Effects of Collocating Integrated Product Teams

Impact on Cost, Schedule, and Risk

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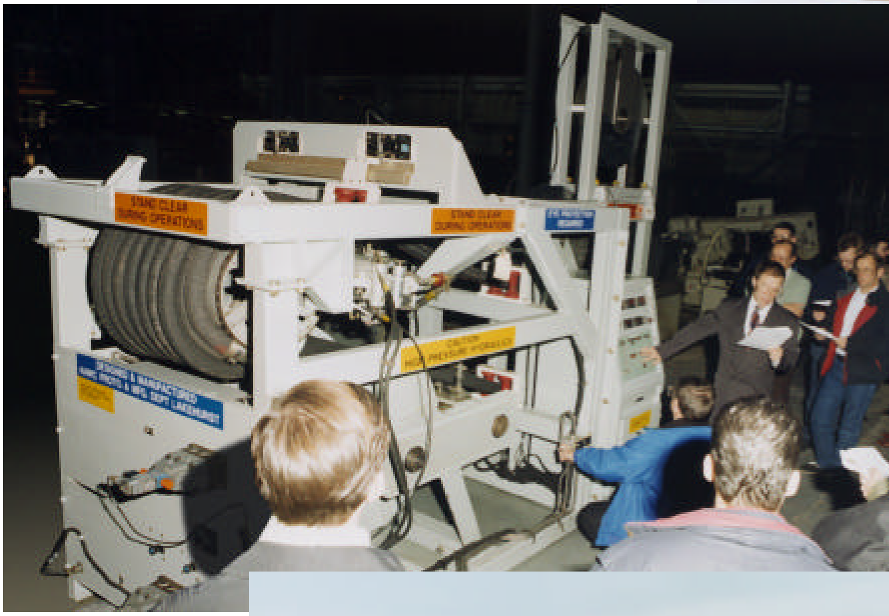
Following the end of the Cold War and the successful military actions in the Persian Gulf, Congress assigned the Base Realignment and Closure (BRAC) Commission the formidable task of evaluating DoD recommendations for realignment to determine how best to downsize military departments without jeopardizing efficiency. Toward this end, BRAC analysts examined commercial industry trends to identify potential ways to reengineer the future military infrastructure.

During the mid-1990s, we participated in an assessment study sponsored by the Navy at its Air Warfare Center in Lakehurst, N.J. We found that while some industry concepts and technological advancements may seemingly offer effective templates for reorganization, other factors need to be considered for maximum efficiency in operations.

Impact of Technology

Technology has permitted many organizations to survive, and in many cases increase efficiency. Layers of management have been removed and the organizations have become leaner and "flatter," suggesting that the organizational chart is losing its traditional pyramid shape.

In particular, the evolution in information technology, including electronic mail, video conferencing, and fax machines has enabled the establishment of links across entire organizations, laying the groundwork for a completely differ-



In-Flight Refueling Hose Reel Test Stand. An Integrated Product Team developed a prototype KC-130 Test Stand to better test refueling hose reels, after malfunctioning equipment led to loss of an F/A-18 and an A-4. The stand was completed in 30 months.

F/A-18 aircraft testing a modern barricade at the Lakehurst facility. Barricades made at Lakehurst are the last opportunity to stop a plane from going off the end of a carrier.

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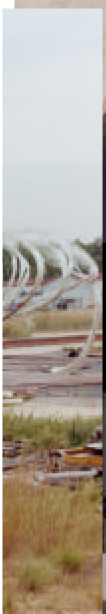
U.S. Navy photos

AN F/A-18 SAFELY CATCHES "THE WIRE" ABOARD THE CARRIER. THE RETRACTABLE SHEAVE HOUSING AND COVERS CAN BE SEEN AT THE END OF EACH WIRE.

AN AVIATION BOATSWAIN MATE SIGNALS AN F-14 TO PREPARE FOR LAUNCH. AS ONE AIR BOSS TOLD THE MANUFACTURING ARTISANS AT LAKEHURST AFTER A RECENT TOUR, "WE JUST ASSUME THAT THE LAUNCH AND RECOVERY SYSTEMS WILL WORK. WE NEVER STOP TO THINK H O WCOMPLEX O R CRITICAL THESE SYSTEMS ARE TO COMPLETING OUR MISSION."



LONNIE WHITE (LEFT), ALRE ENGINEERING, CONFERS WITH ROBERT WIGGINTON, QUALITY ASSURANCE TEAM LEADER, ON A CORRECTIVE REPAIR PROCEDURE FOR RETRACTABLE SHEAVE HOUSING AND COVERS.

ent approach to organizational management.

Physical proximity is no longer a major contributing factor in coordinating the location of functions. Members from different disciplines can be located irrespective of geography and still maintain equal levels of productivity. The electronic sharing of information promises the look, feel, and synergy of working at the same site, enhancing and improving teamwork.

Technology has also improved manufacturing, with tool packages such as computer-aided-design and computer-aided-manufacturing software programs.

Reorganization of the Prototype and Manufacturing Department

The Navy's Prototype and Manufacturing Department (PMD) in Lakehurst is a $200-million manufacturing facility staffed by 214 manufacturing engineers and artisans. The mission of the department, which has evolved over 20 years, is to provide emergency manufacturing, prototype manufacturing support, producibility analysis, and drawing package validation, and to apply new manufacturing technologies to the design, development, and product verification of flight-critical Aircraft Launch and Recovery Equipment (ALRE), support equipment, and similar hardware systems.

When the Navy recognized that the PMD's traditional organizational structure could no longer support the product demand cycle, it redesigned the PMD Lakehurst organization based on the business process, focusing on the department's core competencies, that is, the specific capabilities or activities fundamental to a Service or agency role. This alignment was radically different from the previous organizational system, which senior management basically had designed merely by moving blocks and lines on an organizational chart.

The use of technology facilitated some organizational changes at the PMD. The department adapted well to the new business environment, dramatically improving its operations. The new business process redesign affected the culture and behavior of all involved.

Key to the improved organization was identifying the labor required to perform the tasks necessary to deliver quality equipment and the coordinating activity between different labor disciplines. Analysts determined that a concurrent engineering framework for organizational design was the only structure that would: 1) permit increased responsiveness in terms of shorter cycle times; 2) lower costs; and 3) capitalize on Lakehurst' experienced and proven approach. Using integrated product teams (IPT) to design, prototype, and test equipment represented a major change to the traditional development process.

The Lakehurst Program Studies

With several technological breakthroughs in mind, BRAC analysts proposed separating the departments collocated at Lakehurst and transferring the prototype department to a Naval Depot in Jacksonville, Fla., while keeping the engineering and testing disciplines at Lakehurst to reduce infrastructure and overhead.

The argument was that a virtual ALRE organization could meet the needs of the fleet and be more cost effective by not collocating the multiple disciplines. The virtual organization could use electronic technology to coordinate and control the work. Information could be passed along from engineering departments to dislocated manufacturing facilities. Close physical proximity was not critical to successful manufacturing.

This proposal raised the question of whether the ALRE team *could* operate effectively as a virtual organization with a team player located 1,000 miles away. Could electronic technology be used to coordinate and control ALRE work efforts? Could the physical separation of the ALRE team save money yet not introduce undue risk into flight critical parts?

To answer these questions, Navy Lakehurst conducted a study of five ALRE and support equipment manufacturing programs using IPTs. The particular programs were selected because auditable data were available, and their quality standards and length of schedules represented typical projects found in the prototype department. The programs included the Low Loss Launch Valve (LLLV), the Fresnel Lens Optical Landing System, the In-Flight Refueling Test Stand, the catapult power cylinders, and the retractable sheave housing and covers.

Data collected on the five programs emphasized identifying the time, frequency, nature, and duration of interactions between team members. Program complexity was identified in terms of phase of life cycle, quantity of parts, and number of hours to complete the program.

FIGURE 1. LLLV Program Interactions between IPTs — January 1993 through January 1995

Category	Number/Duration
Number of valves reviewed:	16
Number of repairable parts per valve:	31
Communication actions (average):	25
Request for Engineering Information:	1 per valve
Number of written issues:	16.3 per valve
Requests for Salvage Action:	8 per valve
Total number of written communications actions:	25.3 per valve
Days to resolve all communications actions:	73 days per valve
Days to resolve each written action:	10 days
Other engineering time spent in PMD (not accounted for in above):	5.23 hours per week

The Low Loss Launch Valve Program

This article focuses on the findings from the LLLV program study, which provided the most extensive data for analysis. The valve, which is used on conventional (CV) and nuclear-powered carriers (CVN), admits and shuts off the flow of steam to the launching engine cylinders for the catapults launching aircraft. Only 96 LLLVs exist, of which 57 are actively in service. The remaining 39 valves are either waiting to be overhauled or are not usable.

The LLLV's procurement history is significant. The last three companies awarded the contract to build this valve either went out of business or defaulted on delivery. Because of the lack of continuous supply of LLLVs, Navy Lakehurst became responsible for overhauling or replenishing the valves.

When a catapult fails, the ship requests an LLLV from the supply system. Because a carrier is not fully operational without the catapult, the request for the valve is considered a fleet emergency. The Navy's inventory control point tries to maintain a supply of three LLLVs, but the supply system often does not have any available because overhauling and testing a valve takes about 12 months.

All valves, whether new or overhauled, are fully tested by Navy Lakehurst before being certified “Ready-for-Issue.” The testing procedure is extensive, and includes launching equivalent weights at the Lakehurst facility, which has a land-based catapult system.

Figure 1 charts the type, nature, and duration of interactions between the IPT members on the LLLV program for the period January 1993 through January 1995.

Effects of Collocated Teams

The study showed that the number of written communications actions between team members during testing and evaluation averaged more than 25 for each valve. Communications actions included requests for salvage action, additional information, or inspection reports.

What is particularly worth noting is the time that engineering personnel spent in the PMD informally directing work, changes and so forth, which is not included with other communications actions and visits. This engineering time, which averaged 5.23 hours weekly, is an indication of how often available team members had to address problems and provide direction.

Analysts determined that this immediate availability of engineering support to address problems and provide direction was essential to efficient manufacturing. As the Figure 1 data show, contact intervals between team members were numerous and of short duration. This process led to completion and documentation of success on smaller work units, which, in turn, led to overall success.

Thus, communication is critical to the successful design and manufacture of equipment. Communications between team members must be clear and frequent. Various methods can be used to conduct communications; regular joint visits by the team members to the common sites are important. The communication methods used in Lakehurst PMD project studies were varied and extensive. The review also indicated that more technically complex programs and “flight critical” equipment require and receive the maximum amount of communications actions.

Insufficient communication leads to product failures and dissatisfaction. We have read construction industry studies indicating that 25 percent of problems and failures are directly attributable to poor coordination and poor communication. Further, studies conducted by insurance companies indicate people involved in construction projects resort to legal action when unexpected events or surprises occur, and there is a lack of positive personal relationships and concerns among the parties.

A U.S. House of Representatives Science and Technology subcommittee examining failures determined that communications elements were critical in preventing structural failures.

The Lakehurst studies showed that closely interrelated with the need for good communication between IPT members working on programs involving complex or flight-critical equipment is the need for the team members to be collocated. A multi-discipline team needs to develop a uniformed approach to complete a program; this is facilitated by the availability of all team members and the relationships established between team members. Collocation offers the greatest opportunity of collaboration from IPT members. It allows for a cohesive set of unique disciplines that work toward the common goal of maintaining military readiness.

The Lakehurst products are not conducive to a virtual environment. By its very nature, a prototype is not a mature product. The evolution process to final design requires feedback and interaction between engineering, testing and fabrication. Locating fabrication 1,000 miles away from other team members would minimize this interaction and introduce the opportunity for entering into production a product that has not been through the design maturation process, which increases the possibility of under-designed equipment entering into the fleet and resultant failure. The findings in the Lakehurst studies suggest that the separation of functions may have been a contributing element in the failure of commercial sources to adequately deliver valves.

Our study indicated that dislocation of disciplines not only would not be effective, but also would adversely introduce risk into the ALRE systems. Electronic transfer of information only works when the transfer is complete. For example, when transferring technical information packages via electronic means, the paper document generated must be of

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sufficient quality to be reviewed, interpreted, and understood by different personnel. Questions are more easily and quickly answered if all the team personnel are present to immediately address the issue. If they are not present, either the questions don't get addressed, get interpreted [correctly or not], or get written and forwarded to the originator for resolution. Collocation offers the environment for faster and more efficient resolution.

Any beneficial cost savings obtained by separating manufacturing from engineering and testing departments needs to be compared to any increase in risk. For the LLLV, a cost-benefit analysis showed that the overhaul schedule increased by 42 percent, and cost increased by 48 percent. For prototype products, cost and schedule increases were even higher. Using return on investment evaluation techniques, separating the IPT had no positive payoff. Figure 2 charts the calculated impact on the schedule of several Lakehurst products if the IPTs were dislocated.

Non-defense-related industries are also discovering the importance of collocation to gaining improvements, such as product cost, quality, and schedule. Ford Motor Company, in its goal of improving upon America's most popular car, the Ford Taurus, considered all aspects of designing and building cars for its 1996 redesigned car. An obvious and important innovation on managing this program was collocating the entire Taurus team of 700 people in the same building. By having the engineers, designers, and factory-floor workers working side by side, each discipline was able to critique each other's work as the project went along. According to *Business Week* magazine (July 24, 1995), the new Taurus avoids the mix and match dissonance of many American cars.

At the engineering firm of Day & Zimmerman, Inc., headquartered in Philadelphia, Pa., senior management decided to relocate one-fourth of the company staff outside the city and electronically connect the two sites. However, after a five-year trial period, they realized the virtual office wasn't working. As reported in the *Philadelphia Inquirer* (Dec. 19, 1995), electronic technology turned out to be no match for random conversation, spontaneous interaction, and the ideas that spring from them. Day & Zimmerman moved the entire company back to one location.

A Summary of Study Findings

The success in manufacturing was directly attributable to the use of IPTs. Extensive communication between engineering, manufacturing, and testing teams led to the resolution of problems quickly. Face-to-face meetings were frequent, and issues were resolved in minutes without resorting to technical memoranda or other protracted written documents. Collocating the team members was the most critical factor for benefiting from concurrent engineering.

Having design engineers working closely with the manufacturing team led to savings from identifying problems during the design phase rather than on the manufacturing floor. The IPT structure led to savings in schedule length and material savings because fewer prototypes had to be fabricated. Similar savings have been presented on the F/A-18 E/F, the Joint Advanced Strike Technology Program (JAST), and other defense programs.

Properly employing concurrent engineering and integrated product teams can reduce schedule, risk, and final cost. Physical and durable products that require collaboration from multiple disciplines benefit tremendously by being collocated. Evidence indicates that the more complex a system is, the greater the need for more frequent and local communication, which, in turn, increases the need to collocate disciplines.

Changing an organization that has worked well deserves a fair and careful analysis. Suggesting theoretical approaches and unproved technologies as the answer to cost reduction is naive and sophomoric. The cost of ALRE item failure usually is the loss of an aircraft, a life, or both. Moreover, just a marginal decrease in quality (.00001 decrease) will result in the annual loss of four planes, costing an average of $55 million each. As these figures attest, no economic model supports separating the concurrent engineering organization found at Navy Lakehurst.

Editor's Note: The author acknowledges the critical role Navy Lakehurst provides in supporting the carrier fleet, particularly Navy Vice Adm. John A. Lockard, Commander, Naval Air Systems Command, who implemented the Aircraft Launch and Recovery Equipment Acquisition and Life Cycle Support Plan, dated Sept. 24, 1996. This plan allows the Navy to maintain the organic core workforce at Lakehurst to do research, development, test and evaluation, and limited manufacturing for ALRE systems.

FIGURE 2. Impact of Dislocating IPT Members

Project	Percent of Schedule Increase
Low Loss Launch Valve	42
Critical Item Manufacturer	42
Prototype Programs	105
Fleet Emergencies	30
Engineering Investigations	30
Rework	40
Manufacturing Engineering	30