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THESIS

IMPLEMENTING NEW WORK PROCESSES
AT THE ROYAL NORWEGIAN NAVY MATERIAL
COMMAND

by

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**IMPLEMENTING NEW WORK PROCESSES AT THE
ROYAL NORWEGIAN NAVY MATERIAL COMMAND**

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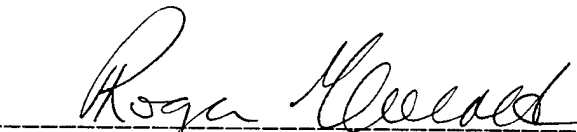
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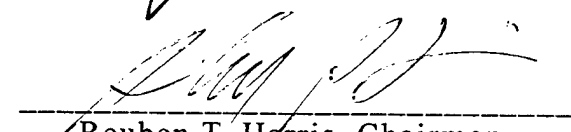
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ABSTRACT

This thesis focuses on key factors that increase organizational effectiveness at the Royal Norwegian Navy Material Command. These factors include implementing work processes throughout the whole organization, implementing information technologies that support work processes, and the use of teamwork across functional areas to solve organizational and technical problems.

Using integrated teams, matched technologies, and tailored work processes in several material programs, RNoNMC observed an increase in quality in the form of quicker results with fewer revisions. Teamwork methods emphasize a systems view towards organizational and technical solutions that integrate the human needs, the technology and the organization.

The RNoNMC can further increase its organizational effectiveness by implementing similar principles to the whole organization. Members of the organization should actively participate in designing and implementing work processes with technologies that support individual, program, and organizational needs. Routine tasks can be automated and time can be more effectively used on solving complex problems. Integrating all parts of the organization in problem solving processes creates an environment of continuous learning.

The recommendations presented derive from a study of change processes in previous programs, socio-technical systems theory, and the expected benefits of information technologies in the work place.

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LIST OF ABBREVIATIONS

CO	Commanding Officer
COD	Computer Operations Division
DoD	Department of Defense
DoD-Std	Department of Defense Standard
DSB	Data System Branch
ILS	Integrated Logistic Support
IncoSe	International Council on Systems Engineering
IT	Information Technology
Mil-Std	Military Standard
N/A	Not Available
OJT	On the Job Training
RNoN	Royal Norwegian Navy
RNoNMC	Royal Norwegian Navy Material Command
SE	Systems Engineering

I. INTRODUCTION

A. PURPOSE

The purpose of the thesis is to evaluate how to introduce and implement new work processes within the Royal Norwegian Material Command (RNoNMC). Some work processes are based on work completed in material programs within RNoNMC. Results from these programs form a baseline for a similar approach to implementing new work processes within RNoNMC's organization.

The research will investigate how human and social effects of the organization combined with new technology can be used to improve organizational performance. Performance is related to the quality of products and services delivered to RNoNMC customers. RNoNMC products are combat systems and its services are maintenance of those systems in support of the user's operational tasks.

B. RESEARCH QUESTIONS

The main research question is how can the current work processes be changed in order to improve the organization's performance? This question is answered by investigating the following questions related to past practices and the environment of RNoNMC.

- Why does the RNoNMC need to improve organizational performance?
- How has RNoNMC worked in the past?
- How is RNoNMC currently working?
- Which work processes can be improved at RNoNMC?

Since the Armed Forces' budget has decreased during the recent years it is reasonable to assume that the economical trend continues. The main resource of inputs to RNoNMC is employees and yearly funds that are transferred from the Norwegian Department of Defense.

In order to increase organizational performance humans need to be better utilized. This can be achieved by implementing and improving work processes with support from suitable technology. Figure 1 outlines the design of the thesis, and illustrates the current work and future work processes within RNoNMC.

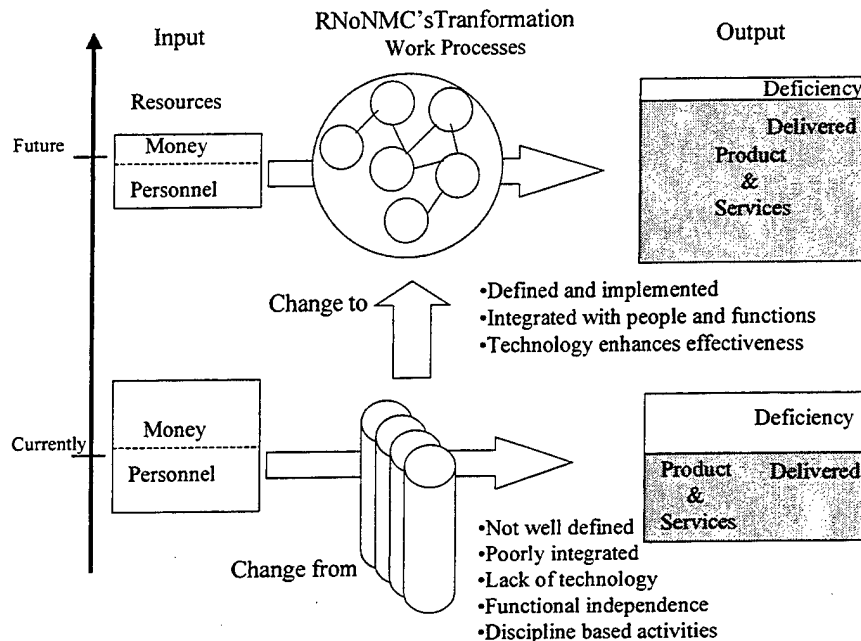


Figure 1. Improving Effectiveness by Changing Work Processes.

Currently, existing work processes function like stow pipes that are functionally dependent and poorly integrated across functional boundaries. The organizational output is not at maximum efficiency. Better definition and integration of work processes increase the organizational output while the input is decreased.

C. THESIS OUTLINE

Chapter II describes the history and how RNoNMC currently works. Chapter III describes a desired situation after the reorganization efforts and the chapter identifies weaknesses with the organization. Chapter IV compares work practices and product results of different Navy programs. Chapter V compares the current situation within the RNoNMC with the

situation before the last reorganization effort. Chapter V is a literature review of socio-technical systems including analyzes of related cases from several industries. Chapter VI analyses contributing factors to a continuous organizational change process. Chapter VII summarizes the results and the conclusions from the thesis.

D. EXPECTED BENEFITS OF THIS THESIS

This thesis forms a baseline from which new work processes can be introduced and implemented in RNoNMC. New work processes enable RNoNMC to better estimate the time and resources required to accomplish complex tasks, such as material programs and major maintenance on ships. The new work processes focus on integration and cooperation between different branches and offices within RNoNMC. The aim of the work processes is to increase the organization's capability to deliver products with better quality to the customers. The customers are the operational users in the Royal Norwegian Navy.

II. THE EXISTING SITUATION WITHIN THE RNONMC

A. INTRODUCTION

The Royal Norwegian Navy Material Command (RNoNMC) is located at Haakonsvern Naval Base, Bergen, Norway, where it has been located since 1962. Currently, RNoNMC has approximately 1400 civilians and military employees. Bergen is located on the Norwegian West Coast, but the RNoNMC has regional divisions at several other locations around the Norwegian coast. The regional divisions are responsible for supplies, maintenance of the local Navy sites and minor unscheduled repairs on the naval vessels.

RNoNMC is responsible for acquiring and maintaining all of the Navy's equipment. In recent years, most of the Navy's fleet has reached end of service life. Several new material programs have been initiated concurrently. These programs include new Patrol boats, Frigates, Submarines and refurbishing of various weapon systems.

Over the last years the Norwegian Armed Forces have experienced shrinking budgets. Ongoing programs compete for scarce resources, including money and personnel. This puts great pressure on all material programs; if there is a delay, the programs are at risk of being cancelled.

The environment external to RNoNMC is also changing. Modern combat systems are becoming complex, and must integrate information from a variety of sources. New technologies enable faster and more efficient processing of available data as well as smoother integration between systems. Effective use of technology in combat systems can result in decreased required resources, manpower and cost.

RNoNMC contractors use technologies to build more efficient combat systems with lower maintenance and supply requirements. RNoNMC must also use technologies and new work processes to maximize organizational effectiveness. If RNoNMC is unable to change its

organizational processes and learn to operate more efficiently it risk jeopardizing the Armed Forces' long term goal of cost reductions.

B. ORGANIZATION

Since the late 1980's, the RNoNMC has implemented two major reorganization processes. The latest reorganization effort began in 1993. The original plan intended to start implementing the new organization by the beginning of 1995. However, the new organization was not in place and operating in late 1996.

Before 1995, RNoNMC had several weaknesses. The functional organizational structure consisted of many offices with only a few employees per office. The structure mirrored the previous reorganization where employees built small communities with narrowly focused and special functional areas. Not every function was required by the Navy's operational needs. The structure also created two distinct teams, the A-team and B-team.

The A-team is responsible for developing new technologies. Members visited military contractors and participated in seminars and exhibitions.

The B-team works with maintenance and supply. The team is responsible for inspections, maintenance, and supply of ships and Navy equipment. They serve as a link between ships and technology section, and between ships and workshops in shipyards.

RNoNMC is a professional organization with highly skilled professional employees. Over the years each individual profession has developed its own internal work standards that are based on known industry standards as well as internal best practices. Tasks within RNoNMC are both simple and complex. Re-supply of items is considered a small and simple task, while developing and acquiring a new combat system is a large and complex task, requiring several years of engineering

efforts from every area of RNoNMC.

As shown in Figure 2, RNoNMC is organized into divisions, departments, and offices. Divisions are generally independent, but there are some inter-dependencies between divisions. Divisions are organized according to their responsibilities.

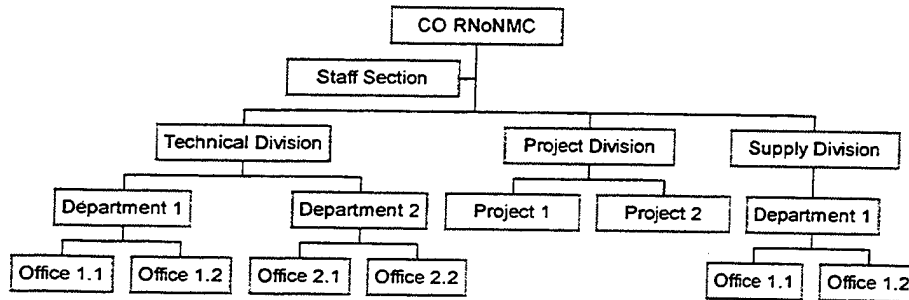


Figure 2. RNoNMC's Organization Before 1996.

The supply division is responsible for all matters related to supplies. Likewise, new material programs are the responsibility of the project division. But at initiation of a new material program input from all the other divisions is required.

The functional structure consists of the Commanding Officer (CO) with a limited staff. Functional specialists and engineers are located in dominant organizational areas such as technology, maintenance, supply, and projects. This structure allows for functional specialization with a

limited ability to cross coordinate and communicate between functions.

Middle level managers stay within their functional domain. It is the responsibility of higher level management to effectively integrate between the functional domains. But higher management levels are mainly focused on the RNoNMC strategy towards external environment, customers, and suppliers. Resources are inadequate to perform needed internal coordination across engineering domains. The integration was not planned at higher levels of management.

Individual job positions do not necessarily contain an accurate description of work or list the responsibilities of jobs. Since few jobs were accurately described, jobs became whatever each person wanted the job to be. Employees enjoyed a high degree of freedom. An organizational culture developed and employees worked with that they found most interesting. The only existing requirement was to complete the required jobs on ships done prior to the next departure.

C. INFORMATION SYSTEMS

Within RNoNMC there exists several systems that provide information needed for planning and managing jobs. There also exist systems that manage and control inventories. Few of these systems are able to exchange information with other systems. There may be conflicting information, making it difficult to find "true" information. In many instances the most efficient means of conforming information is to manually take the forms to the different offices to get necessary approvals and signatures. This approach ensures that the correct information is received. Otherwise, a form may wait in an office with no accountability for correct information or timely circulation.

For new material programs there is no information system that handles all changing needs throughout the program's lifecycle. Some information systems exist, but they are poorly integrated. Recent

information systems require considerable user threshold. An average employee is only able to use portions of the systems. Customizing the IT-system to the needs of RNoNMC requires considerable training and a significant amount of work experience within material program development. Optimum use of the system also requires that work processes are thoroughly described and that an organizational willingness to implement new ways of organizing activities exists.

New material programs are full of opportunities. Except for budget and major milestones, very little is fixed and decided. Therefore, work process inventions in RNoNMC have traditionally evolved from material programs. The program has money and necessary resources. Whenever engineers experience difficulties the program managers have means to overcome these difficulties. Some successful practices are implemented into RNoNMC's organization on a broader basis.

D. WORK PROCESSES

Work processes in use are seldom documented formally nor formally acknowledged. They are developed at the working level and the best practices are passed down by "word of mouth." These routines are affective at each individual office, but they do not function well within complex situations that require cooperation and integration from multiple offices within several divisions. Furthermore, best practices are dependent on individuals. What may work well for one employee may not necessarily work well for others.

Some best practices merely knowing who to call to get a task accomplished. If it may take too long to get through the chain of command and the established bureaucracy, there is always someone who may be able to complete the job sooner outside established routines. However, this is dependent on personal relationships between employees.

Since many combat systems are old, most of the work within RNoNMC relates to maintaining old equipment. It requires more material and resources to maintain combat systems operational. Over time, offices have developed their own routines and best practices. Thus, maintenance personnel find themselves working with old equipment more often and are unable to keep updated and proficient on new technologies.

Shipboard personnel that work with operational equipment understand the operational and technical demands onboard ships. Maintenance personnel know how to maintain the equipment and what work the Navy shipyard is capable of doing on the equipment.

This knowledge is crucial for new material programs. New equipment must meet the operational requirements and be synthesized in a cost-effective manner. This includes requirements for training, documentation, supply and maintenance, commonly referred to as Integrated Logistic Support (ILS). If material programs are not manned and developed by personnel with adequate technical knowledge and skills regarding maintenance and supply, the programs might not meet the requirements of the ILS elements.

Most often, programs have not met the requirements. When new equipment is deployed for operational use, faults occur and the equipment appears difficult to maintain and supply. Sometimes supply items are not available and a ship may spend valuable operational time tied pier-side for repairs. Occasionally, programs have purchased the incorrect spares and ships and maintenance personnel must wait to receive correct spares.

Other problems include incorrect data on spares. Spares may be available in stock, but difficult to find, preventive maintenance is delayed to maintain the ships operational status. As a consequence, RNoNMC may need to shorten the life-time of the equipment.

Other problems involve the people within the programs. Traditionally, these situations lead to the "us versus them" syndrome

where it always is someone else's fault. Maintainers blame program personnel for the problems. Program personnel blame maintainers for not supporting them with required information.

E. THE RNONMC PROGRAMS

The RNoNMC formally runs all Navy material programs. In some cases other parts of the Navy may run a program, or part of a program for a short time. However, RNoNMC always makes the decisions involving the purchase of new technology, new systems or new combat platforms. This is mainly because RNoNMC is responsible for maintaining all weapon and combat systems within the Navy.

Even with new programs initiated, the RNoNMC is still responsible for maintaining old combat systems and the organization does not receive additional resources to handle new tasks. Norway is a small country, and the Navy itself maintains most of the skills and knowledge regarding warship constructions. Shipyards and weapon system suppliers within Norway have not competed on open markets. In recent years, the Navy acquired contracts on major combat systems based on open and international competition. The contract is granted to the contractor that can deliver the best solutions; the most affordable price and the lowest life-cycle costs over the complete lifetime. This is a change from the 70's and 80's where the Norwegian defense industry received most of the contracts with the Navy.

Figure 3 shows how the material programs are organized.

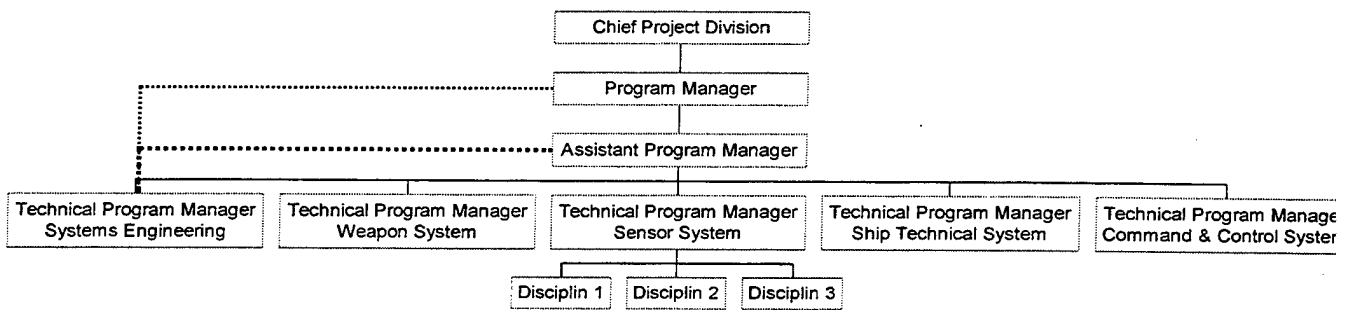


Figure 3. The Current RNoNMC Program Organization.

1. The ULA Class Submarine Program

In the late 70's the Navy looked into a new concept for submarines, the Ula class submarines. A submarine program is more or less a continuous material program. When one program is completed, a new program is immediately initiated in an effort to plan ahead. Usually, this means planning for the next generation of submarine technology.

In the beginning of the 80's, the new submarine program was formalized with a program organization. The program organization consisted of employees from the functional divisions, or line organization,

within RNoNMC as well as officers with broad operational and technical experience. Personnel from RNoNMC temporarily vacated their jobs at RNoNMC to work full time on the program. Their ordinary work with RNoNMC stops and RNoNMC operates short handed for the duration of the program. Some officers are taken directly from their position on ships, many of them do not have any previous experience from working with programs, engineering work, or engineering management. However, they are often assigned to management positions within programs.

The new submarine program was a cooperation between, on one side the German and Norwegian Navy, a German shipyard and a Norwegian weapon system developer and supplier. The program invested great resources into new combat technologies. However, some of the new technology developments did not give the expected results. The program experienced severe technical difficulties and both Navies and contractors had problems in reaching agreements on how to solve the problems.

In an effort to identify and solve the organizational problems some of the personnel involved in the program were assigned to an organizational unit skilled with program management and computer science. The unit was to be part of the Technical Section within RNoNMC, and the unit's first task was to support the submarine program. The experience gained from the submarine program would form the unit's knowledge. In future programs, the unit works together with other engineering domains within the organization.

The unit consists of mostly officers with similar experience and education. They function like a research team. They did not have many formalities within their work, but were assigned to different positions within the submarine program. Their findings suggested that the whole development process within the program was poor. The program lacked a unified design concept and design information was lost in the details of the extensive gathered information. The information consisted of

specifications, design documents, drawings, and other technical documentation, at all development stages. The program did not have the necessary control and traceability between the information and within different layers of information. Some design errors had been identified and fixed two or three times by different engineers.

The RNoNMC invested great resources implementing the recommendations from the unit called Data System Branch (DSB). The consequence for the submarine program was that the entire development process had to be reengineered. While working with the reengineering process new tools to support processes were developed. DSB had become a project within the submarine program.

DSB devoted much time to study the U.S. Department of Defense's (DoD) methods of organizing work and tasks, and the processes behind the U.S military standards that regulated the DoD's and the military's development processes (DoD-Std-2167A and Mil-Std-499/498, etc). However, many of these standards were not well known in Norwegian industry. In Germany, contractors use their own or similar European industrial standards.

The technology needed to effectively implement the described processes relies on computers. Although the submarine program did develop a sophisticated combat platform that relies upon computers, the personnel involved did not accept new methods of working, nor accepting that computers could automate parts of the work.

Within the submarine program, some employees feared losing their jobs. If the DSB described work processes together with new technologies were implemented, some jobs could disappear, or jobs might be transferred to other departments within RNoNMC. The resistance to change grew within the submarine program and word spread to other parts of the RNoNMC. The implementation of more efficient work processes for developing and managing the submarine program was not successful. The

submarine program finalized, but the technical and operational evaluation of the submarine identified several faults. The systems did not initially perform in accordance with operational requirements.

2. Shortcomings with the Change Efforts

When DSB tried to change the way the program worked, they needed to convince the program management, as well as the top management of both RNoNMC and Navy. The program was big and it had political implications, both in Norway and in Germany. Furthermore, DSB also had to change the contractor's way of working. Both the Navy and contractors had to work in an integrated manner. If not combined, the efforts would not be effective with an increasing risk of introducing more problems instead of reducing them.

In late 80's, the use of personal computers, computer networks and structured databases was not yet common in use. Even among the weapon system suppliers, computers and computer networks were technologies they developed for the customer, but not used in development. Databases with traceable process- and design-information were not available.

The only computer network used for administrative and engineering purposes within RNoNMC was installed at the submarine program. Most employees had only experienced working with computers from their jobs at different commands where computers were used for operational command and control purposes. Computers were not yet used for management purposes, nor in the specification and design process of a combat system. Training programs with computers were not easy available and common within RNoNMC. Few people outside the DSB had ever used complex database structures for collecting and controlling information. All these concepts were new to most of the involved personnel.

When introducing and implementing new technology and new work processes, everyone participated on extensive training. Even those not

working directly on the systems had to participate in the training. Employees had to learn about implemented processes and had to understand results generated from applications. The goal was to involve every employee within the program. The reasoning was that as implementation of new processes began everyone would be participating. The work processes were designed to drive the program's development process.

The database structure used to gather information was complex and in order for employees to analyze the information, they needed to read and understand complex data flow diagrams. Not only was it difficult to understand the database syntax, but employees also needed to map the abstract database information to the real world problems described by the database.

The differences in the process, computer, and database skills and knowledge, created a substantial gap between the process experts from DSB and the rest of the employees. DSB gained knowledge through extensive education and through their description of the work and development processes. Simultaneously, DSB developed the necessary database structures to support processes, and they implemented database structure together with necessary reports in a software application, installed on the program's local computer network. They became experts of the work processes, database structure, database syntax, and the content of the database.

Most of the other personnel involved in the program were exposed to this new technology for the first time. A technology gap, a misfit between the technology, organization, and the people, had been created within the program. The control of the information in the database was in hand of a few computer "geeks." Employees had not been exposed long enough to new technologies and processes. Combined with the pressure to solve technical problems in the program, the timing to implement

processes and technologies was bad.

Also, new processes would create a bigger workload, creating additional tasks on each employee. A proper assessment of the consequences of new tasks or suitability to the program organization was not performed. The technology misfit created existed within the rest of the program's lifetime and also spread to other parts of the RNoNMC.

F. THE NEW MATERIAL COMMAND

In the beginning of the 90's it was apparent that the structure of RNoNMC's organization did not serve its purpose. One of the consequences of the distinct split between the Technology and Maintenance section was that the material programs did not take enough consideration to the life cycle costs, or to design for maintenance and supply. The programs came up with new systems based on new technologies, but the maintenance and the life cycle costs were hardly considered.

The RNoNMC's slogan was "from maintenance to investments." That implied that RNoNMC shifted emphasizes and efforts from maintenance to investment activities. This is a shift from old combat systems to new combat systems. Most of the organization is supposed to support the efforts of acquiring combat systems and not maintaining and supporting old systems.

Within the RNoNMC the impression that everybody should work with new systems was created and the employees had great expectations. The goal was to create one team where everyone had enough skills and knowledge to work with new material programs as well as maintaining and supporting the old systems at a minimum level.

The lessons learned from the submarine program were maintained and developed further by DSB. However, due to the organization of RNoNMC and of material programs, DSB did not have any formal

command or influence over programs. DSB was not in a position to demand that material programs followed any pre-described development processes. However, the Project section did not support material programs with any description on development processes material programs should follow. A program's development processes dependent on the program manager. The program manager's preferred method would be the implemented process. The conflicts between the DSB and the other employees within the submarine program were known, and few program managers wanted to risk introducing conflicts into the organization.

The reorganization of RNoNMC was initiated at the same time as the start up of two major programs, the New Fast Patrol Boat program and the New Frigate Program. These two programs fought for the same resources as the reorganization. Even though the two material programs were in different phases, they still needed the best and most knowledgeable engineers. Due to size, complexity, and the Armed Forces' priorities, the New Frigate program was prioritized and was able to get presumably the most skilled and knowledgeable personnel within the Navy.

DSB used the same systems engineering (SE) processes described for combat system development to analyze RNoNMC's organization in order to describe a process that could solve the organizational problems. However, the report from DSB was not taken into account until late in the reorganization phase. At that time it was too late to get any effect of the described processes. The feedback on the report gave DSB a lesson and valuable insight in the gap between the process people in DSB and the rest of RNoNMC. Few people that read the report understood what it was about and they did not take necessary effort to clarify outstanding issues.

DSB continued involvement in smaller material programs and proved that the new development processes, combined with adequate technology, and skilled people, produced better specifications with higher

quality and faster than previously. The programs gained better control, visibility and traceability toward the contractors. Hence, the programs achieved better control, they were able to plan and budget with higher predictability.

In the new RNoNMC organization, the disciplines related to DSB was recognized as inter-discipline functions, functions that integrate and make tradeoffs between competing and conflicting interests. Together with configuration management, quality assurance, documentation, and logistics, remains of DSB were organized in a new branch named Integrated Logistic Support (ILS). ILS was located in the staff division directly under the CO of RNoNMC. The location of ILS was a political decision. Placing ILS directly under the CO gave ILS branch necessary support to solve integration problems between Technical, Support, and Project Division.

The ILS is support activities that integrate the functions between the other divisions. By integrating information, structuring information into a defined structure, the RNoNMC can cut costs. Information can be found and information can be reused. Designing systems for easier supportability and maintainability can create tremendous savings over a systems life cycle.

Figure 4 shows how RNoNMC is organized after the reorganization effort.

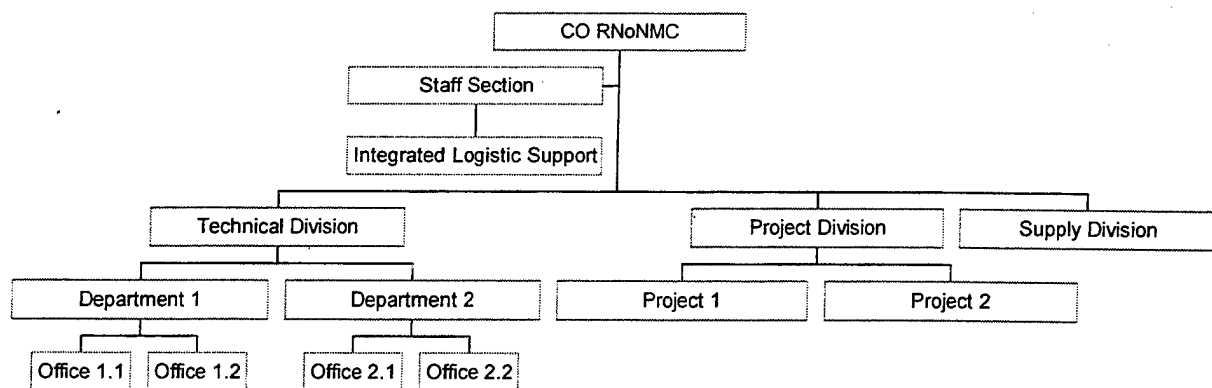


Figure 4. The RNoNMC Organization After 1996.

G. THE IMPLEMENTATION OF THE NEW RNONMC

RNoNMC after reorganization contains fewer departments, branches and offices. The previously large number of departments and offices with a special and often narrow and limited responsibility had been reduced. Thus, horizontal differentiation had been reduced. Horizontal differentiation refers to the amount of specialization within an organization (Burton and Obel, 1995). RNoNMC now contains a few departments within a division, and each department contains few offices. The number of employees within each office has grown.

The concept is to create larger offices with more responsibility. Each employee will, over time, gain more knowledge and experience by working with several systems. Hence, each employee is encouraged to learn more than just a few specialized tasks. Programs would not easily depend on key persons assigned from the organization. Because of cross training several employees are now able to support the programs with the necessary engineering skills.

The employees are supposed to work and participate in an environment that has wider responsibilities and more people available. This concept enables employees to build larger competence networks and have more people available to discuss and solve complex problems with. In the long run, the organization would be more dynamic and able to respond quicker to changes in the environment.

The management of the reorganization efforts failed to fully analyze and decide an important issue; what are the main tasks of the organization, of each section, each department, each office and finally each job position? How are different tasks interrelated and how should each employee perform his job? How should integration and cooperation between all elements be accomplished? The reorganization managed to identify the boxes, or the structure, of the organization, and they managed

to place each individual from the old organization into the new organization. There was no description of new tasks or new jobs. In many instances, the employees transferred some old jobs and old tasks into the new organization. This was not a managed and integrated effort from the management of the reorganization. New ways of organizing work, new processes and new technology were not part of the reorganization efforts. By bringing more people together and removing the old organization structure, new ways of working that included more integration and more cooperation would evolve. It is the management's responsibility together with the employees to define these new ways and to lead the organizational efforts in the right direction

An important assumption for the reorganization process was that nobody risked losing job after the reorganization. During the time of the reorganization, the Navy was required to reduce activities. RNoNMC removed 200 job positions in parallel with the reorganization process. Fortunately, RNoNMC had many vacant job positions. By the end of the reorganization process, the 200 job positions were managed laid off by not integrating 200 vacant job positions into the new organization.

For the different branches, reduction of employees means that there are fewer people to perform the same activities. Combined with an increasing technological complexity of combat systems, required tasks, new material programs, and maintenance of the old equipment, it seems difficult to successfully accomplish all demanded tasks. Employees can no longer continue specializing into narrow engineering fields when the organization is not able to integrate new technologies effectively. The Navy is currently not able to benefit from integration in a way that increases organizational effectiveness, i.e. reduce manning needed on board and still perform at least at the same level as before.

RNoNMC organizational structure and reflection of responsibilities within different branches and offices do not accurately reflect engineering

and integration effort required from combat systems. The New Frigate Program implemented integrated teamwork in accordance with the systems engineering processes described by the ILS branch. Personnel that participated in teams produced technical solutions that helped developing the program quickly. However, many of the decisions relate to integration and do not necessarily reflect established organizational responsibilities. When reviewing integrated solutions decisions and trying to change them it is difficult to identify organizational responsibilities. As technology evolves faster and faster, the teamwork structure is a key element for the organization to handle the consequences of technologies. Not only to any combat system development, but also to necessary organizational change that evolves from new technologies.

In the future the RNoNMC needs to structure the tasks around the integration of new technologies. This demands other types of organizational integration. Internally, but also externally with different suppliers and contractors.

Since the internal resources are decreasing, RNoNMC relies more on external contractors on specific issues in order to cut costs. Especially where knowledge and skills do not require special military experience. RNoNMC must build a task structure that emphasizes integration internally and to a certain degree relies on contractor's specialization. People within RNoNMC must be motivated to work in teams, and trust information provided by the suppliers and contractors. When the confidence that other organizations can perform the same tasks as RNoNMC satisfactorily is established, RNoNMC can concentrate more on integration and resources can be used where it is needed to increase effectiveness.

One key element to establish necessary confidence between contractors and RNoNMC is the ability to exchange information. Traditionally, this has been done by reports on paper format. RNoNMC

has not been able to utilize new technologies so that information can be exchanged more efficiently. With the implementation of the New Frigate Program this has to change. The time of each development phase is so short that in order to accomplish the program's milestones, the huge amount of information has to be structured, analyzed, and exchanged with the contractors on a nearly day to day basis. The users, both at RNoNMC and at contractors, have to perform multiple queries simultaneously and this can only be achieved by online information structures, electronic databases, shared between RNoNMC and contractors.

Using systems engineering processes, the information structure is given, and based on previous material programs the implementation of databases is also given. Probably the only way to interpret massive amount of information is by working in teams and by doing tradeoffs between different engineering domains. The current task structure in RNoNMC's programs is different compared to a few years ago.

Handling all the information is not and should not be part of every employee's tasks. The ILS branch handles databases and information structures. They provide users with information they need to accomplish a task. Usually, a user identifies the needs for the next job and requests the ILS branch to provide necessary information. The ILS branch provides information on the preferred media, which usually is paper.

Already now it is signs that employees are changing behavior. Some still prefer paper reports, but ILS receives more and more requests for information on electronic media. Compared with the ULA class program this is a great improvement. However, this is so far only applied within the New Frigate program. In order to increase RNoNMC organizational effectiveness, the rest of the organization has to adapt to same type of work structure and use same type of technologies.

H. THE NEW FRIGATE PROGRAM

RNoNMC organization has developed a work culture where each division, department, and office work isolated, with little interaction between departments and other technical and engineering domains. When working in programs, people bring their attitude and they tend to work in their own engineering domain without considering others' view too much. Integrating these different views and technical domains is currently not allocated to any specific part of the organization. However, it is the nature of systems engineering, putting it together and making a system work across the engineering disciplines.

When implementing the Frigate program, ILS lacked support from the program management team. Also, some of the involved engineers just wanted to start working immediately on their requirements. There was little support for spending any time on defining and planning the total integrated work processes. How the program, together as a team, was to accomplish the tasks and milestones were not actively put on the agenda. The only support for the SE approach came from the Command, Control, Communication and Information (C3I) department. They had previously worked together with the ILS on other programs and knew that for this program the RNoNMC had to organize the work differently and more effectively than on previous programs.

The ILS managed to receive necessary resources for implementing an IT-structure, software, hardware, and development processes that enabled use of automated engineering tools. The IT-structure was based on previous experiences from other programs. The concept was that if the IT-structure worked for small programs it could also be applied to larger programs. The ILS believed that when engineers was involved, gained knowledge about the work processes behind the SE approach, and saw the possible savings in time and control, they would want to use the same processes and tools on a much broader basis.

Since ILS had described SE processes together with a plan, and previously had worked successfully on other programs with the weapon systems engineers, they were given responsibility to ensure that the weapon domain implemented and followed the process and plan. With the goal to deliver their specifications in accordance with the plan. At this time the weapon domain was considered to be the most risky part of the program. The other main domain of the program, the ship technical domain followed a traditional bottom up engineering process.

Since the SE plan relied on a working process that was implemented in a systems engineering tool, it appeared that the weapon domain could not develop their requirements completely without visibility into the ship technical domain, and vice versa. The integration part had to be implemented from day one. This meant that everybody working with requirements had to work in the same manner, they had to write requirements in the same way, and they had to make sure that each requirement was measurable. Ideally, everybody should start at the top-level descriptions and then break down the product until a comfortable detail level had been reached with a number of manageable and controllable requirements, as described by Incose (1998).

The engineering tradition within RNoNMC does not promote this type of engineering. The ship technical and weapon domain developed distinct different ways of solving their design tasks and establishing the requirements. ILS was able to support the weapon domain so that they followed tailored SE processes, while the ship technical system started from the bottom and engineered upwards. In the end of the definition phase the ship technical domain had developed over 4,500 requirements that were not consistent and not checked for content. The weapon domain had developed 700 requirements that were consistent and coherent.

The program management did not feel that they had the necessary control over requirements. When the first version of the requirements was

released and reviewed, the level of change proposals produced made it obvious that the program could not continue working in this manner. The program management agreed that the number of requirements was too high and it was decided to capture every requirement in a database

Within the weapon domain the SE tools had been used and each requirement had been captured in a database with traceability to the requirement hierarchy, and to the proposed system architecture. Agreed changes to the first version were implemented within a week. For the engineers outside the weapon domain this had previously seemed impossible and now they wanted to have the same capabilities within their domains.

1. Implementation of Process and Information Technology Solutions

The success within the weapon system domain was based on several factors. First (but not necessarily the most important factor), the ILS had implemented an IT-structure that enabled them to run and maintain the software and hardware they needed locally. This also achieved a controlled growth of the system or IT users.

Second, the involved personnel received an introduction to the structure behind the work processes and how the processes ensured that their requirements were captured. They also gained confidence that nobody could access the IT-system and remove any information without approval from the configuration management team. The information was kept in databases under strict configuration control.

The introduction to the SE processes was an "On-The-Job-Training" (OJT) course. When the OJT was completed the personnel produced the first draft version of the structure they were going to work with in the program. They generated the necessary technical and engineering

information and made sure that the information was correct and that it was integrated with other engineering disciplines.

Third, the process was made as a working democracy. Everyone could get information out of the database, they could evaluate the information, and if needed they could ask to change, remove, or add information. The final information decision would be made by an engineering team, which was represented by the senior engineers from all RNoNMC departments, allocated to the program. When the majority of the engineers accepted the processes, ILS proceeded and implemented the SE processes.

Fourth, when implementing the processes, ILS created cross-functional teams and made sure that each engineering domain within RNoNMC was represented in each team. Traditionally, everybody fights for their requirements to be part of the specifications regardless of costs. Working in teams, which purpose is to integrate the requirements into one product, each participant has to justify requirements and associated cost. If unjustified, requirements risk being deleted if the overall costs to the program are too high. The justification for each requirement was documented and traced in the requirement database.

In the New Frigate Program, studies performed during the mission exploration phase predicted that the proposed budget was not enough to acquire all six ships with the established performance requirements. But until the program had received bids that included total costs, there existed no method to predict which parts of the program that could not be accomplished. The program plan included a period with design and requirement adjustments after final bids were received, but before awarding the main contract.

Fifth, everyone worked with the same schedule. From the first draft version of requirements each team got two working weeks to change and make new input to the last draft version. The teams submitted their new

proposal to the SE team that implemented changes into the database and generated a new version of requirements. Each team received an electronic copy of the new version and they had two days to work with the new document and make their comments. The most senior engineer from each team met in an integration team and every paragraph in the document were reviewed, commented or changed during a two day work session. Every change was captured and traced in the requirement database by the SE team. By the end of session, a document that told each team their new tasks, based on comments during the two day session, for the next two weeks were generated and each team leader received an electronic copy. The team leader was responsible for getting tasks completed and submitting new information back to the SE team for the next version of specifications.

The SE team depended on that information inputs to the requirements were electronically received and in a certain format that allowed parsing from source documents into the requirements database. However, the SE team made every effort possible to even manually enter information into the database. The important constraint was time. It was critical to get new versions of requirements generated quickly so that the engineers could continue working.

The weapon system domain delivered their specifications according to plan and within budget. The program management felt that the allocated weapon systems cost could be within budget. However, the program had no insight into cost of the ship technical system or to the integration. As the first milestone was reached it became obvious that the ship technical domain was not able to deliver their specifications. They lacked the necessary design and requirement control that enabled the program to implement changes to the design and to the requirements when the integration between the weapon and ship technical domain started.

The ship technical domain had to rework most of the requirements to make sure that they were consistent and coherent. A program decision was taken that required every requirement to be captured in an information structure similar to that of the weapon domain database. Furthermore, each requirement needed to be traced within a requirement hierarchy. For the SE team this meant that they had to make new iterations through SE processes, but this time it would be faster and easier. They started by parsing the electronic existing ship technical requirements into a draft database. The engineers from the ship technical domain performed database evaluations. When the tasks were completed the ship technical requirements were merged together with the weapon requirements, and further analyses of the complete integrated combat platform could be conducted.

The positive effect of participating in SE team is that the team learned everything about the requirements. By working with the information on-line, the team could answer nearly every possible question related to requirements. They sometimes identified requirement errors in content and consistency and could call up the responsible engineers to correct the mistakes. The SE team became "the requirement team," and when the ship technical evaluation started with integrated teamwork they used the SE team as consultants with respect to the requirements and how to write the requirements. The SE department had created a situation where the participants are mutually dependent on each other, and together could increase program effectiveness.

2. Lessons Learned

Use of new technology, IT and work processes, can improve productivity. But every organization has a history and a culture, which has to be considered and possibly implemented into new systems. New systems bring new methods of organizing work. The technologies must be

introduced and implemented together with personnel that are going to use the systems. They have to be given confidence that systems help them in their tasks, and that they do not risk losing their jobs.

The SE department did not force people into using the system. By populating the information database, the involved personnel got an overview of the content that proved valuable. The weapon engineers realized that they would gain knowledge only by working with the database so they wanted to participate and actually use the database on a daily basis. The implementation of SE processes, together with IT-systems that support processes, has to be taken step by step and when end-users, the engineers, experiences benefits they will use the system extensively. The engineer knows how to do his tasks so he will be in the best position to suggest improvements.

When the engineers from the different technical areas within RNoNMC were allocated to cross-functional teams they were forced to critically review the importance of their responsibilities versus other engineering areas. By participating in teams the engineers, with the process backup from the SE department, adjusted their behavior from being responsible for only their technical part to take responsibility for the output from teams. Allowing people to actively participate overcome many obstacles that usually are associated with working in big and complex programs.

Based on the use of IT-systems the SE department had to change parts of the working processes and customize database queries and reports to different user's demands. As soon as users experienced that they could get any kind of reports and views from the database, they expanded the use and consequently the need for customizing grew. The understanding and value of the database grew within the different engineering domains; the database became a valuable asset for the program.

I. SUMMARY OF THE EXISTING SITUATION

The functional organization of RNoNMC seems to have several shortcomings faced with the challenge of declining budgets while at the same time major parts of the Navy's fleet grew older and created a urgent need for investing in new material. In parallel with the initiation of several big and complex material programs RNoNMC implemented a reorganization of the organization.

The organization could, before the implementation of the new organization, be characterized by: increasing work load, highly specialized employees, few identified and documented work processes, nobody responsible for the work processes, little integration between functional areas, little communication between functional areas, and inadequate information systems.

Table 1 gives the different characteristics of the organizational effectiveness related to processes, individuals and organization in the current situation. High is considered a good organizational situation where the organization is able to utilize its resources efficiently. Medium is an acceptable organizational situation where positive improvements could be made. Low is an unacceptable situation where the organization is ineffective and improvements are required. If the level of specialization is categorized low it means that the level is a threat to organizational effectiveness. However, the actual level of specialization could be categorized high within each engineering area.

Process Characteristics	Category	Organizational Efficiency
Level of engineering specialization	High	Medium
Level of integration	Low	Low
Domain protectiveness	High	Low
Information flow	Medium	Medium
Use of information systems	Low	Low
Communication	Low	Low
Automated procedures	Low	Low
Implemented development processes	Low	Low
Responsibility for work processes	Low	Low
Systems Engineering processes	Low	Low
Configuration control	Low	Low
Organizational and Individual Characteristics		
Organizational hierarchy	High	Low
Personal accountability	Low	Low
Physical location	Medium	Medium
Work load	High	Medium
Learning conditions	Low	Low
Change resistance	High	Low
Joint optimization of technical and social systems	Low	Low
Risk taking	Low	Low
Internal control	Medium	Medium
Systems thinking	Low	Low
Multiple broad skills	Low	Low
Collegial collaboration	Low	Low
Commitment	Low	Low

Table 1. Characteristics of the Existing Organizational Effectiveness.

III. A DESIRED SITUATION FOR THE RNONMC

A. ORGANIZATION

A governmental organization is governed by rules and regulations, and rules are often beyond control of each specific organization. The RNoNMC could be organized in many different ways, and there will always be discussions as to which way is the best way to organize. According to Van De Ven and Joyce,

The design of an organization is the structural arrangement of resources i.e., land, labor and capital of an organization in order to achieve desired ends. (Van De Ven and Joyce, 1981, page 3)

The structural arrangements are the sum of how to divide the labor, what forms of departmental structures to adopt, how to organize work units, how power and authority are distributed, and what systems of coordination, controls and incentives are appropriate. The organizational design often reflects strategic choices over years, environment in which the organization operates, and cultural context of organization and society. Organizational design is also processes by which structural arrangements are created, maintained and in the end changed.

The organizational structure is the best trade-off between many different and often conflicting views. It reflects the best perceived way to transform input to produce desired output. For RNoNMC, desired output is highest possible operational availability to users of operational combat systems.

However, what is sometimes overlooked when designing an organization is that an organization is a social entity. It exists for and is made up of individuals. Without the effort of individuals, the organization will not produce anything and it will stop existing. Unless the

organization has established goals and members of the organization share its purpose, the efficiency of activities will be low. An organization also interacts with society outside the organization's boundaries. The society is an important factor. If the organization is not accepted by society it will struggle to survive.

The latest reorganization effort emphasized the organizational transition from maintenance of the old equipment to investment in new equipment. The top management group realized the gap and the unsuccessful integration between people working with technology and people working with maintenance and supplies. The transition from maintenance to investment means an organizational transfer from working with old equipment towards working with new equipment.

Shifting the organizational focus from maintenance to investment introduces more activities and tasks into the organization. With a higher level of tasks, or task differentiation, more integration is required. More integration means more coordination and control. Control is concerned with ensuring that correct decisions are made. Coordination makes sure that proper and relevant information is available at the right time to make right decisions. When people lack information they risk making wrong decision. This also happens when people receive too much information. Making information available means that knowledgeable employees know where to find information and they gain access to information whenever they need it.

Since many new material programs had been initiated concurrently during a short time, more resources were needed to assist the Project division. That means more money and people. However, only transferring a number of people from maintenance to new programs does not increase organizational efficiency. People need knowledge and skills, they need to know what is expected of them, how work and tasks are organized, both at individual level, within an office, within a branch, within a division, as

well as how to interact with people from other divisions.

The goal is to create an organizational fit between the organization, people with their knowledge and skills, with required tasks, and with technology used to produce desired output. The organization must also fit to the external environment. People without the right skills or too many people without work processes will not acquire an optimum fit. Also, if people are allowed to only concentrate on their own engineering activities the organization will not be efficiently integrated, thus its ability to produce effectively will not be at the organization's optimum.

The following characteristics describes an effective organizational design (Burton and Obel, 1995):

- An organization is effective if it realizes its purpose and accomplished its goals.
- An organization is efficient if it utilizes the least amount of resources necessary to obtain its products and services.
- An organization is viable if it exists over a long period of time.

For a government organization to survive these criteria do not necessarily have to be met. Government organizations are not exposed to open markets and competition from other organizations. The existence of the Armed Forces in Norway is decided by the government's perceived need to ensure the nation's stability and security. The Armed Forces is not driven out of business because it does not operate in an economic efficient manner or because an another organization offers the same products and services cheaper.

The incentives to continuously monitor organizational effectiveness are therefor not as strong as in an industry where individual businesses compete on a daily basis. However, the resources transferred to the Armed Forces is decreasing and the different services need to closely start monitoring it activities to ensure that it operates effectively so that resources are used to maximize operational output.

Another reason for keeping an organization efficient is that employees need to find work meaningful and that their time at work is efficiently used. Unless humans feel a purpose and experience personal growth they may not be as efficient as possible. In a inefficient organization challenges are not as fulfilling, time is less effective spent, variety of work may be less, opportunity to learn may be less and the social fit between individuals and organization may decrease. Thus, creating conflicts and human dissatisfaction. It may also be difficult to keep the best human resources unless the organizational criteria for effectiveness at least are partly fulfilled.

B. RESPONSIBILITIES AND FUNCTIONS

In order to function properly an organization needs to have identified its purpose, its functions and its responsibilities. The organizational structure reflects the best possible breakdown of these functions and responsibilities. At the lowest level each individual job description represent the tasks and functions to be performed by each employee.

When the RNoNMC transits from maintaining old equipment to investing in new material the consequences are that some old activities have to be remove while other activities continues and new activities are introduced. For some of the employees this mean that they will continue doing whatever they were doing before reorganizing. But many employees have to start learning and understanding new activities. Some of these activities are dependent on technology, and especially information technology, to function effectively.

Over the next years, some old tasks need to be maintained; while at the same time new tasks are introduced. That means that the task variability will be higher. Since the organization gradually transits from maintaining old equipment to investment in new equipment other types of

problem solving processes has to be defined and introduced. Applying the old type of problem solving used on the old equipment will not necessarily give the desired solutions on new systems based on new technologies.

Most of the operational systems within the Royal Norwegian Navy are very complex. Systems are hierarchical in subsystems, components, and units. RNoNMC's organization reflects the most common way to structure combat systems with weapons, sensors, command and control, and communication. However, with current technologies it is not possible to achieve a direct and clear cut where one system ends and another starts. Similarly, allocated organizational responsibilities will not reflect a clear cut. There will be many instances when personnel from different divisions and offices are involved in solving a problem. Success is measured as to if problems are efficiently solved or not. All personnel involved have their part of success or failure off teams.

Participating in team and group work over time increase each individual's skills. When the employees master the skills demanded from their jobs they are able to take on other tasks. Not to the level required for being a specialist in another domain, but to the level that an office, or the organization, not is dependent on key individuals. Participating in teams where members have various skills also make the teams more dynamic. They may be able to complete the tasks even if some members are not participating or only partly participating.

C. EXPERIENCE FROM SOME MATERIAL PROGRAMS

Systems engineering is a new work area within RNoNMC. RNoNMC's own rigid requirements to documentation combined with increasing complexity of combat systems made it clear that RNoNMC had to change their program organizations to work more efficiently. If a given program generates 5,000 requirements, RNoNMC's organization lacks

resources to fully check that requirements are consistent and the existence of these requirements in the final product delivered from contractors. RNoNMC's program record shows that most of the material programs experienced conflicts between RNoNMC and contractor. Conflicts were often generated from inconsistent information or lack of information. A majority of the conflicts arise from poorly stated requirements.

A complex combat system program, like a Frigate, does not consist of only a few requirements. Rules and regulations put a lot of design constraints on ships, including naval ships. Many requirements evolve from good practices and the laws imposed from the government. Using systems engineering principles, combined with the possibilities in information technology, enables a better control of information and many manual tasks can now be automated. The underlying design principles and information structure can be communicated to the contractor so that both RNoNMC and contractors have the same consistent information available when the final contract is signed. Thus reducing risk of misunderstandings.

Since information technology enables massive data handling capabilities, one of the objectives for program management is to design an information structure that give decision makers, both in the program as well as the operational users in the Navy's chain of command, information they need on time. At the same time, the technician can access engineering information about technical details, at any level. The SE processes help ensuring that programs avoid information overload and that all parties can access information they rely on. By using Internet technology as a communication channel, RNoNMC, the Navy and contractors are able to communicate and exchange information online.

However, it is a challenge to avoid that the technology segment of the SE processes becomes focus point. The level of efficiency of SE processes rely on computers, databases, and (computer) networks. If

personnel working with SE becomes more interested with technologies supporting processes, the SE processes may not be as efficient as possible.

Currently, the ILS branch runs necessary hardware, computers and networks, software applications, including interfaces to other applications such as spreadsheets and word processors, and SE processes. Due to technology development, the SE processes need to be constantly maintained and updated. A change in technology can create new possibilities and new ways of automating individual work processes. Table 1 gives an overview of RNoNMC's defined SE processes.

Engineering Process Areas	Project/Program Process Areas	Organizational Process Areas
Analyze Candidate Solutions	Ensure Quality	Coordinate with Suppliers
Derive and Allocate Requirements	Manage Configurations	Define Organization's Systems Engineering Process
Evolve System Architecture	Manage Risk	Improve Organization's Systems Engineering Processes
Integrate Disciplines	Monitor and Control Technical Effort	Manage Product Line Evolution
Integrate System	Plan Technical Effort	Manage Systems Engineering Support Environment
Understand Customer Needs and Expectations		Provide Ongoing Knowledge and Skills
Verify and Validate System		

Table 2. RNoNMC's SE Process Areas.

In its present (and still evolving) form, systems engineering combines elements of many disciplines such as operations research, system modeling and simulation, decision analysis, program management and control, requirements development, software engineering, specialty

engineering, industrial engineering, specification writing, risk management, interpersonal relations, liaison engineering, operations analysis, and cost estimation. Any one system engineer is not expected to be expert in all of the disciplines. But over the years a typical system engineer gains experience in most of them.

Systems engineering is an overarching discipline, providing tradeoffs and integration between system elements to achieve best overall product and/or service. Although there are some important aspects of program management in systems engineering processes, it is still much more of an engineering discipline than a management discipline. It is a very quantitative discipline, involving tradeoff, optimization, selection, and integration of products from many engineering disciplines.

The growing complexity in all areas of development has increased the need for system engineers. The need for systems engineers is most apparent on large, complex system developments such as weapons and transportation systems. But they are also important in development, production, deployment, and support of much smaller systems, such as cameras and printers (note that some "systems" can also be subsystems of larger systems).

Systems engineers perform many useful tasks during a program's lifetime, but most managers consider their role during the development phase as the most important. During this phase systems engineers define overall requirements and help evolve system architecture (its key elements and their configuration). Systems engineers help allocate and "balance" requirements to lower level system elements.

The systems engineering process is an iterative process of deriving and defining requirements at each level of the system, beginning at top (the system level) and propagating those requirements through a series of steps which eventually lead to a preferred system concept. Further iteration and design refinement leads successively to preliminary design,

detail design, and final, approved design. At each successive level there are supporting, lower-level design iterations that are necessary to gain confidence for decisions taken.

During each iteration, many concept alternatives are postulated, analyzed, and evaluated in trade-off studies. There are many cross-coupling factors, where decisions on one subsystem effect other subsystems. These factors must also be evaluated. Systems engineering is involved in all steps and leads during Mission Analysis, Requirements Analysis, Concept Analysis, and Conceptual Design down into subsystem level, and integrates many other activities including design, design changes and upgrades; Goals & Objectives for element iteration; customer feedback, and operational support.

The introduction of Product Development Teams became a mechanism for handling integration better than with a typical departmentalized organization. Teams are primarily responsible for internal integration within their team during preliminary design, detail design, and development. System engineering representatives closely monitor these development activities and integrate interfaces and other issues between teams (IncoSE, 98).

D. TEAMWORK

Teamwork is a main mechanism for solving complex and non-routine tasks. People with a variety of skills from different offices and divisions, form teams as a basis for problem solving and mutual learning. The teams are mechanism for organizational learning. When more people participate in teamwork the probability that gained knowledge remains within the organization increases.

The established organizational structure with allocated responsibilities remains. However, there will always be situations that the established structure can not handle. The solution must then be not to

dismiss problems, but rather to encourage untraditional methods for problem solving. When a problem is solved, the organization has to investigate how to integrate solutions into the organization as well as learning so that the organization is better prepared for the next event. The goal is to enhance problem solving, or innovations, while at the same time keeping internal structures and environment at a steady state. Problem solving processes may be used as an organizational process to overcome forces toward organizational ineffectiveness.

Effective problem solving processes exist when

Problems are being solved, (b) in such a way that they remain solved (c) with minimal necessary expenditures of energy, and (d) with minimal damage to the continued effectiveness of the problem-solving process. (Argyris, 1964, page 137)

Since problems occur in many different circumstances, it is difficult to foresee all possibilities, thus the organization can not train for every possibility. But the organization can establish an environment that enhances problem solving thinking and processes. There are two aspects of problem solving. One is related to solving a problem so that it does not occur again. The other is to solve problems before they arise by implementing processes that prevent problems, hide or transfer problems into less complex types of problems.

A problem-solving environment can be established by leaders being more direct and by leading discussions so it is kept on track. The leaders must avoid being rulers. Their purpose is to encourage and ensure that the team behaves within the established norms. The agenda need to be definite and with a clear-cut objective. Furthermore, the value of the contribution from strong personalities must be critically considered and continuous troublemakers need to be silenced or potentially removed.

Other characteristics that improve the problem-solving environment are the awareness of the problem. That is being able to understand the full

complexity of the nature of the problem and its impact and significance to organization and environment. Simplification of problems that makes problems manageable and more understandable within the organization also helps to identify appropriate actions. But oversimplification will do the exact opposite. Simplification also means that alternative ends-means combinations can be developed and used. Alternative and the consequences of actions need to be determined and by that the organization builds an experience from which the organization can check and take new directions whenever necessary. Finally, appropriate resources within the organization need to be identified and mobilized.

When working in groups the individuals are encouraged to, and realize that they can, be candid about their own and others ideas and feelings. They can be open, and experiments with possible failures are allowed. The members also need to help and encourage others with these aspects.

Furthermore, the organization and teams have developed norm sanctioning factors such as individuality, trust, concern, and internal commitment. There also exist norms against conformity, antagonism and mistrust. Failure to manage these factors will not create a problem-solving environment. Employees will only perform whatever is in their job description. Problem solving requires that people move out of their traditional box thinking and explore other areas.

Even if the organizational structure, organizational culture, management system, control systems, and use of teams and groups are major contributing factors for organizational effectiveness, the organization still consists of people. Focusing on employees needs do not mean a completely people-centered organization. When people are well integrated in the organization both individuals and organization experience growth. The organization will be more efficient and people experience self-esteem, they participate in decision concerning

themselves, and their own work situation. The organization offers meaningful challenges and for those who are willing to participate there are many opportunities for learning and possibly creating new career paths.

But the employees must be capable of fulfilling the challenges and also accepting the responsibilities. Exploring the unknown involves both risks and opportunities. Although failure is allowed within the organization, each individual exposed to failure has to be able to handle such situations. Success may also have unintended consequences and each individual has to be prepared to handle the extra pressure that follows success.

To cover the future needs of technologies involved in designing and engineering combat systems the organization need highly skilled professionals. The employees need a variety of skills and they need a high level of education. The officers first receive a military education, but many officers also choose to study at civilian universities. After completing studying officers conduct a pay back tour, usually determined before the officer is allowed to start studying.

The civilian employees are often recruited internally from either engineering interns or previous officers that receive a higher salary as a civilian. One major problem is that the Armed Forces are not able to compete with industries for the best educated people. Therefore, civilian employees may lack some of the higher education demanded to handle new technologies. However, most of the employees have a broad experience since they change jobs within the organization.

The challenge for teams is to successfully integrate those with different education and different experiences into an effective team. The employees need to be positive to new ways of arranging work and to implement new work processes when necessary. Instead of being afraid technologies which purpose is to enhance performance, employees need to

be open, experience, learn and foresee possibilities. Provided they receive support and training needed for a successful implementation.

E. SUMMARY OF THE DESIRED SITUATION

In the desired situation, RNoNMC's organization has shifted from a highly vertical differentiation to a more flat organization based on employee's participation. Organizational responsibilities and functions are still allocated to proper levels within the organizational hierarchy, but use of teamwork enhances complex problem-solving as well as resolving unallocated responsibilities. Teamwork is also used to solve unclear or unidentified responsibilities.

People are recognized for their knowledge and skills and they are considered the most valuable resources of the organization. New information technology is introduced to increase organizational efficiency and people are an integrated part of and complementary to technology. Technology is not introduced without an identified need.

New technology, teamwork, and members active collaboration, emphasizes joint optimization between all factors contributing to organization's effectiveness. Teamwork uses internal control mechanisms for regulating work, thus ensuring that each member contributes to tasks.

New problem-solving techniques create a culture where innovative solutions are the goal, where people are allowed to fail in a secure environment. Creating innovative solutions require that people are willing to take risks. Risks create uncertainty about the outcome. Unless both failure and success are allowed employees will not feel safe and thus avoid any decisions that involves risk.

The engineering activities are based on SE processes that focus on integration and functional requirements rather than on detailed design engineering. The SE principles are implemented within all levels of engineering as means to ensure better integration between the

organization's different responsibilities and functions.

Table 3 shows the different characteristics of organizational effectiveness related to processes, individuals and organization in the future situation. Compared to the previous organizational state the categories of the characteristics have changed and positively shifted organizational effectiveness.

Process Characteristics	Category	Organizational Effectiveness
Level of engineering specialization	Medium	Medium
Level of integration	High	Medium
Domain protectiveness	Low	Medium
Information flow	High	High
Use of information systems	High	High
Communication	High	High
Automated procedures	High	High
Implemented development processes	High	High
Responsibility for work processes	High	Medium
Systems Engineering processes	High	High
Configuration control	High	High
Organizational and Individual Characteristics		
Organizational hierarchy	Medium	Medium
Personal accountability	High	High
Physical location	Medium	Medium
Work load	High	Medium
Learning conditions	High	High
Change resistance	High	Low
Joint optimization of technical and social systems	High	High
Risk taking	Medium	High
Internal control	Low	High
Systems thinking	High	High
Multiple broad skills	High	High
Collegial collaboration	High	High
Commitment	High	High

Table 3. Characteristics of Future Organizational Effectiveness.

IV. COMPARISON OF THE CURRENT SITUATION AND THE DESIRED SITUATION WITH NAVY PROGRAMS

A. PROGRAM FACTORS

With the new way of organizing the work in the New Frigate Program, the program organization implemented teamwork as opposed to the old hierarchical way. Previously, material programs organized the program around a component decomposition structure of the final product. The structure also tried to consider the impact of RNoNMC's line organization so that functional responsibilities could be allocated into the program. The engineers from different domains were allowed to accomplish their tasks according to best engineering practices. There was little or no common methodology that structured the program's efforts and activities.

Previously, it was possible to receive additional funding for major activities like material programs. In today's environment it is difficult to receive excessive funding outside the budget. A material program receives its funding from the total of the Armed Forces' budget. Additional required funds may ultimately be decided and allocated by the Norwegian government. The budgeted funds are expected sufficient for all necessary program phases. Asking for additional funds is not considered good workmanship.

The material programs are supposed, for planning and budget purposes, to cover the complete life cycle of the product. That includes activities and budget for the initial period of the product's operational service. It is not considered good practice to release products into operational service without extensive testing and thus ensuring that faults not occur when the equipment is deployed for operational use.

The New Frigate program planned and implemented new ways of

working. Even with the very tight timelines the program was able to deliver most of its products within milestones. Many employees were experiencing a new working environment. They received initial training before major work sessions and training was based on OJT. People worked in teams where they took responsibility for their domain. At the same time, they had to analyze financial implications of requirements they introduced into the program.

Traditionally, cuts to match budget are performed by program management after all engineering activities have given their inputs to the program. For some, these cuts may later appear unexpectedly and it often creates a gap between program management and engineers. Employees question why they were asked for opinions and inputs when the program after all does whatever they feel necessary to stay within budget. This creates an environment of misunderstanding and lack of interests. The long-term consequences for the program can be an environment of suspicion and mistrust that may decrease the organizational effectiveness.

In the Frigate program people worked together in teams where they discussed and negotiated each subject they wanted to bring into the program. When all teams delivered their product, the SE team integrated all results into one product that was reviewed by all members before approval.

This process created an ownership to the product. The product was the specification that later was sent to contractors wanting to make a bid for the New Frigates. The specification structure helped teams to identify areas that were not covered. Some of these areas were not part of organizational responsibilities within RNoNMC. By putting people together in teams the program managed to cover every important area. Either a potential high cost or a safety and security issue. Some of the less important areas were left open and planned covered by contractors.

By combining the use of information technology together with

necessary work processes the program was able to produce its products on time. More importantly is the creativity and enthusiasm that was created by people working in the program. Material programs are usually able to create a positive work attitude among those that are employed directly and on full time. It is more difficult to create the same enthusiasm from people that are only partly involved. For them, the program is additional tasks to an already overloaded workday. Participating in the program they are away from familiar work situation where they are on top of the situation. They know what the day consists of and they know the work schedule ahead. In the programs they have to familiarize themselves with new people, with a very demanding work pace and a new work culture with a different social setting. Also, program tasks are often not well defined and the workdays are categorized by non-routine. Every day comprise of new tasks and a lot of uncertainty. In addition, the management of the programs is often competitive and they demand the same from all others involved.

Participating in programs exposes the employees to new technologies, both in the product as well as new ways of organizing the work. The working environment is challenging. Internally, because the employees have to learn how to handle the program activities. Externally, because the different contractors have their own methods and programs usually integrate with several contractors. The consequences are that implemented technology and work processes change frequently during a program's lifetime.

Programs also offer a high degree of freedom and individual's creativity is challenged. Finding new solutions under time and budget constraints challenge engineers to be innovative and search outside their traditionally domains for new solutions. Engineers also realize that nobody can do all tasks alone. They all depend on each other and the final results are the sum of contributions from everyone involved.

The New Frigate Program realized that putting everything together required a variety of skills. The program needed an environment that inspired people to be creative but at the same documented what was done in a manner that enabled other people to later understand what happened and why. And even more, contractors bidding for the final product had to understand requirements, intentions behind requirements and they had to design the best solution fitted to the requirements and RNoNMC's budget.

For the first time in a complex material program, the management realized the need for someone that managed work processes and that documented results as work progressed. They could not let everyone work in their own manner and by their own speed. By implementing a unit that planned the work and managed integration efforts pay off soon materialized. Based on the ongoing work, the unit was able to change work processes according to needs. Everyone working with specifications got together in an environment that focused on the same results. The culture and social relationships developed together and created a positive attitude towards work.

Since the program had established one unit responsible for the work processes, the other involved personnel did not worry about integrating products from the other teams. Neither did they have to worry about learning new computer applications unless they thought they could be more productive and wanted to learn. The computer applications needed to create specifications was run and maintained by the SE team.

The program did not experience any lack of interest or unwillingness to participate. Personnel showed up on a regular basis and delivered products they were expected to on time. The teams knew the schedule and they knew when integration was performed. They knew that if they wanted to change anything or make sure that nobody made any unexpected cuts they had to participate. They needed to deliver their products when it was demanded. They found that if they had valid

arguments nobody would do any unjustified cuts.

People were also willing to participate in work that was only remotely connected with their responsibility in the organization. If the program needed someone to solve a specific issue they seldom had problems getting people to participate. In previous programs it could be difficult to get people involved in anything outside their job description.

B. COMPARING PROGRAMS RESULTS

The success of material program in RNoNMC and in the Navy is mostly measured by delivering products on time and within budget. Quality is an important issue as long as programs are on schedule. If schedules start slipping it is tempting to take short cuts in established quality procedures in order to save time and bringing the program back on schedule. Quality procedures are often considered non-productive, that is spending resources on quality does not add any extra amount or measurable figure to the program's final product deliveries. It is true that implementing and initiating quality procedures is costly. However, when the organization is focused and trained on quality the assumed cost is not recognizable. Quality is part of the business. When problems occur and schedules start slipping, quality processes and procedures are mechanisms that can make the difference in bringing programs to a successful conclusion.

A product's level of compliance with requirements can only fully be demonstrated when the product is in operational use. These requirements include operational elements together with functional, architectural-, and integrated logistic support requirements. The cost of failing to comply with requirements can only be shown on future maintenance budgets, but technical engineers on ships and land-based workshops experience increasing workloads.

During the development process of programs and after awarding the

main contract it should be possible to forecast the level of faults to occur during the operation of the systems. A material program consist of time from start of the program until delivery of the first tested product, money spent on the product compared to budget, number of requirements, number of corrections to requirements, both internally within the program as well as after main contract award, number of faults identified during warranty period and number of faults identified during operational service. In addition one has to consider the complexity of the material.

The complexity of the material can be categorized into level of development of new technology, level of existing technology, level of integration between sub-systems, security issues with respect to personnel, number of people operating the system, performance required of the system with sub-systems, and other technical issues. This list is not conclusive. To relatively assess the differences between different combat systems relationships between some of these factors are established. The relationships help predict the outcome of new material programs.

- Level of new and old technology, 1.0 is considered a low level, 1.9 is considered a high level.
- Number of sub-systems (depth of the system hierarchy), 1.0 is considered a low level, 1.9 is considered a high level.
- Level of integration between sub-systems, 1.0 is considered a low level, 1.9 is considered a high level.
- Number of allocated requirements
- Number of changes during the development phases.
- System delivered on time.
- System delivered within budget.
- Number of faults detected during the test and evaluation-, and the warranty- period.

These factors have to be addressed in conjunction with the engineering capabilities available to the program organization. In addition

the development process applied by the program has to be considered. Did the program use a defined and described development process, or did the engineers just start up working according to best practices? Did the program apply any automation tools that enabled consistency checks and generation of documents? Several issues can be identified to establish the appropriateness of the development process, but that is outside the scope of this thesis.

In the following sections the descriptions, name, type, and contractor of the systems are not identified due to legal agreements between contractors and RNoNMC. The data is provided by ILS branch at RNoNMC.

1. Program A

Program A consists of some new technology development, only a few sub-systems with relative little integration and a small crew. The program did not follow any development process as outlined in Military standards recognized by DoD. Table 4 shows categories and associated characteristics for product and development qualities of the program.

New Technology	Sub-systems	Integration	# of Requirements	# of Changes	On Time	Within Budget	# of Faults
1.2	1.1	1.1	>2000	>1000	Delayed	Above	>500

Table 4. Product and Development Qualities for Program A.

2. Program B

Program B consists of some new technology development and many sub-systems with a high level of integration. A small crew with emphasis on a high level of security. The program did not follow any development process as outlined in Military standards recognized by DoD. Table 5

shows categories and associated characteristics for product and development qualities for the program.

New Technology	Sub-systems	Integration	# of Requirements	# of Changes	On Time	Within Budget	# of Faults
1.5	1.5	1.5	>5000	<500	Delayed	Within	Not known

Table 5. Product and Development Qualities for Program B.

3. Program C

Program C is based on existing technology with a proven design. The challenge was to integrate the new system together with all existing systems. These systems consisted of a variety of different technologies and with different levels of documentation.

The program followed a development process based on Mil-Std-499, Mil-Std-490 and Dod-Std-2167A. The program emphasized an integrated teamwork together with the contractor. Major success factors during the development and design-phases were traceability from and between the requirement hierarchy, level of automation implemented in the systems engineering tools, and level of automated information transfer between the program and contractor.

Table 6 shows categories and associated characteristics for product and development qualities for the program.

New Technology	Sub-systems	Integration	# of Requirements	# of Changes	On Time	Within Budget	# of Faults
1.1	1.0	1.7	>250	<15	Delayed	Within	<10

Table 6. Product and Development Qualities for Program C.

4. Program D

Program D is based on existing technology and proven design. However, some major systems need to be developed. The design emphasizes a high level of integration with a relative large crew. The program followed a tailored development process based on Mil-Std-499, Mil-Std-490 and Dod-Std-2167A. The complexity of the program and difference in engineering practices initially created a split in two distinctively different methods of engineering efforts. Consequently, two distinct different development processes were applied in the phases before the contract award. The different measures will therefore only reflect milestones in phases before contract award.

Program D consist of two major subsystems, Subsystem D.1 and Subsystem D.2.

a. Subsystem D.1

The subsystem D.1 was developed using a tailored development process based on Mil-Std-499, Mil-Std-490 and Dod-Std-2167A. The process was tailored to needs from each participating work group. Several changes to processes were identified and implemented during the development. The product was one specification that covered all requirements for this subsystem. The current version is a result from several reviews, both internally within the program as well as externally with contractors competing for final bid. Table 7 shows categories and associated characteristics for product and development qualities for the subsystem.

New Technology	Sub-systems	Integration	# of Requirements	# of Changes	On Time	Within Budget	# of Faults
1.8	1.8	1.8	<650	<20	Yes	N/A	N/A

Table 7. Product and Development Qualities for Subsystem D.1.

b. Subsystem D.2

Subsystem D.2 was developed using the traditional way of engineering. The subsystem was divided into a component break down structure that followed traditional engineering practices and responsibilities within RNoNMC. Each engineering area structured and organized work in accordance with their best practices.

The product consisted of several specifications with more than 3000 requirements. Due to limited resources and time, complete reviews of all specifications, together in an integrated manner, was not performed between all baselines. After the program dead line for products, several reviews showed that some requirements were inconsistent, some were not really requirements but rather intentions, and some requirements could not be tested in the final product to demonstrate compliance.

A major effort to restructure information was initiated. The goal was to obtain the same type of structure and traceability that had been achieved in subsystem D.1. Substantial effort was put into the tasks, and the key personnel involved in subsystem D.1 was allocated on the job. However, this effort delayed the program and increased internal costs associated with producing necessary product specifications.

These costs consist of the effort of all involved engineers who could have spent their time doing other engineering activities. For the organization this is one example of organizational ineffectiveness. Table 8 shows categories and associated characteristics for product and development qualities for the subsystem.

New Technology	Sub-systems	Integration	# of Requirements	# of Changes	On Time	Within Budget	# of Faults
1.8	1.8	1.8	>2000	>1000	Delayed	N/A	N/A

Table 8. Product and Development Qualities for Subsystem D.2.

c. Comparison of the Engineering Efforts

An comparison of the two methods implemented to design and establish requirements for the subsystems shows that with the same effort, time and available engineering resources, subsystem D.1 managed to establish a complete baseline on the milestone, date and event, decided by the management. Subsystem D.2 did not manage to establish a complete baseline. The baseline was estimated to be 50% complete.

At next revision of the baselines, subsystem D.2 was estimated 70% complete. At that time more than 800 changes had been introduced affecting 3900 requirements. Subsystem D.1 had introduced 35 changes to 650 requirements. Subsystem D.2 was now following the same method for design and engineering as subsystem D.1 had implemented in the previous phase.

Several more revisions of baselines have since been established. With respect to number of changes introduced in the subsystems the trend continues. More changes are introduced into subsystem D.2 compared too subsystem D.1. Consequently more engineering effort is needed to increase the quality of specifications in subsystem D.2.

Table 9 shows the data at each baseline. The engineering effort is measured in amount of total man-hours spent between each revision. One week equals five days, one month equals 20 days, and a

year is 220 days. One day is eight work hours. N/A means data not available.

	Sub-system 1	Engineering Effort	Sub-system 2	Engineering Effort
Baseline 1				
#Requirements	641		3913	
#Change proposals	35	1 month	539	>5 years
#Requirements Changed	35		>800	
Baseline 2				
# Requirements	641		3470	
#Change proposals	3	3 days	60	3 months
#Requirements Changed	3		60	
Baseline 3				
#Requirements	638		N/A	
#Change proposals	150	10 days	250	1 year
#Requirements Changed	N/A		N/A	
Baseline 4				
# Requirements	638			
#Change proposals	300	5 months	1000	>3 years
#Requirements Changed	N/A		>1500	
Baseline 5				
# Requirements	598		3044	
#Change proposals	N/A	2 months	N/A	>3 years
#Requirements Changed	N/A		N/A	

Table 9. Data Comparison of the Development Efforts of Subsystem D.1 and D.2.

The changes consist of removing inconsistent requirements and adding new requirements as well as correcting errors such as misspelling and incorrect facts. The changes are not sorted by importance. An error in the specifications forms a basis for incorrect information and consequently risks that another reader, mainly a contractor, misunderstands content, and thus possibly implementing wrong solutions.

Table 10 identifies major differences between the engineering teams before baseline 1 was established. The characteristics are ranked high, medium and low. High is considered an effective organization and describes a healthy work situation. Medium is acceptable, but changes can affect work situation positively. Low is an unacceptable situation. Major changes are required to improve work situation and effectiveness of the organization.

	Subsystem D.1	Subsystem D.2
Described development processes	High	Low
Implemented development processes	High	Low
Level of customization of processes	High	Low
Automated procedures	Medium	Low
Use of information technology	High	Low
Use of software based engineering tools	High	Medium
Individual level of use of IT	High	Medium
Use of integrated teams	High	Medium
Process responsible allocated	High	Low
IT responsible allocated	High	Low
Information flow	Medium	Low
Level of hierarchy	Medium	Medium
Job specialization	Medium	Medium
Domain protectiveness	Medium	Medium
Individual participation	High	Medium
Focus on individual learning	High	Medium
Focus on systems thinking	High	Low
Planned engineering effort	High	Medium
Individual knowledge of plan	Medium	Low
Configuration control implemented	High	Low
Alternative action plans established	Medium	Low

Table 10. Quality of Work Indicators Before Baseline 1.

A similar comparison on the status of the program before baseline 5 shows that some of categories describing subsystem D.2 have increased from low to medium or from medium to high. The categories describing both teams are now more equal and the teams perform

practically at same level of efficiency. These data are shown in Table 11, System D.

A simple cost-benefit analysis of the situation in the teams developing the subsystems demonstrates a large economic cost on restructuring information and introducing large number of changes. The effort spent on subsystem D.2 supercedes effort spent on subsystem D.1. Even if there may be technical differences between the subsystems these differences can hardly justify the substantial cost associated with doing the job twice.

The cost associated with up-front planning, implementation of the development processes, and technology required to run the processes is not part of costs in Table 10. However, this cost must at this stage considered as sunk cost. Even if the cost was accounted for both teams would be equally accounted.

C. COMPARISON OF THE PROGRAMS

The assessment of data from different programs shows that the number of requirements is one factor that determines number of changes in specifications. The number of requirements also drives number of faults identified during further development with contractors and after the product is delivered. Correcting changes and faults require engineering effort internally in RNoNMC in all phases of the program as well as during lifetime of the product.

Table 11 gives a comparison of number of requirements, number of changes and faults, and performance related to schedule and budget for some of programs in RNoNMC. The number of changes, delivery on schedule, and within budget are assessed after the main contract was awarded and the products delivered. Thus, product quality is a measurement of the combined effort of RNoNMC program and contractor.

Program D has not yet awarded the main contract. Therefore, data is not available (N/A).

	System A	System B	System C	System D
New Technology Sub-systems	1	1.5	1.1	1.8
Integration	1	1.5	1.7	1.8
# of Requirements	>2000	>5000	>250	>3500
# of Changes	>1000	<500	<15	N/A
On Time	Delayed	Delayed	Delayed	N/A
Within Budget	Above	Within	Within	N/A
# of Faults	>500	N/A	<10	N/A

Table 11. Product and Development Qualities for the Programs.

Causes that led to a product delivered after schedule are many. Even when RNoNMC delivers specifications to the contractor on time the contractor may experience technical problems that led to a late delivery. However, if the contractor has negotiated a delivery date, it is expected that he is able to confirm to the contract. The contractors often experience unrealistic expectations from customers during contract negotiations. The balance between realistic and unrealistic deliveries is critical. The customer has to take responsibility for listening to contractor's advice and not try to push contractor's limits on his delivery dates. Delayed deliveries increase costs at both parties.

Assessing organization of work in all programs gives an indication of quality and effectiveness of program's efforts. For simplicity, System D consists of both subsystems before baseline 5.

Table 12 assesses organizational characteristics for all major material programs.

	System A	System B	System C	System D
Described development processes	Low	Low	High	High
Implemented development processes	Low	Low	High	High
Level of customization of processes	Low	Low	High	High
Automated procedures	Low	Low	High	Medium
Use of information technology	Low	Low	Medium	Medium
Use of software based engineering tools	Low	Low	Medium	High
Individual's level of use of IT	Low	Low	High	High
Use of integrated teams	Medium	Low	High	Medium
Process responsible allocated	Low	Low	High	High
IT responsible allocated	Low	Low	Medium	High
Information flow	Medium	Low	High	Medium
Level of hierarchy	Medium	Medium	High	Medium
Job specialization	Low	Low	Medium	Medium
Domain protectiveness	Low	Low	High	Medium
Individual participation	Medium	Medium	High	High
Focus on individual learning	Low	Low	High	Medium
Focus on systems thinking	Medium	Low	High	Medium
Planned engineering effort	Medium	Low	Medium	Medium
Individual knowledge of plan	Low	Low	Medium	Medium
Configuration control implemented	Low	Low	High	High
Alternative action plans established	Low	Low	Medium	Low

Table 12. Organizational Characteristics for all Programs.

A comparison of programs' results and quality of work indicators show that there is a relation between result and quality of work. A perceived low quality of work may indicate a poor result. However, data

must be interpreted carefully. The assessment is performed in the current environment with knowledge about today's technology. If the assessment had been performed at time when all programs were active, the assessment could show different results. The relative differences between programs and programs' results do however give validity to the hypothesis that quality of work influence product results.

The size and complexity of material program are also indicators of how efficient the program organization can operate. Smaller programs usually indicate that the product is less complex with respect to technical solutions. A smaller program will more easily agree on development methods, establish an open communication, be more capable of giving individual support, help, and training, and the program environment is generally less hostile. Smaller programs depend more on each individual's contribution compared to large programs.

D. SUMMARY OF THE SITUATION COMPARISON

Comparing the results from some programs in RNoNMC demonstrates that it is possible to establish a relationship between number of requirements and number of introduced changes to requirements. The number of requirements determines number of faults expected to occur when the product is in operational service. An increasing number of requirements will most probably result in an increasing number of changes and faults.

The complexity of the product also determines number of changes and number of faults. However, if the programs avoid detailed design the effect of increasing changes and faults may be prevented.

The implementation of described work processes in forms of customized development processes also affects number of changes and possibly number of faults. One of the programs demonstrated that applying two different development methods produced different results.

One method produced the product within required time. The other method did not produce the required product.

The quality of work also establishes an indicator of the organization's performance. Low quality of work produces products with poorer quality than higher quality of work.

Cost-benefit analysis between programs is difficult to perform. The conditions for each program differ and RNoNMC do not have resources to run a program several times with different development processes and holding everything else constant. The cost of establishing such a controlled environment where a program is subject to economic research is not feasible. However, the cost-benefit analysis of the two subsystems in System D indicates differences in cost associated with a successful and unsuccessful development process.

V. SOCIO-TECHNICAL SYSTEMS; THEORY AND PRACTICE

A. INTRODUCTION

This chapter examines three key books in the field of socio-technical systems. Socio-technical system theory and concepts are further illustrated and analyzed by four cases from different industries.

The three books "Organizational Choice" by E. L. Trist, G. W. Higgin, H. Murray and A. B. Pollock, "Socio-technical Design, Strategies in Multidisciplinary Research" by P. G. Herbst, and "Management of Work A Socio-Technical Systems Approach" by Thomas G. Cummings and Suresh Srivastva give a historical look on development of socio-technical systems. They address the topic from different viewpoints and they use different cases to illustrate the topic. From Trist & Bamforth studies of social and psychological consequences of the longwall method of coal-getting in British coal mines in the forties and fifties, to Herbst's use of a Norwegian ship organization's challenge to change based on new environment with use of technologies. Cummings and Srivastva used white-collar workers in an aluminum forging plant as their experimental design. Common to all cases where a long term involvement in field programs, with big and complex social and technical issues, aimed at improving conditions and content of work. These cases provide the basis for development of their socio-technical theories and applications. The cases apply socio-technical concept to the whole organization as an extended social system.

The books introduce history of socio-technical systems, theoretical foundation of socio-technical systems, problems encountered in socio-technical design, approaches to fundamental problems of socio-technical theory, and methods for studying relationships between task structure and work organization. Work is defined and theory is extended to management practices. They are concerned with how people structure their relationship to technology for productive achievement. Major assumptions are that work is a primary source of human enrichment and provides people with a

structured way to master their environment. Also, people possess an infinite capacity to solve problems, to innovate, to learn, and to grow. Finally, collaboration between people is basic to human's existence.

B. DEVELOPMENT OF WORK

The basic concepts of socio-technical studies started with Trist & Bamforth studies of the social and psychological consequences of the longwall method of coal getting in British coalmines in the forties and the fifties. The basis was a technological system expressive of the prevailing outlook of mass-production engineering and as a social structure consisting of the occupational roles that have been institutionalized in its use. These interactive technological and sociological patterns are assumed to exist as forces having psychological effects in the life-space of the (face-) worker, who must either take a role and perform a task in the system they compose or abandon his attempt to work. The worker's contribution to the field of determinants arise from the nature and quality of the attitudes and relationships he develops in performing the tasks and in taking on the roles. Together, the forces and their effects constitute the psycho-social whole. Figure 5 shows the relationship between technology, social structure, performance and disorders.

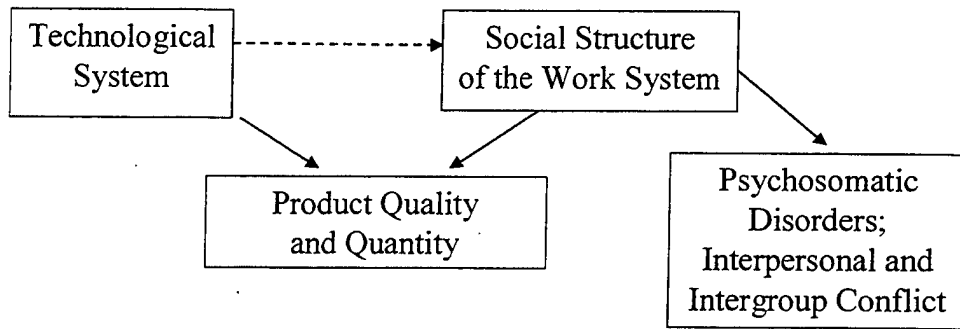


Figure 5. Relationship Between Technology, Social Structure, Performance and Disorders.

Certain qualities, evolved from the experience of successive generations and characteristic of traditional mining systems are especially appropriate of the organization of work groups:

- Acceptance of responsibility for the entire cycle of operations.
- Recognition of the interdependence of one man or group on another for effective progress of the cycle.
- Self-regulation by the whole team and its constituent groups.

How far a work group is capable of such responsible autonomy and is able to adapt itself in correspondence with changing conditions indicates the extent to which its social structure is appropriate to the demands of the situation.

The development of work has changed dramatically during the history. During the Middle Ages, work was structured and organized

according to specific skill, the craft oriented work, where the product was recognized by the level of craft put into it by the craftsman. The craft-orientation of work provided both for economic rewards as well as psychological satisfaction and social acceptance.

When mechanization was introduced into coal mining the usual self-regulating work groups were broken up. The teams now became bigger, consisting of up to forty men, and each team and groups within the team, worked independently. The teams were dependent on each other, but each group and team optimized its own condition and passed on bad conditions to the other groups. This situation created several types of conflicts and the end result was lowered performance.

With mechanization work was analyzed and structured so that the individual tasks were identified and they were decomposed into its simplest units in order to be mechanistically designed and implemented by machines. Tasks now contained low variance that only needed limited input from the worker. Most of a worker's physical skills were challenged, not his social and cognitive skills. The result was (often) economically advantageous, but social and psychological benefits were mostly lacking.

An important principle of mechanization and production design is that many tasks can be analyzed into a sequence of elementary operations. Given an input I there exists a sequence of operations π such that if the sequence of operations are applied to the input a predictable output P results: $\pi(I) \rightarrow P$. All these tasks can in principle be designed to be carried out by a machine.

Once a worker's tasks are reduced to a single and simple repetitive operation it requires little to fully automate the production line. It becomes uncertain what the human requirements are and basically only a few types of personnel are needed: process-, monitors-, control-, maintenance-, and repair-, workers.

The continuous process techniques allowed the work pace to be set by machines. Operations are more or less foolproof, but the worker loses his work relationship and his creativity is of little or no use. The worker has no freedom, he has become functionally a machine component that can be controlled like a machine.

With the transition to automated process industries, and currently with the emphasis on production control, information technologies and automation, more fundamental changes are required. There will be fewer people working, people will form teams, for shorter or longer periods, and generally people will have to be more flexible and willing to learn more throughout their entire working life.

The task requirements today are very different from those of the mechanization area. Costly equipment and production losses, poor quality performance, absenteeism, high job turnover are all strong indicators of discrepancy. These indicators show that the work place contains a very strong social component that has to be integrated together with the other aspects of the work space like technologies allocated to producing products and services, informal and formal organization where the work takes place, individual incentives to perform work, and the complexity of work. But technology also shapes the design of work and provides for a nearly unlimited capacity for producing goods and services. Work organizations have to better match the requirements of the new technologies. Self-regulating teams may be appropriate to facilitate these kinds of working conditions.

C. REWARDS AND CONTROL OF WORK

Human beings are capable of adapting to a wide variety of conditions and behavior. They are social animals that relate to the environment to fulfill their needs. Behavior is therefore directed towards the things that bring satisfaction. Consequently, the structure of work

affects workers behavior. Work design affects motivation by the individual's perceptions on which performance give the valued rewards, both intrinsic and extrinsic rewards. Work design has to enhance the relationship between performance, and self-esteem and accomplishment. The work design needs to specific address feedback about performance, challenge the worker's abilities, and worker's ability to set and control goals and methods for reaching goals. These characteristics are highly individual and dependent on the workers personality and cultural norm.

The changes that have occurred since the industrial revolution have mostly been concerned with the balance between coercion and extrinsic rewards, and with the way in which coercion or manipulation is applied. Before the trade unions the autocratic control was vested in the foreman. He had all the power to do what he wanted and the workers had nothing to bargain with. Coercive control was maintained or increased.

When the trade unions became an important part of the industrial organization, control was done less by coercion and more on extrinsic rewards. However, the workers now operated like a machine and had lost part of their previous freedom working as a craftsman. The organization was not able to make adequate use of all of the human resources and conflicts started to surface. The production system is less efficient and has a high cost due to non-productive controls and conflict handling.

D. SOCIO-TECHNICAL CONCEPTS

The concept of a socio-technical system arose from the consideration that any production system requires a technical organization, equipment, process layout, and a work organization relating to each other those who carry out the necessary tasks. The technological demands place limits on the type of work organization possible, but a work organization has social and psychological properties of its own that are independent of technology. A socio-technical system must also satisfy

the financial conditions of the industry of which it is a part. It must have economic validity. It has in fact social, technological and economic dimensions, all of which are interdependent but all of which have independent values of their own.

Traditionally the technical system has been taken as given, and therefore any changes in an organization has focused on the socio-economic system with respect to the requirements of the technical process structure. However there are two problems with this view. First, technological systems have been designed specifically to give a maximum breakdown of jobs. Second, implementing changes in an existing work organization requires a great deal of effort and it is not an easy task.

Inherent in the socio-technical approach is the notion that the attainment of optimum conditions in any one dimension does not necessarily result in a set of conditions optimum for the system as a whole. If the structures of the various dimensions are not consistent, inference will occur, leading to a state of disequilibrium, so that achievement of the overall goal will to some degree be endangered and in the extreme made impossible. The optimization of the whole tends to require less than optimum state for each separate dimension.

When any aspect of a production system is examined, the manner and extent of the interdependence between all dimensions must be taken into account. The economic system such as capital, operating, maintenance, and wages costs has considerable bearing on the structure and functioning of the socio-psychological system and must be taken into account. However, it is through the people who compromise the system that technological and economical changes are determined to be successfully or unsuccessfully.

As long as the technological change was slow it was possible to adjust the social system accordingly. With the increasing rate of technology change this is no longer feasible. The rate of change of

technology is fast and it increases while the social change is much slower and the rate of change is stable. The organizational change needed to incorporate new technology is so slow that by the time an organization has changed and adapted to the introduced new technology, additional new changes to the technology has again been introduced and thus disrupted the conditions for maintaining the social organization. This seems to be a major contribution to the turbulent changes in the environment. Man controls the technology, but no longer the intended and unintended consequences caused by the introduction of the new technology. The problem now is not to create a social organization for a new technology, but rather an organization that can cope with the ever so fast changing technology. This implies a set of requirements at the organizational level, for the work roles, and for the tasks and tasks elements for the minimal conditions for effective task performance to exist from the start.

Industrial organizations do not operate in its vacuum. They adjust to their environment and currently the environment is unstable, chaotic and changing with an increasing speed. Basic changes in work roles and interpersonal relations within the work organizations can be expected to spread out into the society directly or as a model. Industrial development leads higher living standards, better education, more knowledge, changing social classes and family organization. These types of changes are cross-linked and the intended and unintended consequences of the changes have to be accounted for so that the effects are not being unnecessary damped or intensified into other sectors. Today, people have a choice over a wide range of alternatives. It is currently possible to make choices that determine the best direction of social change, both in industry and society. Overall, technology and social choices have to be joint optimized to facilitate maximum performance for the industrial organization, for the society, and for each individual.

E. SELF-ADJUSTING WORK GROUPS

Production design techniques are based on the successive decomposition of the total production process. This decomposition then requires additional coordination and imports produced variances into the next higher level. Finally, the system produces more variances than it can control and the surplus is exported to the environment. The environment can no longer absorb the surplus and more problems will be created. The problems arise as diseases, health problems, environment pollution, and they influence every individual person. Not necessarily limited to those working at a given production unit, but possible also to the society which the production unit is part of.

To avoid these problems, viable systems at the production process should aim at avoiding production of variance, and providing for the variance to be controlled and handled within the producing unit. This implies that the social-organizational implications of any technical decision have to be studied before any decision is made.

The principle of critical specification design can be applied to identify and analyze the minimal set of conditions required to create viable self-maintaining and self-adjusting work groups or production units. Several different types of work organizations can operate a given technological system in several ways. Variables that may be free are the pattern of task allocation, the allocation of task responsibility, and the method of payment. When a self-adjusting work group obtains an optimum solution there is little or no external supervision and control, no internal staff and the management functions are concerned with supportive roles and mediating the relationship to the environment.

Self-maintaining systems do not possess a single rigid structure, but they have the characteristics of a matrix organization that can adapt to both its internal structure and external environment to meet all of the task demands.

Supporting conditions for self-maintaining groups are a clearly definable total task with a measurable outcome, a single social system responsible, individuals that do not lay claim to ownership of any task or equipment, relevant decision making are brought down to the lowest level, and responsible autonomy can only be achieved if the available tasks require personal responsibility.

The organization should be adaptable to technology change, provide conditions for autonomous and group based activities, exchangeable component structure, not overlapping or multiple role structure, mutual relations to perceived and demonstrable competence, minimize psychological tensions, control interpersonal tensions, provide for stability of team and organizational membership. Work roles should provide the basis for technical or professional competence, facilitate recruitment, and be consistent with career advancement. Tasks and task elements should be consistent with the requirements of the social system, complete task regions, and operate towards a joint aim for the team.

The changing technology enables a greater level of automation and change adjusting properties need to be built into an organization. For a given set of tasks, the number of people involved will decrease and the traditional hierarchy structure with the separation of work execution and authority will diminish. Work execution and work authority will be pushed down in the organization as close to the working level as possible. To facilitate maximum performance only a minimum structure should be built into the organization. This will allow the constant adjustment to technology changes needed to be allocated at the team level where individual capacities and competence are effectively utilized. This requires that the individual team member has a high level of education and that the individual is willing to pursue more education when needed and demanded.

F. WORK IN SOCIETY

As long as technology dominates work, work is perceived as a mechanical process where the machines and the methods define the situation. For many people, this leads to not engaging in work, people serve the technology and they feel disconnected. However, work exists through the choices and pursuits of the people, of each individual participating. If people feel unconnected and not able to perform at their best, the performance at work, technology included will also be lower. Work must be defined to include both people and the technology and both components integrated together. Furthermore, people exist outside the work place as well, work is only a portion of a person's total life. Workers have a social life with relations outside work. To ensure better performance these relations, the social life and society in general, also have, to a certain extent, to be embedded into the workspace.

Work is a social process that involves social contracts between people, carried out by human beings. Human beings exist in the context of others where work is only one form of interpersonal relationships. These relations may affect task performance in a work setting that may affect a group of workers and finally may affect the organization's performance. Work can be defined as an agreement between two or more persons to perform a stated task. How these people understand and manage their relationship is then a major fundament from which performance is being done.

The performance of the stated task implies that work is an interpersonal process as well as a rational process. Cause and effect will drive a person's behavior where the right behavior will drive the desired result. By possessing the right technology individuals will be able to perform the tasks, to transform input to the desired output, or to produce the right amount of goods and services. Workers relate to technology for

effective performance. After producing, the worker receives feedback and is able to adjust undesired behavior towards the goals of the tasks.

Figure 6 from Cummings and Srivastva, 1977, outlines the forces that influence the work relationship. All the major forces applicable to an organization also drive the work process and the work relationship. Unless these forces have a positive influence on the workers and enhance the human experience, the organizational effectiveness is not in its optimum.

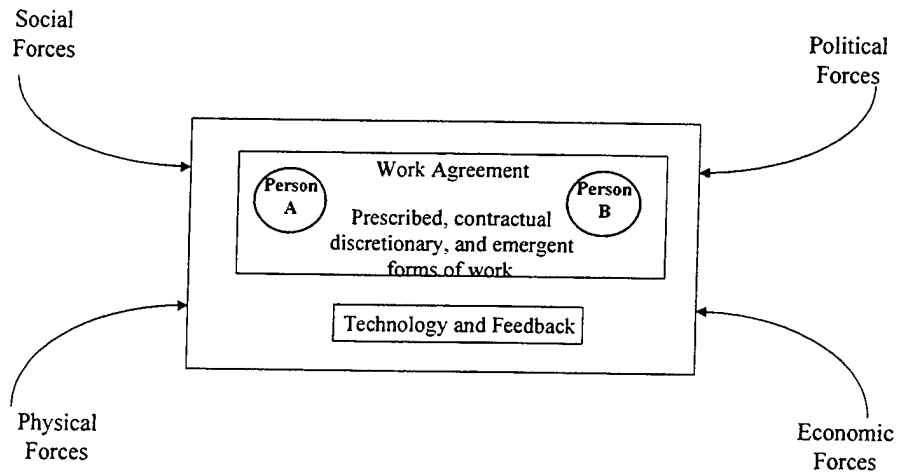


Figure 6. A Two-person Work Relationship Environment.

A social system is the relationship between people that interact with each other in an environment, and it is a self-generating system. The purpose is to achieve an agreed task or goal. This requires people to develop mechanisms for its accomplishment. All human interactions have consequences for other humans, and society needs some common values to nurture and develop these interactions. People develop and maintain social interactions and these interactions are integrated by certain symbols that act as social integrators. The social relationships affect the ability to solve problems and manage conflicts in the established and recognized context.

G. TECHNOLOGY

To be able to live and evolve, humans exchange with the environment all the time. The technology helps the human exchange processes and it is therefore a consequence of human's activities and

interactions in the social system. Technology is a key component for humans to develop and maintain the social system.

The technological system is not a self-generating system, it exists when people (and the society or social groups) bring it to existence, initiate it and maintain it. It consists of tools, techniques, and methods of employing task performance and its sole purpose is to serve the humans. However, humans and technology operate under different laws. Humans operate under biological and psycho-social laws while technology operate under the laws of physics, mechanics, electronics, and hydraulics. Thus, technology is a reactive system.

The technology system has consequences for the social system in the work setting: the characteristics of the material being produced, the physical work setting, the spatio-temporal dimension, the level of mechanization, the unit operation, and the degree of centrality of different operations. The interface between the technology and the social systems becomes critical to work performance, and the two systems relate to each other in some systematic manner. Both systems need to be jointly put into an overall framework for effective task accomplishment. The part functions of each component needs to jointly function in order to produce the desired outcome and they need to be jointly optimized for optimum performance. The next step involves relating the jointly socio-technical system of the workspace to the environment, which it is operating within.

The technology- and social- component of an organization has to be viewed together and considered as a whole, a complete system. These two components may be separate, but the interrelations between them require that they be looked upon as a whole. There is no social event that has no technical or ecological component. No technical process exists without a social component. An activity needs to be analyzed from both sides. When a technical component breaks down, the event has both a pure technical process consequence as well as social consequences such as stress on an

individual or on a team, interfering with other kind of work, less production because of the breakdown etc, etc.

H. SOCIO-TECHNICAL SYSTEMS

A system is a sum of its objects, relationships and its attributes, and it is defined as

A set of objects together with the relationships between the objects and between their attributes. (Hall and Fagen, 1956, p. 18)

This definition does not consider a system working together with other systems, nor does it consider the whole of the system or the whole of all systems. Socio-technical systems are organized wholes. It considers the whole of a system, or the whole of several systems, i.e. the social and the technical systems. A socio-technical system can be defined as a system with a nonrandom distribution of social and technological components that co-act in the physical space-time for a specific purpose. This definition helps to differentiate the general class of all socio-technical systems from other organized and non-organized entities in the environment.

Socio-technical systems are dependent on the environment and in fact socio-technical systems has a high degree of interaction with the environment. Socio-technical systems also require certainty to function rationally, and thus socio-technical system reacts in accordance to properties of both open- and closed- systems.

Since open systems have a hierarchical ordering, each higher level of system being composed of systems of lower levels, it is possible to look at socio-technical systems at three levels: the individual-, the group-, and the organization-level. Table 13 gives an overview and example of the hierarchical ordering of socio-technical systems.

System Level	Composition of Parts	Example
Individual	One individual and the technology he uses for production	Man-machine system
Group	Several interrelated individuals and the technology they use for production	Work team
Organization	Several interrelated groups and the technology they use for production	Business organization

Table 13. Hierarchical Ordering of Socio-technical Systems.

At each level the system consists of both a social and a technological component organized for the specific purpose. Open system functions have several cross-level explanations on how the system maintains itself independently while interaction with other systems in the environment (or simply just interacting with the environment). The import-conversion-export cycles replenish the system and permit the system to exist at a high level of complexity. A boundary separates and relates the system to its environment. The steady state defines the system and sets the parameters for survival and growth. Regulations and controls enable the system to maintain a steady state while engaging with the environment and performing in work. Finally the system needs to be able to achieve the preferred steady state from a variety of initial states and in many different ways.

There is no best way to design socio-technical systems. Given certain criteria such as the social and technical components, the environment and the preferred steady state of an organization, there exist a choice in designing the relationship between components to achieve desired outcome (the optimal production of goods and services). Since the social and technological components follow different laws and have different development process, both forms of growth must be accounted for in the design process. Both systems must be able to exist, to maintain, and to grow in the design of the socio-technical system.

In order for socio-technical systems to survive, to develop, and to provide for the organization the ability produce at maximum, or optimum, performance, it must be managed. Both the socio-technical relationships and the system itself, and the relationship to environment need to be managed. When the work system is jointly optimized, with respect to the social and technological components, the task requirements of the technical system, and the biological and social/psychological needs of the social system, this condition also needs an economic validity within the organization which it is embedded.

I. DESIGN OF WORK

The technological system determines the characteristics of the social system through the allocation of work roles and the technologically given dependence relations between tasks. A work relationship structure specifies the work roles and interrelationships that people must occupy if they are to perform the tasks of the technical component. Work roles relate individuals to tasks. They are the links that tie people to technology.

In one direction they are related to tasks which are related to each other; in the other to people, who are also related to each other, (Trist & Bamforth, 1951). Figure 7 shows the work relationship structures together with some of current technologies that affects the organizational rate of transferring input to output, and thus affecting organizational effectiveness.

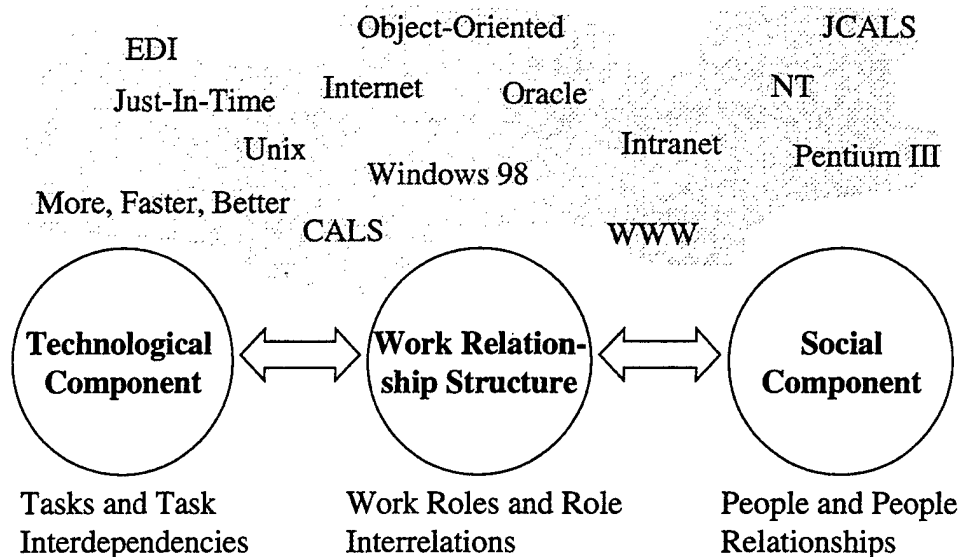


Figure 7. The Work Relationships Structure.

Work does not exist independent of the social groups that bring work into existence and gives work meaning in the day to day life. Work involves social and technology choices, at an organizational-, group-, and individual level. A basic function of management is then to bring into existence a jointly optimized work relationship structure. An optimized work relationship structure emerges the technological and sociological forces to improve task performance and humans need fulfillment. That means that the manager, who is assumed to be a professional (based on his role) and who knows his trade, has to be involved in the design of work, and not only rely on the industrial engineer to specify the design as a given. The managers and not the industrial engineers are those who best know the needs of their workers and the needs of their organizations.

Although the technology places limits on the kind of work organization possible, it does not uniquely determine its form and design, which may be analyzed in terms of:

- The quality of the work roles to which each system gives rise through the division of labor.
- The kinds of task group – the groups who together carry out given operations and share a common pay note.
- The work culture – customs, traditions, and attitudes – which governs how these groups are built up and conduct themselves.
- The nature of inter-group relations between task groups making up the team/group.
- The managing system through which the work of all faces is supervised, supported, and coordinated.

Work roles mean the jobs that people do every day and with which they become identified. In thinking of themselves as such they gradually take on certain common characteristics and may be said to acquire the character of the role. The work role is primarily determined by the formal division or allocation of the tasks constituting the cycle of operations among the men who form the group. There is a distinction between the formal or specified work role and the actual role that develops under a particular set of operating conditions. Recognition of such differences may not only indicate the efficiency of system functioning but also point the direction in which explicit technological or social change may profitably develop to achieve a better fitting together of the different aspects of the system as a whole.

A formal work role usually constitutes a main task together with the sub- and ancillary tasks that are associated with it. Since in certain systems the shifts on which main tasks are carried out are fixed, it is meaningful to talk of task-shift roles. According to the system of organization, tasks may or may not be specific to particular roles. The range of tasks and shifts comprising a work role may be narrow or wide depending on whether there is a formal rotation or shifts of tasks. The task range of a role may also be increased by disorganization, as when the

work a man normally does becomes unavailable because of cycle breakdown and he is required to undertake activities properly belonging to another role. The delineation of work role is, therefore, to some extent a function of the period of time over which the role content is observed.

The primary work group in the coalface is the smallest group whose membership carries out the whole set of activities constituting of the unitary cycle of coalface operations. The boundaries of this social unit are defined in terms of the technological unit – the work cycle that it has to perform. Just as the technical system of a coal face forms part of a larger system – the seam – in which it must be integrated for effective working, so does the primary work group – the cycle group – form a part of a larger social system. At the level of the cycle group, the technological, economic, and socio-psychological dimensions differ in the degree to which they constrain modification of the system by the group.

Task groups; In identical role groups all concerned are supposed to do the same amount of the same task and work more or less independently of each other. In reciprocal role groups the interdependent component activities if a main task are shared among two or more persons who work together in order to complete it. Isolate roles in which a man carries out a main task alone.

Work culture; The customs, traditions, and attitudes that regulate how men achieve membership of the various groups and conduct themselves as group members. For groups to be autonomous and self-regulating they must develop customs and traditions for regulating their behavior and relationships which are internal to them and binding by force of the authority of the group itself. The psychological climate of a group and the kinds of relationships it has with other groups involved in completing the same primary task are to a considerable degree determined by the way in which the group are built up. It is important to determine

the route through which men achieve membership of particular groups, the permanency of membership, and the route by which men leave.

Inter-group relations; An appraisal must be made of the way which task groups are related to each other and to the extent to which their activities and attitudes facilitate or hinder completion of the overall group. The degree of segregation of the various task groups comprising the cycle group, their number, and work relatedness to each other determine the basic pattern of inter-group relations. The technological interdependence of activities is such that task groups are to varying degrees dependent on preceding groups. A situation of this kind tends to give rise to differences in status and power – according to the relative independence of a group's work and its significance for cycle completion.

The managing system; The total means adopted to maintain the boundary conditions of given operating systems. Important for a differentiation of systems of work organization is the extent to which coordination of task groups is internal or external – is carried out by the cycle group itself or effected by management external to the face team. Specific activity and task groups may be internally self-regulating without accepting responsibility for coordinating themselves as a shift group. It is necessary to identify the level at which responsibility is taken for coordinating the cycle group as a whole and the means by which this is done.

A major dimension of a task is the individual task dependencies. These dependencies regulate the way tasks are grouped and hence how different tasks relate to each other. The dependencies also regulate how people interact with each other, and how technology must be integrated.

An independent task does not require any cooperation between workers and one person can complete the task. Independent tasks can be arranged in many ways, and the tasks may be assigned to one work role,

and the work roles can be grouped together. Grouping work roles with independent tasks require minimizing external control and supervision.

Dependent tasks require cooperation between workers and the tasks facilitate the completion of on overall task. The dependent task imposes constraints on the possible work structures that are able to achieve the desired performance. Tasks are grouped around coordination and the coordination is constrained by the degree of dependence between the part tasks. Furthermore, coordination is also constrained by time lag between the completion of tasks and to the degree several work roles are assigned to different part tasks. Some of these dependencies may be slacken by grouping work roles around a whole task.

1. Cases

a. *A National Food Processing Corporation*

William A. Pasmore and Donald C. King, 1978, conducted a research program designed to investigate differential impacts of socio-technical systems, job redesign and survey feedback interventions on attitudinal and performance measures in comparable units at a production facility of a national (U.S) food processing corporation. The units employed each approximately 200 unionized hourly workers, nearly equal numbers of men and women that produced different products, but controlled by same top management group.

The findings from this research concluded that improvements in employee attitudes are not enough to improve productivity or system effectiveness. Pure techno-structural interventions are often threatening to employees, especially when rumors of layoffs and/or job changes occur. Instead, a more balanced and system wide approach to an organizational change is more appropriate. The interactions between people and technology and among people themselves are what make an organization more than just an aggregate of individual efforts.

These case findings fit well with the findings of E. Trist et al, and Thomas G. Cummings and Suresh Srivastva.

b. A Software Development Firm

A. B. (Rami) Shan and James A. Sena, 1995, examined the implications of the implementation of a local area network (LAN) and its concomitant impact in a software development firm over a four year period. New information technology is likely to have different implications in companies in terms of system integration, work design, and organizational structure. These implications are likely to necessitate a realignment of the entire organization.

After introduction of LAN, information processing became centralized, standardized, formalized and automated. Processing was linked within the department and among other departments. Groups and individuals created storage area to facilitate information sharing and level of access to databases were established.

The importance of the availability and reliability of LAN led to stop use of experimenting and testing of new software on the LAN. Also some organizational responsibilities were reallocated.

The use of LAN and knowledge of its use increased ownership and use technology that represented the firm's product. It also changed and streamlined internal communication. Less, but more meaningful face-to-face communication, while announcements and memos were distributed through email on LAN. The use of email also introduced a new level social interaction.

The organization's size increased from about 30 to 70 persons and sales increased from about \$5 million to \$21 million. The introduction of LAN aided a change in structure and enabled growth both in revenue as well as organizational. The LAN facilitated increased productivity,

changed the way individuals worked, altered their commitment to work as well as increased motivation.

The findings from this research show that when people and technology are effectively integrated over time, most likely organization will experience growth, both economically but also on an individual working level. It also shows that information technology transforms many facets of our society, from society, to organization all the way to each individual within an organization. Information technology facilitates transformation of individuals, teams, functions, roles and boundaries. It becomes a key mechanism for future integration of change of organizations.

c. A Computer Operations Department

James C. Taylor's, 1986, research on an organization change in a computer operations division (COD) of a research and development laboratory concludes that socio-technical systems analysis is appropriate for white-collar settings and can generate long-term success. The results are examined three to eight year after the program's initial design.

The operations division experienced problems with maintaining their level of service and they had a high operator turnover rate combined with employee apathy. A steering committee was established and they formed a "Socio-Technical Analysis Work Group," that consisted of employees and managers. Workers participation was considered key to success of any organizational change.

The work group recommended a reorganization of the COD along with a development of operators as a valued and necessary resource. The reorganization included reallocation of hardware, office space as well as a recognized training group and an operations-oriented line management hierarchy. The work group used variance analysis to identify requirements of reliable service and high quality. One of the most

important findings was the lack of any relationship between two major teams within the division.

One design solution was to strengthen management. The senior section supervisors became more visible, participatory and task related, emphasizing team work across shifts and more direct communication, as well as an active role in employee development. Under this design operators worked in small groups dedicated to the defined mission of customer service. The design also reduced the span of control by one half at shift level, thus improving communication; routing communication directly to where it was needed.

This design turned out with positive results. The division's product was seen as better, quality of product delivered and volume of production increased, and user complaints were decreased. Managers ability to manage had improved, the operators morale was higher as well as a reduced operator turnover rate. These results are consistent throughout the whole research period.

d. Ford: Team Taurus

In mid-1980 Ford Motor Company found itself with sales off 42% and a loss of \$164 million for the quarter. Ford had been the leading U.S. automaker in non-U.S. markets for past decades, but the company did little to gain U.S. advantages from its worldwide operations.

Ford was very centralized, vertically organized by function and these vertical organizations had become so powerful that they were referred to as "chimneys" of power. Traditionally, Ford thought about its workers as a single purpose machine tool, and people were told what to do and not to ask any questions. Quality was controlled through inspection and the line kept moving regardless of defects.

The Ford Taurus program was an attempt to replace Ford's mid-sized cars with innovative new products to attack the heart of General

Motors' market. Ford implemented concurrent rather than sequential car design and development, and all units would work together as a group and take full responsibility for the new vehicle.

All constituencies were involved in creating a "want" list from which teams concentrated on a subset of all proposed items. Even the customers, consumers, and suppliers were involved in this process. These efforts led to reduced production and marketing entities of the midsize car segment.

The management process was based on a key events schedule with focus on what and when as opposed to whom and how. Involving all groups in the process lowered cost because groups avoided sub-optimizing at its own level. The responsibilities could no longer be passed-off, groups were responsible at its level and they had to integrate among groups.

Together with same type of quality processes previously implemented at Japanese auto companies, where only quality advance and anyone can stop the entire line to ensure quality, continuously reduction of variability, training its engineers and suppliers in new quality methods, employee involvement; encouraging workers to comment design, suggest any improvements, and the belief that people are the source of strength, Ford managed to reduce production time with seven months. Furthermore, savings on the cars' development was estimated at \$250-\$400 million. Number of design changes was reduced from cost of \$150 million to \$35 million, compared to previous cars.

The Ford Taurus experience shows that employee involvement and active participation combined with right level of technology and right use of technology increase productivity, gains employees and increase economic efficiency.

2. Findings from Cases

The findings from different cases show that organizations increase productivity when employees are actively involved in organizational design. The employees are well experienced and they know about shortcomings and bottlenecks in the organization. When they are involved in redesign of the organization and actively change their own workspace the results are often positive and over time more sustainable in the organization.

The increasing technology change affects organizations on a broad basis. Any organizational change today has to consider use of technology to increase efficiency. Just introducing email on every work position reduce number of face-to-face meetings and time is available for other purposes.

Work is an important part of an adult's life. Currently, the trend is that people work more and spend increasing time at work. In the industrial world there is an intense competition for qualified and skilled work force. With more competition for work force and with the diversification of labor it is easier for disappointed workers to shift jobs. Furthermore, people growing up today are used to much more freedom with many more choices than their parent generation. The employers that satisfy workers most are going to gain a competitive advantage.

Figure 8 shows relationship between technology and how technology impacts quality of working life. This could be further extended to also include total quality of life.

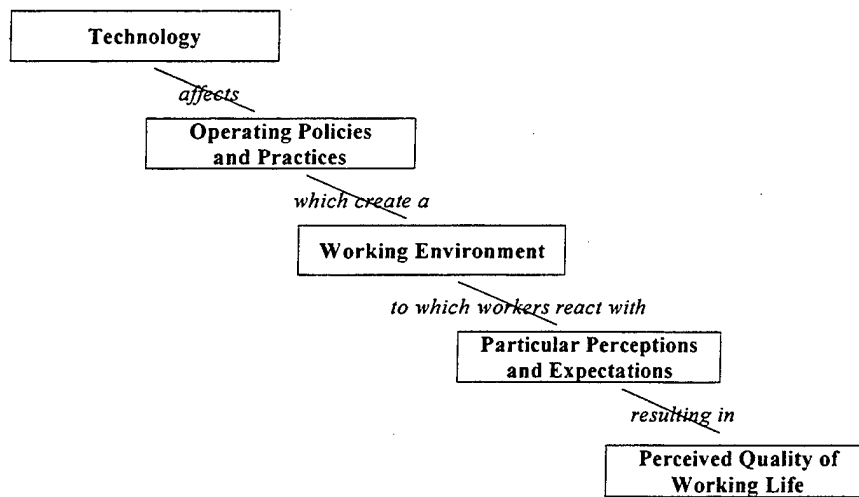


Figure 8. Technology and the Working Environment.

Frederick Taylor's "scientific management" approach to analyzing and structuring work and tasks certainly were a revolution in the workspace. It generated economic growth and more efficient industries. The failure to utilize more capacity of each individual worker in the workspace may lead to the next revolution. Today's environment with focus on automation and information technology demands that human's creativity, cognitive and social skills are coming more into play. Only a portion of human skills is currently effectively used. The next step of growth not limited to only economic growth, but include quality of life and quality of work, happen when human knowledge and skills are better integrated with technology. This can only be achieved when designers of work and managers of work are able to listen to human needs and maximize work design to accommodate those needs.

VI. CONTRIBUTING FACTORS FOR CONTINUOUS ORGANIZATIONAL CHANGE PROCESSES

A. REORGANIZATION

In the last decade, RNoNMC has managed to initiate and implement two major material programs and a reorganization of the organization. These efforts have shaken up the organization and shown employees that the future is uncertain. Employees have learned to work in an unstable internal environment, but they have gained confidence that it is possible to change and that the organization is capable of handling many different and complex tasks concurrently.

RNoNMC's top management group realized that the latest reorganization effort did not create an ideal organization. One of the first objectives after implementation of the new organization was to communicate that in this volatile environment RNoNMC has to be used to changes on a more continuous basis. At the same time, the top management group developed a strategy document for the future where organizational strengths and weaknesses are analyzed. This document forms basis for future efforts to change organization and to increase organizational effectiveness.

The current goal is to create an organization that continuously changes in order to avoid a state of organizational ineffectiveness. The organization needs to do more for less. This can only be achieved when the organization's core activities are accomplished at a constant or increasing level of efficiency with the same or decreasing increments of inputs of energy (Argyris, 1964). RNoNMC's core activities is investing and acquiring new combat platforms while at the same time maintaining combat components in existing Navy operational structure. As long as the organization is able to maintain old systems while at the same time still

acquiring more combat systems, the organization is working effectively but not necessarily at its maximal efficiency.

The creation of ILS branch located in Staff division is another commitment from top management to keep focus on continuous changes. The ILS branch is responsible for work processes and better integration between divisions and functional areas. The ILS branch is also responsible for implementation of information technology and structures that support work processes within the whole organization. IT-solutions can not be implemented before necessary work processes are identified and described.

B. NEW MATERIAL PROGRAMS

The initiation and implementation of two major material programs, New fast Patrol Boats and New Frigates, in parallel has required a lot of effort from engineers. The two programs used different development processes, but both programs relied on information technology and software applications to get tasks accomplished. The integration of different software tools was implemented at a previous unprecedented level within RNoNMC and Navy. This level of integration also established the need for someone, in each program, responsible for work processes, implementation of work processes and tailoring the development process. Previously, these activities have usually been ignored and not accepted as a separate professional area within program organizations.

The work processes had to be adjusted and implemented at a level where engineers were able to work and produce desired results. The personnel responsible for work processes need to be integrated with other engineering areas. The integration between different engineering areas led to a better understanding of problems, and engineers experienced problems outside their usual domain. Also, some of them took on work within other disciplines where they had little or no previous experience.

Working together with other fellow engineers, teams created good solutions where RNoNMC traditionally did not have any.

C. INFORMATION TECHNOLOGY

Most of administrative IT systems currently in use within Navy and RNoNMC are old and based on an outdated technology with a low level of integration between systems. It is difficult to implement necessary interfaces to other systems. Both because RNoNMC does not have enough resources within the IT department and because some technologies are so old that resources are not available in the civilian IT industry.

Facing the year 2000, it is anticipated that some of these systems will experience severe problems and there is a risk that they will remain in-operational after the turn of millennium. The cost of repairing these systems may be high and there is a question if required technical expertise is available. There are currently several efforts trying to reduce the risks of these systems as well as trying to implement new systems based on available technology.

Two major material programs have successfully used IT as a strategy to minimize work efforts during development phases of the programs. A high level of automation reduced required engineering effort as well as helped ensuring a better level of consistency in documentation. The use of IT identified and implemented necessary integration of different functions within RNoNMC organization.

However, the introduction of new information technology is better implemented in small increments. Solve the small and manageable problems before trying to change the whole organization. When an IT solution functions within a small domain it can be expanded to a larger domain. But without a described work process or at a minimum what the technology is supposed to do an implementation increases risk of failure.

D. TEAMWORK

Traditionally, material programs depend on innovations to get the job successfully accomplished. The programs realize that they need to use untraditional methods to accomplish all their tasks, often within a tight time and resource budget. Small teams are usually established to solve problems, both on short- and long-term.

These teams are mostly nonhierarchical. Only the leader is formally appointed. How teams solve their problem is entirely decided by the team. Sometimes teams identify new problems that may initiate other teams. Some of the people involved in a program may be participating in many teams at the same time. Therefore, it is critical to the program that teams are large enough so they do not rely on a few key people. On the other hand, teams must not be too large. Large teams are harder to manage and they may not work as efficient as small teams.

Team is created to solve a specific problem. The problem may be of short term or it may require a group to work on a more long-term basis. Teams are used when problems need to be viewed from many areas and it involves different offices from different divisions. The teams are given their tasks with a finalization date. How the team chooses to solve the problem is decided internally. They are given a structure to work within, but the structure usually only applies to formatting. The group is responsible for internal scheduling so that each member can handle the rest of daily tasks.

Working in teams allows each member to be creative and to participate in tasks decided by the team. The team can be viewed as a working democracy where each member contributes and shares the final result. Each member will exercise pressure and constraints on the rest of the team so that everyone contributes equally.

The results from the team are often greater than the sum of each individual. The team takes responsibility for the success or failure and

very often there exist a strong ownership to the problem. The ownership goes beyond each individual's usual area of responsibility. Since the team is dependent of the contribution from each member the team creates an environment of constant individual learning. In order to achieve progress the team ensures that each member learns necessary skills to contribute effectively.

In the daily work within RNoNMC it can be difficult to get people involved in work or tasks that are not naturally within their job description, or within the responsibilities allocated to the office. Some of these tasks may be critical to parts of the organization, but they may not be adequately described or specifically allocated.

Participating in teams create individual relationships in the organization that reach outside responsibility boundaries for an office or a division. Being in a team creates an opportunity for each individual to experience other parts of the organization and to see what kind of difficulties that exists elsewhere. This kind of relationships may then be basis for future co-operations within organization, but not necessarily related to only material programs. Information technology helps creating personal networks that is not only dependent on face to face contact or meetings, but also on formal and informal communication on electronic media.

With the increasing complexity of new combat system combined with the decline in the Armed Forces' budget it is a possibility that less resources will be spent on education and training. Participating teamwork could to a certain level substitute for using resources on education and training. It would therefore be in best interest of employee's carrier to contribute actively in teams.

Integration of systems can only be achieved by personnel with a great variety of skills. With the increasing complexity of systems and decline in resources RNoNMC must be prepared to hire or buy specialists

within certain areas for a limited period of time instead of employing professionals on a permanent basis. The challenge for RNoNMC is to manage activities needed as well as manage consultants with special skills only needed for a limited period. Unless managers has a broad variety of skills and experiences the management will be a serious problem.

E. PHYSICAL LOCATION

After reorganization most of the branches and offices were physical relocated. Employees within an office were tried located together or in close proximity. Offices that were closely related with responsibilities were also tried located as close as possible. However, many employees need to physical move from their office location when they need to accomplish certain task. If an employee is assigned to a program he will most likely have a workspace in work area allocated to the program. If one need to attend a meeting it is most likely held in a location outside office.

These activities show that employees are used to changes in their daily work routines. Few days look alike. In the future it will probably be easier to introduce other changes since employees lately have been exposed to a constant environment of changes. Not only within the organization, but also how employees have changed their interaction with other employees.

From an organizational view, the employees are spending more time than desired moving from one location to another. Whenever an employee is not present at his office or not performing work, he is considered unproductive. In order to maximize organizational efficiency each employee has to spend more time doing productive work.

Encouraging employees to use electronic communication instead of face to face meetings can increase organizational efficiency. Reducing the number of face to face meetings allow employees to be more present at

their workspace. The meetings are not completely removed, but some of them can be substituted by use of electronic mail and software that allows people to share, edit, and comment information electronically. Thus, reducing the need for face to face meetings to a minimum.

However, physical activity prevents injuries and makes people to feel good. Moving from one office location to another lets people have a few minutes off from a hectic workday. It allows people to relax, enjoy physical activity, and have some free time to think without demands from other employees. The efficiency loss from workers being physical on move as compared being constant at work position is difficult to measure.

F. EXTERNAL ENVIRONMENT

1. Of the RNoNMC

The continuous cuts in Norwegian Armed Forces' budget means fewer resources. That is in form of both money and personnel. RNoNMC has currently a pool of unmanned jobs. This situation will continue in the future. Material programs receive less funding with a higher emphasis on financial management. It is a difficult balance since every manager wants to get the most operational use of money available. This may create a situation where program managers optimizes the program's short-term goals and does not pay proper attention to long-term goals.

The major contractors to RNoNMC now use information technology to cut costs and to work more efficiently. IT helps contractors to assembly components and combat platforms faster and with higher quality. Unless RNoNMC are able to adjust and to integrate with contractors, RNoNMC will loose the ability to control and follow up work until products are delivered. When product is delivered, RNoNMC may not be able to either use the equipment efficiently or to maintain and supply at recommended levels. Unless RNoNMC is capable of using IT to manage and control programs in co-operation with contractors, the organization will not gain

necessary knowledge needed to use equipment effectively.

RNoNMC also experiences problems with implementing new work methods into the organization. Material programs are good test cases for trying out new innovations in a small scale before implementing them into the whole organization. Also, material programs work closely with contractors and therefore they gain a valuable insight into business practices that are difficult to obtain elsewhere. Often, these contractors have done businesses with a large range of customers, both private and with other government agencies, and together they utilize some of best practices available.

RNoNMC need to effectively exchange technical data with suppliers. Many routine tasks can be automated and by establishing long term contracts with suppliers, RNoNMC can reallocate resources from routine tasks to more complex tasks that not occur frequently. Technology is available and most of the suppliers and contractors already have capabilities for automated information and data transactions. If RNoNMC is unable to enhance technology they risk paying suppliers and contractors extra for not following industry standards. Transforming information from automated systems into manual systems is expensive and it requires extensive human resources. The risk of introducing errors is high and the total costs may be too high.

2. Of the Navy

The Navy Staff first experiences consequences of budget cuts. These consequences then transfers to different branches of the Navy. The yearly cuts in budgets require a financial management system so that all money spent can be accounted for. Previously, it was allowed to transfer funds from a fiscal year to another. Today, this is not considered good practice. Funds allocated to a fiscal year are expected spent during that year. It is difficult to receive additional resources during a fiscal year.

The Navy does not have a management system in place that supports these requirements. Reporting is done manually by paper reports. If specific data is needed a request has to be sent to the actual agency that handles the data. The consequence is that there is little real time reporting and the ability to query information is limited. All requests for data create additional tasks and valuable time is lost. Also, request for data may not be given proper attention and priorities.

The Navy has initiated several programs with goal to streamline information exchange and making information more easily available. Easy available means that correct information is available to right organization and to appropriate level within the organizational hierarchy. Decision-makers at all levels should have information available for making good decisions.

People currently recruited to the Navy are young people used to new technologies with computers, Internet access, and other complex systems in the society. Many of them are interested in new technologies and they receive a high level of education. When being onboard the Navy, they experience how the Navy works and many times they identify changes that can make a difference. However, the Navy works slow and the proposed changes may not be recognized as necessary, or the Navy does not have adequate resources to implement the proposed changes. Few changes are ever tested or implemented. The lack of changes may create enough frustration so that skillful young employees needed by the Navy end up leaving.

G. SUMMARY OF CONTRIBUTING FACTORS

Several internal and external factors contribute to a positive culture towards organizational change processes. The employees have during the 90's been exposed to constant changes through several new material programs and the latest reorganization effort. They are accustomed to

changes and resistance to change has decreased.

The employees working in material programs are introduced to new ways of organizing work, and they have seen positive effects of utilizing technology to increase the organizational efficiency. The concept of teamwork enables a better systems approach to solving problems and technical solutions are better integrated.

The external environment continuously changes. Since RNoNMC relies on contractors, these changes affect the organization. Unless the organization is able to change and adapt to external environment the organization will use its resources inefficiently

VII. CONCLUSIONS

The main research question is how the current work processes can be changed in order to improve RNoNMC's performance?

By examining previous and current work processes, impact of changes in external and internal environment, and comparison of results from material programs, the research shows that RNoNMC can increase organizational effectiveness by changing existing work processes, identifying, describing and implementing new work processes tailored and optimized to organizational and members needs. The work processes must be matched with technologies that automate trivial and routine tasks so that human resources can be used on complex problem solving. If the work processes are not fit to the employees and supported by sufficient technologies the organizational effectiveness will be low, as shown in the material programs D described in Chapter IV.

Teamwork that emphasizes a systems view provides a mechanism for solving and integrating complex organizational and technical problems, including organizational change processes. Employees participating in teamwork take ownership and commitment of the solutions. Participating in teamwork let the employees actively decide on issues that affect their work situation. When employees decide their own work situation the solutions are effective and their commitment ensure an integrated implementation across functional areas. This provides for more effective organizations. This effect has been demonstrated in several programs further described in Chapter IV.

Technology increases efficiency, but technology is only helping people by automating non-critical tasks that occur frequently. However, technology needs to be implemented after the work processes are identified and described. The work processes and supporting technologies

must be analyzed with respect to the total impact on the organization and members of the organization before implementation.

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