how to implement it. Thus, General Motors might decide to downsize by a certain amount, and give the target levels to lower level managers, or it might simply make random cuts to get to the desired level of staffing. The Japanese method of "kaizan" is to achieve continual gain in productivity by expecting managers to improve by some small amount, perhaps 10%, every year, so that after several years the overall change is significant. While it seems obvious that such a superficial approach to re-engineering would be fraught with unintended consequences, examples of this approach arose both in the literature and in our interviews.

Iteration. Any suggested change needs a period of testing, of trial and error, to correct the mistakes and smooth out the areas of poor fit. This can include simulation of some sort, in order to make the discoveries early in the development cycle.

One of the most important reasons for trial and error evaluation is to discover unintended consequences, which are a threat to all attempts to introduce dramatic change. The danger of unintended consequences is greatest for a top-down approach, because the wholesale re-organization will create a large number of alterations in functions that may be poorly documented or even undetected. The danger of unintended consequences is also a threat for a bottom up approach; there are many stories about small changes that led to catastrophic losses in critical capabilities.

Section 6: Lessons Learned

From the case studies investigated we have extracted important lessons learned and present them here in the form of guidelines for future re-engineering efforts. Each guideline is supported by examples from our case studies so that contextual information is available to the reader. Although the lessons learned presented here are gathered from the implementation phase of previous efforts, they have important implications for the planning and selecting of strategies for future re-engineering efforts. The section is divided into three subsections: Unintended consequences, historical precedent and cultural barriers, and technology solutions.

Unintended Consequences

As change is introduced to an organization, unintended consequences are unavoidable. It is impossible to anticipate the full impact of a new technology or organization scheme before implementation. Although modeling and simulation can do much to help designers envision the implementation of a new system, unexpected consequences are inevitable. This section of the report documents some common unexpected consequences in re-engineering projects. By examining the surprises from previous re-engineering efforts, it may be possible to minimize negative consequences in future efforts.

Dual Modes. One common strategy is to model and plan for the typical, everyday operations when planning a reorganization. However, many organizations actually operate in dual modes. To ignore a less prevalent mode of operation in planning a reorganization results in considerable stress on the organization when the less prevalent mode is evoked. This problem is particularly serious in organizations for which the dual mode is actually a crisis mode. For example, in a nuclear power plant, when an upset of any type occurs, an Emergency Response Organization made up of plant personnel is called into action. Although this is a subset of people who work in the plant during typical, everyday operations, their roles, functions, and goals are quite different in a crisis situation. In any reorganization effort in the nuclear power plant, it is critical to take into account the different goals, functions, and needs of the Emergency Response Organization.

The Navy is another organization which clearly operates in at least two modes. In re-engineering Navy ships, one must carefully consider the damage control function. On the USS Yorktown, new technology allowed for a more streamlined damage control process. Interviewees described the somewhat convoluted process used before the Smart Ship project:

> If a fire occurred in a trashcan, the entire ship went to General Quarters (weapons were loaded, lockers were manned). Spaces were locked down and boundaries were set. A heavy attack team would be brought in to find the fire. After finding the fire, the on-scene leaders would tell the locker leader the current situation. The locker leader would tell the

> Damage Control Officer, who would write it on a clipboard. A messenger would then physically run this information to Repair 3 and tell the Locker Chief who would tell the Locker Officer. The Locker Officer would hand the message to the phone talker who would read the message to the Damage Control Central Phone Talker who would write it down. The Damage Control Plotter would then plot this information on a schematic of the ship using a grease pencil. The Damage Control Assistant could then give the on-scene leaders permission to enter the space where the fire was. The Damage Control Assistant would tell the phone talker to relay this information to the Damage Control Plotter on the bridge, who would then plot it on another schematic of the ship and tell the Captain what had happened.

The Yorktown now uses HYDRA to allow the people who locate the fire to communicate directly with others on the ship, eliminating the need for runners and phone talkers. In addition, a new computerized damage control system includes sensors that aid them in finding the source of the problem. Anything picked up by the sensors is displayed on a computerized schematic which can be called up in any of five locations. It is possible to add information to this schematic based on verbal updates (obtained via the HYDRA), and then display this schematic on multiple sites through the ship so that all people involved in the damage control function have a shared assessment of the situation. By eliminating the need for so many links in the communication chain, the Yorktown was able to reduce the number of people needed for damage control from 124 to 64. Operating under the new damage control system, the Yorktown passed all required inspections and was endorsed by the Propulsion Examining Board and OPTEVFOR.

In the crisis on the Samuel B. Roberts every person on the ship was needed. This crisis lasted over 10 hours and employed every one of the 200 people well enough to fight for the entire time. In a crisis such as this one, redundancy is needed because of all the unanticipated tasks that arise. In this case, people were fighting multiple fires; working to bring the engines back on-line so that the ship could move to a safer location; working to bring the weapon systems back on-line to fend off adversaries in the area; working to stop progressive flooding to maintain the ship in a non-sinking condition and maintain some operational capability; caring for people wounded in the mine blast; repairing and then flying the helicopter to bring fresh water to the people working, bring more firefighting materials, and remove wounded people; etc.

The designers of the Smart Ship and the crew of the Yorktown carefully analyzed previous events involving major battle damage such as those faced by the USS Stark, the USS Samuel B. Roberts, the USS Coyningham, and the USS Forrestal. The structure of the damage control teams on the Yorktown, as well as the technology introduced, were designed based on these analyses. Furthermore, vital fire fighting and flooding control equipment were relocated for emergency access from weather decks, focsle and fantail to further reduce the risk to personnel in damage control situations.

The Yorktown's Smart Ship damage control organization was tested every way the Navy could contrive, short of burning it down. Rushton reports that he finds the damage control organization on the Yorktown to be more effective than any other damage control organization he's been associated with in over eleven years and on six different ships.

The point to be made here is that as the Navy continues to investigate means to reduce the number of personnel on ships, it will be important to carefully consider the damage control function. The Smart Ship team clearly took this issue very seriously and has designed the re-engineered Yorktown with damage control situations in mind. However, as the Affordability project moves forward with the goal of reducing further to only 95 people on a ship such as the Yorktown, it will be important to consider the shear number of people needed to deal with the types of situations that are likely to occur in battle situations, minefields, etc. Although it is desirable to reduce the number of people needed to locate, isolate, and extinguish a fire, one must also consider the larger scale crises likely to occur when a Navy ship is operating in a hostile situation.

Training. Often in re-engineering efforts, in reducing redundancy one may also inadvertently eliminate important training opportunities. Many commercial ships are operating with drastically reduced crews and highly automated navigation capabilities. The introduction of new technology is recent enough that there are trained personnel to operate the ships. However, no one has figured out how to train the next generation of people to operate these ships. In the commercial maritime industry there is a strong tradition of on-the-job training. Now that there is no longer a need for assistants and manual helpers on the ship, mentoring and on-the-job training opportunities have been lost.

If the Navy continues along the same path the commercial maritime industry has taken, it will be important to create means to provide much of the training that has traditionally taken place shipboard on shore, as fewer sailors will be going to sea and those at sea will likely be the most qualified. If there is no role for junior sailors on the ship, it will be important to determine what is lost in terms of training and how to best address those skills via other training modes.

Changing the System. Although the human factors community has traditionally advocated a function allocation approach, it is important to realize that introducing new technologies and changing organizational structure changes the nature of the functions needed to fulfill a task or mission. It is simply not possible to determine all the functions and then assign functions to humans and machines as if each function were independent of the other functions and as if the means by which functions were carried out had no impact on the larger system. There is a strong tendency for those planning a reorganization to underestimate the widespread impact that a new technology or change in organizational structure will have.

Several examples come to mind. In the case of automated navigation systems, the function of navigation has become blended with propulsion. These two functions have traditionally been considered quite separately. In some cases there is no need to manually steer the ship. The function of steering is accomplished by the automated navigation system. Now there are three separate functions that have become blended together and it is difficult to determine where one begins and one ends. Furthermore, a human is now required to monitor the automated navigation system to ensure that things are running smoothly. In the event that things are not running smoothly, the system may be switched to manual and the human may resume control of the ship. The introduction of the new technology has changed the very nature of the functions needed to run the ship.

When General Motors re-engineered its organization in the 1980s to accommodate the design and manufacturing of smaller cars, it implemented a completely reasonable organizational structure to meet those goals. However, it did not anticipate the impact the reorganization would have on the information networks used to accomplish much within the organization. The re-organization paralyzed the company for over a year until informal networks could be re-established.

A third example comes from the health care industry. Traditionally health care in remote areas of Alaska has been handled predominantly by community health aids. If something serious occurred, the patient (and perhaps a family member) would be transported to a regional hospital. With the introduction of telemedicine, the function of transporting patients has been greatly reduced, but the functions involved in treating patients have changed considerably. The health aid now has to interact with the technology that allows the consultation with doctors at distant locations. The health aid must also communicate the situation accurately and succinctly to the physician. The physician no longer assesses the patient directly, but must make recommendations based on the health aid’s description and other data that are transmitted electronically. In our conversations with Dr. Pearce, it was clear that they were very much aware of the dramatic changes in function they would be introducing and made efforts to prepare users and provide follow-up support during the transition to the new technology and procedures. This anticipation of the changing functions and their impact on the health care system contributed much to user acceptance and the overall success of the project.

Historical Precedent and Cultural Barriers

A difficult part of any re-engineering project is overcoming historical precedent and cultural barriers. Often these are transparent and not immediately visible. Legacy systems exist that everyone considers necessary and reasonable. It would not occur to one familiar with and operating within the system to question the usefulness of such a legacy system. But when asked to articulate the means by which the legacy system supports the goals of the organization, people struggle to generate a reasonable rationale. In this case, the difficulty is in recognizing the legacy system. For example, in designing the FFG7, designers based their vision of use of the ship on World War II scenarios. These were the most recent types of conflicts the U.S. Navy had been faced with and no one thought to consider how the world had changed. General Motors was ten years behind the rest of the automobile industry in realizing that Americans were interested in smaller, more energy efficient cars. The cost of not recognizing they were operating under legacy systems was great. On U.S. Navy ships, two hours are spent every day polishing the ship's bell. They have been polishing the ship's bell every day since 1782. It wasn't until the Smart Ship project was implemented that the crew of the Yorktown had a context in which to question whether this was really necessary to maintain pride in the ship and good morale.

A second challenge those planning and implementing re-engineering efforts face is overcoming cultural barriers to change. Cultural traditions are often tightly held and highly regarded. One striking example we encountered was on the Yorktown. CDR Rushton decided that it made more sense for the Officer of the Deck (OOD) to sit rather than stand during his watch. This went against years of Navy tradition in that there are only two chairs on the bridge of a ship. One is reserved for an Admiral if s/he happens to be on the ship, visiting the bridge. The other chair is reserved for the Captain or the Executive Officer if s/he happens to be on the bridge. The OOD has always stood with a pair of binoculars around his neck, looking out the window. Rushton's experience was that the binoculars are heavy and put strain on the person's neck. His observations were that as the OOD gets tired, s/he finds a place to lean which may not be the best vantage point for looking out the window (the primary task). It is really important for the OOD to be alert, so why not provide a chair? The chair would relieve the neck strain from carrying the binoculars and ensure that the OOD had a good vantage point.

Although there was a clear rationale for providing the OOD a chair, implementation was more difficult than anticipated. When the additional chair was initially mounted on the bridge, those serving as OOD did not feel comfortable sitting in it. It went against their culture, so they ignored the chair. Over the first few weeks, CMR Rushtron continued to encourage those serving as OOD to use the chair. People began to lean on the chair, but still were not comfortable with the idea of sitting. Eventually the crew of the Yorktown got used to the idea and seeing the OOD sitting became commonplace. However, as the Smart Ship project began to get publicity, more and more visitors came to observe the ship. Other Navy officers visiting the ship were very uncomfortable with the idea of the OOD sitting. One interviewee reported that some Admirals even chose to sit in the OOD chair (rather than the chair provided for the Admiral) to prevent the OOD from sitting.

Similar cultural barriers arose in Leicester General Hospital as they began to merely suggest that there may be ways to run the operating theater that might reduce the number of costly delays and disruptions (Buchanan, 1997). Systems and procedures for using the operating theaters have developed through 50 years of history and tradition in England. Issues of responsibility, autonomy, and status between surgeons, anesthetists, surgical specialists, nurses, and other health care professionals stood as strong barriers to the otherwise reasonable goal of streamlining the scheduling procedure for using operating rooms and providing guidelines for dealing with cancellations and delays.

Technology Solutions

Most of the re-engineering cases we studied introduced new technologies. Although we have no evidence that simply introducing new technology leads to successful re-engineering, new tools, when viewed as part of a larger re-thinking of the organization, can have a positive impact. We have identified three categories of technological solutions that have had a positive impact in terms of reducing staffing and improving performance in previous efforts.

Situation Assessment. In many of the cases we examined, better tools for maintaining, updating, and communicating the big picture allowed for more effective teamwork and fewer team members. In some cases, technological solutions were sophisticated communication systems. In other situations the solution was as simple as a well-positioned whiteboard and a better understanding of which information is critical and to whom it should be communicated. However, each of the examples below illustrates how providing better tools for situation assessment can reduce the amount of confusion and the number of people needed in a crisis situation.

The use of a computerized damage control system combined with HYDRA on the USS Yorktown has allowed for a much more streamlined dissemination of big picture information during damage control situations. As previously described, under the old system fewer remote sensors were available, so members of a damage control locker would search for the source of the problem and report back to two - three commands center via runners. Information would pass through the ship as humans ran up and down ladders and spoke through tubes. The information about the location and extent of the damage, and the urgency of the situation was recorded on a schematic of the ship using grease pencil at each command center. The use of word-of-mouth communication with a string of runners meant that every update required several humans in the loop and was open to error at each information transition. The new technology includes sensors to detect the location of the damage; software depicting a schematic of the ship that can be called up on any PC in the ship, so that all command centers have a shared assessment; and the use of HYDRA, which eliminates the need for the human runners and reduces the likelihood of communication errors as fewer people are responsible for passing the information along.

In the Emergency Response Organization, observers noticed lines of people waiting to provide information to the decision makers in the room, indicating that no process was available to get critical assessment information to the decision makers in a timely manner. Other people appeared uncertain to whom their information should be passed and would move throughout the room, passing the information to everyone. Although a whiteboard existed to indicate the current status of the plant and the current actions being taken, it was hung behind a row of filing cabinets so only a few people could view it at a time and each had to leave his/her work station to see it. After re-engineering, the whiteboard was moved to a position visible to all people in the Emergency Response Organization. In addition, roles and functions were reviewed so that each person knew what information was critical to pass along and to whom it should be passed. This reduced the need for assistants to either wait in line or to pass information to everyone in the room. As a result, each player knew what information was critical and to whom it should be passed.

Remote Specialists. One promising solution to the need for personnel reduction is the use of centralized specialists whose expertise is available to several remote locations, rather than having specialists on site at each remote location. For Navy ships, this concept might be applicable to health care providers and maintenance specialists. The concept of having a reduced number of technicians on a ship who have the hands-on skills needed to maintain systems, but also having access to more experienced troubleshooters who can diagnose problems and direct fixes from a shore location, is very appealing. This would allow for fewer specialists on each ship and a greater experience base for the specialists who would now serve on several ships in an advisory capacity.

This concept has been tried in remote regions of the U.S. in the form of telemedicine with a high level of success. Although these have not been efforts to reduce staff but to provide better medical care for people living in remote locations, the lessons learned from telemedicine efforts warrant examination here.

One prominent telemedicine system is being implemented by Dr. Frederick Pearce of the University of Alaska (personal communication, 1998). Alaska is made up of small remote villages which can be considered individual nations. Each rural village has a community health aid who has had 12-16 weeks of training. Most are older women who are more “shaman-like” than doctors. Previously, if a person in the village was sick, s/he would go to the community health aid who would determine whether the person could be treated in the village or whether a specialist would be needed. If the patient needed a prescription drug or further examination or treatment, the patient would be transported via helicopter to Anchorage. The cost of the transport alone for one trip to Anchorage is $1000.

Pearce’s goal was to reduce the money spent on transportation so that savings could be used to treat patients and provide better medical training for the community health aids. His solution was to implement a telemedicine system that allows community health aids direct communication with physicians in Anchorage. Twenty remote villages now have the hardware and software needed to communicate with Anchorage, and the community health aid in each has been trained to interact with the system. Images and numeric data can be transmitted to Anchorage electronically. This allows for better initial diagnoses because the community health aid can consult with a physician. It also allows the physician to provide input into treatment earlier in the process.

The most difficult part of this project for Pearce was user acceptance. The community health aids and the physicians were both concerned about diminished authority. The health aids are important figures in each rural village and did not want to lose that authority. Physicians were concerned about diagnostic decisions being officially shifted to other health care providers. By including both communities in the planning and implementation phases of the project, Pierce was able to overcome these objections. The technology needed for such an effort is for the most part straightforward and easily within reach.

Using technology to allow real-time communication and transmission of data between non co-located specialists and health aids has had high payoff for a telemedicine project headquartered in Denver, CO, serving 85,00 people in rural and frontier sites (Lain,1998). Services include cardiology, orthopedics, dermatology, podiatry, and radiology. They have reduced unnecessary patient transfers and increased timeliness of care. The Arizona Regional Behavioral Health Authority provides psychiatric evaluation, monitoring, and treatment, plus consultation among clinicians. As a result of this effort an estimated $41,000 in health care costs were realized.

Central Monitoring Systems. For many monitoring and control tasks, the introduction of computerized systems can reduce the number of people needed.

For example, on the USS Rushmore machinery operations were streamlined significantly through the introduction of a centralized computer system and two portable computers. Previously there were 16 people on watch whose job it was to monitor and operate the ship's engines. There are four engine spaces throughout the ship that required people on site at each. The new computerized system allows for all four engines to monitored and controlled from a single station. This software can be accessed through any of a number of PCs on the ship. The number of people on watch has been reduced from 12 to 3. One person is able to monitor and control the engines for a single PC. Two others are rovers who walk through the engine spaces with portable computers checking specific functions that require in-person surveillance.

In the health care domain, telemetry units allow nurses to observe and monitor critical data for multiple patients from a central location. Telemetry units generally house patients who are particularly vulnerable and need constant monitoring. The use of electronic monitors which can transmit critical information regarding the patients' heart rate, oxygen saturation, etc., to a central location reduces the need for nurses to be constantly disturbing patients to check on their status, and reduces the number of nurses needed for the monitoring task.

Section 7: Recommendations

The previous sections detail the lessons learned from the case studies effort. In this section, we will extend the lessons learned to recommendations for the Navy Affordability project. Although there is a strong convention to present recommendations in a list of simple, clear bulleted points, we will resist convention in this case. This topic is not one that can be reduced to a list of bulleted points and still remain useful.

In designing future ships, it will be important to use some combination of downsizing strategies. Our recommendation would be to understand current operations, and identify leverage points for change with high payoff. It is also important to survey the user community via interviews or suggestion boxes to better understand the user. Finally, some form of a top-down strategy will allow one to question current function allocation, current means of accomplishing tasks, etc. It will be important to step outside of our view of current operations to avoid maintaining legacy systems that are difficult to see from within the system.

It will be important for the Navy to use an iterative approach in designing ships of the future. This will require the use of high-fidelity simulations and realistic testbeds. It will also be important to build iterations into the project timeline. Iteration was a constant theme in the successful re-engineering efforts we reviewed. In the nuclear power plant Technical Support Center, they were able to run exercises with different configurations of people and furniture until things ran smoothly. On the Yorktown, many new procedures were introduced, tested, revised, and tested again before they were accepted. Technology was introduced and revised iteratively until the system ran smoothly. In contrast, the design schedule for the LHA did not accommodate revisions. After the initial shake down voyage, policy was set. Even though it required only a simple fix to change the software so the engine spaces could be reliably monitored electronically, based on the initial failure, the software was abandoned and the ship has always run with manned engine spaces.

The use of a clearly-stated goal, which can be used as a guiding principle and motivator for all people involved in the effort will be important for future design and re-engineering efforts. Without a clear goal, people begin to question the rationale behind new procedures and technologies. This can set an adversarial tone before new procedures and technologies have even been tested. A clearly stated goal can help unify the effort and engage people at all levels of the organization. For the Yorktown, the goal was to reduce workload. For the Southeastern nuclear power plant Technical Support Center, the goal was to improve performance during drills. The goal also serves to guide the selection of new technologies. It is easy to be seduced into purchasing new technologies because they exist and demonstrate exciting new capabilities. This can lead to a scattered approach to selecting new technologies, and chaotic or counterproductive implementation efforts. If one has a central goal to fulfill, and one assesses the impact any potential technology will have on the goal, the technology selection process will be much more focused and effective.

Training will be a key issue for the Navy as ships operate with fewer people. A likely consequence is that only the most qualified people will be on ships as more mundane tasks are taken over by technology. The consequence will be that the Navy will need to find ways to train people skills that are currently learned via on-the-job training and mentoring. It will be important to plan for this and build training infrastructure *before* a lack of skilled personnel becomes a problem.

One key challenge in designing the ships of the future will be to consider the impact of change at all levels. As illustrated by the Yorktown, this is not a trivial task, but clearly an important one. One critical element is to consider the workings of the ship during different modes of operations. For the Navy this will include battle situations, littoral warfare, operations other than war, and damage control situations. The Navy will be forced to consider tradeoffs as it may not be possible to provide optimal staffing for all of these situations in future ships. For example, in the commercial maritime industry in Japan, tankers are operated by nine or ten people. These are large ships, over a quarter of a mile long. If a fire occurs, the ship is simply abandoned. The industry is willing to accept the risk of losing a ship in exchange for the savings of operating with fewer people. Although the Navy clearly is not willing to build disposable ships, it is imperative that the Navy consider the impact of change for different types of situations and modes of operation.

It will be important to take into account the changing conditions of the world. Although much can be learned from the past, designers must question the relevance of previous scenarios and world conditions for the future. In the cases of the FFG7 and of GM, a failure to take into account the changes in the world provided serious setbacks. For the FFG7, this meant a ship designed for short missions that never happened. The ship has always operated without the shore-based maintenance structure intended. For GM, a failure to see the changes in the world meant a costly delay in changing the types of cars they made and the ways in which they made cars.

Although much of this paper emphasizes the early stages of re-engineering such as identifying leverage points, choosing a strategy, and designing the re-engineering effort, it is important not to underestimate the implementation phase. Managing the re-engineering effort is critical. Interviewees on the Rushmore stressed the importance of keeping people at all levels of the organization apprised of changes that will impact them. They also talked about the importance of a feedback mechanism for people to use during the implementation. Another key element identified by the crew of the Rushmore was the need to coordinate the installation of new technology, training, and workload peaks so that personnel are not overloaded during the implementation. A failure to manage the implementation phase can lead to resentment and skepticism within the organization that is likely to have a negative impact on acceptance and the overall success of the effort.

Benchmarking is a powerful tool as illustrated by the Beville Engineering case presented in this report. Although there may be few direct comparisons to be made for benchmarking for the U.S. Navy, foreign navies do offer relevant examples. It may be useful to investigate the Royal British Navy's use of more specialized officers who choose a branch upon entering the Navy and continue to build experience within that branch, and the use of less specialized enlisted personnel who are crosstrained to fulfill several functions. The use of contractors to fulfill adjunct functions such as maintenance, laundry, and tailoring may be a means to reduce costs on U.S. Navy ships. Analyses of other foreign navies who operate with smaller budgets is recommended to obtain benchmarking data, as well as a better understanding of the tradeoffs involved in downsizing a navy.

The importance of informal networks in a large, bureaucratic organization should not be underestimated as illustrated by the General Motors case. Although the re-organization in the 1980s made good sense on the surface, the failure to take into account the impact of the re-organization on the informal networks within the organization had devastating effects. Reports indicate the company was paralyzed for 18 months (Debbink, 1996). Although this may be less relevant for an individual ship within the Navy, as large-scale re-engineering takes place, the impact on informal networks must be considered.

As the Navy is interested in introducing new technologies to support re-engineering efforts, it is important to keep in mind that changes in technology impact an organization at many levels. Across the cases we studied, technologies that seem to best support downsizing efforts fall into three categories: tools to build and maintain shared situation assessment, technology to support the use of remote specialists, and central monitoring systems that allow for fewer humans to monitor a larger area from a central location.

Potential Tools

In addition to the general guidelines listed above, our case studies have suggested a number of tools to help the design community achieve dramatic reductions in staffing. These tools are like a ruler or a level in a carpentry box, to make sure that the construction is properly sized and shaped. For teams, the tools are to establish that the right balance of factors is established. These tools have been suggested by our analysis of the case studies, but have yet to be formalized or tested in any way. We offer them here as a promising set of hypotheses that warrant further development.

Ratio of the Decision Makers to the Overall Staff, in a Command Post. We propose that the goal should be 1:5 or better. We have NO data for this. It is just a starting point, but we need to start somewhere. If it is wrong, because it is insensitive to conditions, then we can learn what those conditions are. The tool needed here is a way to identify the real decision makers. The strategy of identifying the actual decision makers was demonstrated in the nuclear power industry, and is likely to hold in other domains.

Percent Time Spent on Overhead and Information Management Tasks. This relates to the u-shaped function of staff size and workload. The more time spent on disseminating information (e.g., preparing briefings, sorting messages, etc.) the more likely that the team is too large. We don't yet know the appropriate ratio, or how the components would be measured, but believe exploration of this through future research would have high payoff.

Concentration of Expertise. If experts are needed to operate systems, that is a sign that an equipment re-design may be needed. If the expertise required is about domain knowledge, that may suggest other types of aids. Similarly, if two people need to coordinate frequently, perhaps their positions should be merged. What is preventing this: is it the workload (having to control many subordinates, etc.) or the expertise (having to learn a new domain)?

Benchmarking. We need command-and-control tools to establish standards for performing given tasks. We also need to identify these tasks/functions. For example, as a starting point we might hypothesize that at most we would want four planners on a team. Anything more than that is going to reduce productivity. Within a C2 setting, it may be possible to identify standards for the number of elements or subordinates that should be controlled before it is desirable to add additional staff members.

Tracers. It would be nice to slap a tracer onto a certain proportion of messages or data elements and watch them propagate through the system. Then we could estimate the value added/transaction, and perhaps use this as a metric of effectiveness. We would expect that the technology for tracing data streams could be readily available, and could be a useful adjunct to any information management system. Car mechanics and other specialists make sure they have diagnostic capabilities to see if components are running well. Command and control systems should include diagnostics as well, to permit the information managers to develop metacognition about where their system is running well, and where it is running rough and needs recalibration.

Gridlock. Where does the flow of interaction get stopped? Are there certain positions that hold up the others? It would be useful to have tools to identify these. The other people in the command post would spend disproportionate amount of time waiting for the gridlocked positions to clear out.

Ratio of Handoffs/Transaction. A tool here would indicate the number of times a data element was rerouted before a meaningful transaction occurred. The ideal ratio would be 1:1, a single handoff for each transaction. Too often, the ratio is high, as messages are sent to assistants, transmitted through assistants, relayed, and so forth. Information managers could benefit from a tool or procedure that allowed them to determine the number of times a data element was rerouted before a meaningful action was taken. Just as we have grammar checkers that let us know the average sentence length of a document (so we can revise the wording and make the document more accessible to readers), so the C2 systems should permit evaluation of the handoff/transaction ratio to permit continual improvement, or at least to permit the information managers to flag cases where the ratio seems high, so that further scrutiny can be made.

Audit Trail. It would be helpful to construct an audit trail of the decisions that generated a product, such as a plan. It could be helpful to information managers to construct an audit trail of how critical decisions were made. For plans, for resource allocations, for judgments of timing, the control room staff should be able to recreate the team decision making process so that after the fact, it would be possible to identify weaknesses, diagnose these, and take remedial action.

Ratio of Information Received Versus Information Sought. This would indicate the level of passivity in the command post. One observation we have made is that as information technology is introduced, the command post personnel become more passive. Often they spend their time merely scrolling through emails. They fail to show the proactive stance of actively seeking information, perhaps because they lack a good mental model of how the system works, and how to search for what they need. One potential indicator would be a metric for given positions of how many messages were merely received, versus the information items that were actively searched for. We don't know what the "ideal" ratio would be, if it even makes sense to speak of an ideal ratio. However, if information managers saw how lopsided the ratios actually were (compared to command posts with older technology) they might be motivated to make changes.

For a Given Individual or Cell, What is the Impact or Value of Outputs? Can we set up a market economy in which people "purchase” those products, in order to gauge their value? Too often we have seen cells that were maintained even though no one used their products. The metacognition was so poor that no one noticed the lack of value. One way around this is to find some artificial way to establish a market economy. For example, staff members in a current operations cell might have a limited number of tokens that could be used to purchase the next modification of a plan, or the listing of named areas of interest, or decision matrix overlays, or other products. The information manager might learn very quickly that many of the products were never purchased, and that the cells generating these products were not worth continuing.

Message Value. Can we set up a market economy to gauge the value of messages emerging from a node in the command post? That is, how much would the others pay to receive those messages? That could be a valuable diagnostic. It could also help to redress some of the inefficiencies of a cost-free email distribution system.

Degrees of Separation. The claim is that skilled decision makers need selective access to raw data. How many steps are they removed from raw data in their work? Suggestion: if it is always more than three steps, then their expertise is being compromised.

Increasing the Visibility of Information Management. The u-shaped function suggests that organizations balance between competing forces. There are pressures to add staff members [to increase the amount of expertise, to speed up reaction time by having more people prepared to respond, and by performing tasks in parallel, to reduce workload by having more people available to receive and send messages, to monitor more input channels, to operate more specialized systems, and so forth]. At the same time, there are counter pressures to reduce staff: cut the work needed to manage information, reduce the number of handoffs, reduce the confusion and number of people to be notified when plans are changed, reduce confusion over roles and functions, reduce the need for 'integrators' to pull things together after a task has been decomposed in order to have several people working in parallel. The difficulty is that the information management costs of adding staff are not immediately visible, and sometimes are never visible even after an organization spins off to the right-hand side of the u-shaped function. So what is needed are some markers to make the information management costs of adding more staff become visible up front.

Cogwheel Experiment. Schon (1984) refers to a cogwheel experiment in which command post functions were speeded up to two or three or four times the normal pace. The result was an initial period of confusion, followed by rapid development of workarounds and telegraphic messages. The experiment allows the information managers to see what are the critical functions, and to identify potential strategies for improving effectiveness.

Section 8: Conclusions

This paper presents an important study of re-engineering. It goes beyond previous compilations of case studies in focus. Specifically, the cases investigated here involve organizations that have undergone dramatic personnel reduction and introduced new technology. Previous case studies have focused predominantly on proceduralized tasks. The case study research team has emphasized command and control settings and tasks that require considerable teamwork. Furthermore, our analysis includes an in-depth examination of what steps organizations have taken and steps that have been avoided. We have gone beyond recommendations that are little more than slogans found in similar efforts, to a level of specificity that provides a view of *how* previous efforts were accomplished.

Our emphasis on command and control organizations is driven by the interests of the U.S. Navy. Organizations such as the CIC of a ship present a much more complex downsizing challenge than other parts of an organization. Our examination of the nuclear power plant Technical Support Centers and the USMC Regimental Command Post provide important insights into re-engineering of command and control centers. These cases indicate it is possible to reduce the number of people in an organization and actually improve efficiency of operations. A set of hypotheses regarding the development of downsizing tools for command and control environments have been offered as part of this report. Although re-organization of CIC clearly warrants careful consideration and study, it is important to point out that gains in terms of affordability are limited if one focuses solely on the CIC. As with the Technical Support Center, reducing the number of people in this command and control environment does not necessarily reduce the number of people needed to operate the larger organization (i.e., the nuclear power plant or the ship). It will be important to consider the re-organization of the CIC in the context of the larger ship if affordability goals are to be achieved.

A set of recommendations based on lessons learned from the re-engineering efforts studies here are offered. In addition, we propose a set of tools that can help the design community achieve dramatic reductions in staffing. Future efforts should include a formalization of these tools and evaluation of their effectiveness in a real-world re-engineering effort such as the DD-21.

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