Integrating The Social And Technical Systems Of Organizations

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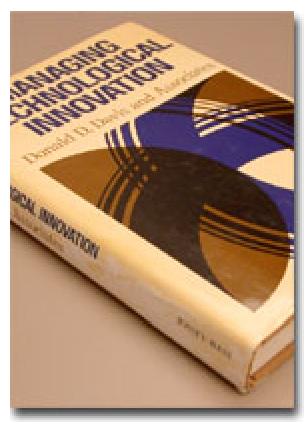
Chapter 7: Integrating the Social and Technical Systems of Organizations

In 1978, Zilog Inc., a California affiliate of Exxon Enterprises, built a new semiconductor (S/C) circuit plant in Nampa, Idaho. The manufacturing processes were designed using sociotechnical systems (STS) approach, which resulted in product-related work groups rather than the technology-based or functional work groups typical for the industry. In other words, groups were arranged to produce an identifiable part of the completed S/C circuit chip (and to control technical variances associated with product quality), in contrast to merely being grouped around a the of machine or technical function. This work organization proved to be so successful that two years later the STS approach began to be used to redesign work in other areas of the company. The S/C product-design department (known hereafter as Component Design Engineering, or CDE) was one of the first.



CDE had been growing and changing as Zilog developed. Since Zilog was founded in 1975, CDE as a department had successfully provided the company with two generations of microprocessor devices (eight-bit and sixteen-bit) without paying much attention to how it was organized. But times were changing in the S/C industry. What has begun as a strictly high-tech industry was fast changing from being "engineering driven" to being "marketing driven." Furthermore, for the company to remain competitive, the products CDE would be designing were much more complicated than those of the past and would require more than individual designers working alone to create them. This paradox, or engineering no longer being the sole arbiter of design but being expected to design ever more complicated S/C products, was apparent in late 1979 and early 1980 when the present project in CDE began. This chapter describes how CDE redesigned its organization to address its future - to cope with new process and product technologies, with dynamic competition, and with ever-changing markets.

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This case is unique in several ways. To our knowledge it is the first application of the STS analysis and design technique to the computer-assisted design (CAD) technology of circuit-layout drafting. This case also addresses the place of professional engineers in the organization and how they are organized. Finally, and perhaps most importantly, the STS analysis described here places CAD technology within the total structure of the CDE department as an engineering systems, and places CDE within the context of the other departments in the company and of its industry environment, The upper limit in capability of the CAD system (or any) technology is not achieved because of an exclusive focus on the technology itself but us placed as an extension of the organization that applies it, which is in turn dedicated to providing the company and its other departments with appropriate technical and social products. This case describes not only technological improvements but changes in management procedures and organization as well. These changes include the gradual dissolution of traditional separations between design and manufacturing, and between design and marketing.

Sociotechnical Systems Management

The STS analysis and design technique, as applied in this case, represents a purpose-oriented approach to organizational improvement. Efforts to improve organizations can be classified into three major types: problem-oriented approaches, solution-oriented approaches, and purpose-oriented approaches. There are many examples of the first two approaches, but apart form open-systems planning and STS, there are few methods for applying the purpose-oriented approach. These methods approach organizational improvement by discovering "what business we're in" and "what we need to do to excel at that business." Thus, STS is not simple a managerial technique of applying group solutions, examples of which are quality work circles and computer-aided mechanization.

Since the first introduction of STS, a substantial body of evidence has accumulated to show that STS, as a purpose-oriented approach, can be applied to significantly improve organizational performance and quality of working life. It is established as a high-level management approach for improving any work process in a manufacturing or service organization. It has been developed over the past thirty years in Europe and the United States, and the results set new standards for white-collar and blue-collar effectiveness (Davis 1981; Emery, Foster, and Wollard, 1978: Taylor, 1978; Trist, 1982). For example, Procter & Gamble began using the approach as early as 1969 and has continued to refine it. Other long-time users of STS include General Motors, Shell Oil, Best Foods, and Cummins Engine Company.

Why STS Management Works

There are three reasons for the success of STS management: joint optimization, purpose orientation, and structured process.

Joint Optimization. STS management gets its name from the way it integrated the production (technical) requirements of the work process with the organizational (social) functions of the people working in the process. We use the expression work process because STS management can be applied to any process in which work is being performed. These processes include manufacturing production, research and development, engineering, data-center operations, office automation, and clerical operations.

Many industrial-engineering (IE) techniques focus on the efficiency of the work performed, which is the technical part of the work process. Although IE practitioners consider social functions, they don't integrate them into the management of the process in any systemic way. The people portion of the process is usually organized around the technology on the basis of seat-of-the-pants opinion of how best to mange people. Organizational-development (OD) techniques focus on the social functions in the work process, but the OD practitioners tend to overlook the work that needs to be done.

STS uses many IE and OD principle, but the focus is on integrating them to obtain joint optimization of the social and technical functions in the work process. The overall effectiveness of a work process, however it is measured, can be thought of the combined effect of the social and technical subsystems, each with its own optimal joint. The work process that optimizes the technical functions is often not optimal for the social functions, and vice versa. What is best for the work process as a whole may not be optimal for one or the other sub-systems.

Purpose Orientation. Because STS management focuses on the work process as a whole rather than on its parts, it is a system approach. It starts with the particular mission or purpose of the organization and develops a design for a system of management tailored to the purpose. This purpose orientation is much more powerful than the more common problem-oriented approached (for example, technical audits and questionnaire surveys) or solution-oriented approached (for example, office automation and quality circles), which address only a part of the system and which often ignore strategic management issues and overall mission.

Stuctural Process. The third reason for the success of STS management I the structured approach it uses to analyze and implement the operational improvements. Many other management models are conceptually interesting but operationally soft. Most managers find it difficult to implement such approached because there is too large a gap between the concepts in the models and actual day- to-day activities in the work process. The STS approach provides a process for data collection and analysis and thus makes the model operational.

Products of STS Analysis and Design

A lot of information has been developed on STS management. What we will focus on here are the products of the approach as used in successful cases in North America and how these were used to make important improvements in the work process. These products are:

- Systems scan
    - Management mission and philosophy
    - System inputs and outputs
    - Boundaries of the organizational system
    - Important environments for the system
- Technical analysis
    - Unit-operations flow chart
    - Key-variance matrix
    - Variance-control table
- Social analysis
    - Social-system grid
    - Focal-role-network chart
    - Quality-of-working-life evaluation

Design recommendations for improved organizational outcomes

This is an iterative process. The analysis continues after improvements are implemented, resulting in a continuous process of analysis and change.

Scan Any organization of part of an organization or parts of more than one organization can be considered a sociotechincal system if it contains a purposive transformation process (a technical system) and people working together over time in stable relationships (a social system). A purposive sociotechnical work system can be considered part of a larger organization, from which it is analytically separated, if its mission and philosophy are aligned with, and contribute to, those of the larger body. Scanning involved the fairly brief but extensive overview of the system to be examined - purpose (technical mission and social philosophy), boundaries, inputs, products, staff, relationship to its environments, and the presenting problem, if any.

Technical Analysis. Once the boundaries of input into the system and output from the system have been defined, it is possible to identify the unit operations in the technical process. The output of each unit operation is the result of the transformation of input, where that input is either physical or informational.

The output can be physical or informational also. It can be a product or a service, but it must express in measurable terms the tangible results of the system's mission or purpose.

The STS analysis has the advantage of defining technology by its input and product rather than by its tools, processes, or techniques. This focus ensures that the technical system will be analyzed separately from the jobs and work of people on the one hand, and from the supervisory and control system on the other. In identifying these unit operations, STS managers frequently find that they can establish fewer unit operations for their system than they at first thought because many of the operations performed on the input are checking, verification, or inspection activities rather than fundamental changes in the state of the input.

Identification of key variances is the second part of technical analysis. Once unit operations have been determined for the system, they follow the important tasks of identifying the many technical requirements, stated in terms descriptive of the output, and, from among those factors, or selecting the most important ones.

The actual process of identifying key variances involves first the listing of all known variances (aspects and conditions) of the product for each unit operation. Variances representing human failure or breakdowns in the technical process itself are not included in this listing. The next step is preliminarily to identify as key variances those that are most direct or important in their impact on quantity, quality, or costs of the system output.

The key-variance matrix is the final step in identifying key variances. It is an interaction table that includes all the variances, grouped within their unit operations, arrayed along both sides. Cell entered in this square table represent the relationships between each part of variances throughout the work process. Once this interaction table is constructed, informal rules are applied that define a factor as key if it has an impact on one or more of the key factors identified in the preceding step or several other factors in unit operations downstream.

Variance control forms a bridge between the technical and social analyses; it is central to the design process. In it, key variances are examined one at a time to determine the manner in which they are currently controlled (for existing work processes) or are usually controlled in conventional plants (for designing a new work process). The analysis is accomplished through the use of a table of variance control, which lists the unit operations in which each key variance originated, is observed, and is controlled. The table also lists who or what controls the key variance, what actions are used to control it, and the source of information used in control. Tables of variance control frequently reveal that variances are not controlled where they originate and that much of the control is undertaken by management or support staff long after the variance limits are exceeded. The copletion of this table provides the transition to social analysis.

Social Analysis. The social system comprises the work-related interactions among people. These interactions include vertical (superior-subordinate) relationships, either internal to the work process or across its boundaries, and horizontal relationships among persons within the same class (for example, nonsupervisory, supervisory, managerial) or, more specifically, among persons at the pay or status grade. As with vertical relationships, horizontal relationships may be internal to the work process or may cross its boundaries. The initial boundaries of the social system are the same as the boundaries of the technical system: the point of entry of raw material and the output of results or product. In addition to relationships among people, social interactions are driven by the role expectations that people face. Our positions as parent, spouse, friend, supervisor, and subordinate create many and sometimes conflicting role expectations for us.

The social analysis essentially involves examination of the roles and relationships within the whole work process. This activity includes mapping both the persons who have work-related interactions in the system and the reasons for that contact. Because a comprehensive analysis of all positions would be too time consuming, the social analysis focuses on those most involved in the control of key variances, based on the assumption that every organization exists in order to meet the short-term goal of producing its product. We refer to this process as the focal-role analysis; of maps the cooperation of and coordination between those with focal roles and others within and outside the work process.

Define this way, the social system is not mere friendship or recreation but rather the coordination and integrating buffer between the technical-transformation process and the demands and constraints of a turbulent environment. The demands of this environment go beyond merely satisfying a consumer market or coping with supplies of raw materials or the other tasks directly affecting the technical system. The environment is actually many environments - legal, legislative, labor, cultural, climatic, and so forth.

Any social organization, if it is to survive in these environments, must perform four basic functions: goal attainment in controlling key variances (G), adaptation to the external environment (A), integration of the activities of people within the system (I), and long-term development (L). Every organization exists in order to meet the short-term goal of producing its product (G). However, in doing so, it must not adversely affect its capacity to survive as an organization. It must adapt to, and be protected from, short-term changes and pressures in its immediate environment (A). It must also combine or integrate activities to manage internal conflict and to promote smooth interactions among people (I). Finally, it must ensure the long-term development of knowledge, skills, and motivation to cope with goal-related, environmental, and systems requirements in the future (L). In social analysis, the letters G,A,I,L, are used to indicate what type of functions are affected in contracts among people.

Manu organizations have departments to perform these functions. For example, IE, planning, personnel, and training department can have the main responsibilities for one or another of the four basic functions. Yet we know from experience that not all such activities are handled by special departments. Indeed, informal activities at the level of the focal role are often more frequent and more influential in affecting functional behavior than are formal methods and policies. For instance, the informal initiation that production operators receive often contradicts formal instructions form training classes. The task a hand for the social analysis is to describe the ways that these necessary social-system functions actually get carried out and to evaluate how effective these methods are for satisfying the human and technical requirements of the organization.

The examination of the presence or absence of a fixed set of functional relationships in a social system is aided by charting them in a way that combines not he four functional requirements (G,A,I,L) and the particular relationships (vertical, horizontal, internal, and cross-boundary) describing the work process. This combination is charted on a 4 x 4 grid of social relations.

From the behaviors noted in the social grid, the patterns of interaction with the focal role can be mapped according to frequency and direction of contact, and these contacts can be identified by social function(s) served. Mapping these patterns produces a focal-role network.

Finally, incorporating human preferences into the design of organizational systems is vital to STS management, In part; human preferences are assessed through discussion and development of the design principles and management philosophy. Assessing preference, however, must also consist of identifying those aspects of work that are seen as desirable by members of the organization. These aspects of work that are seen as desirable by members of the organization. These aspects are the elements in the evaluation of quality of working life (QWL).

QWL is more than merely wages, hours, and working conditions. Those are important, but QWL also includes dignity and respect, social support, prospects for advancement, and challenging work. Recent research into comprehensive employee-generated lists of QWL revel that employee also value a job that is central to the essential business of the enterprise, and that this centrality is an important contributor to employee attitudes when jobs are enhance. It has been found with STS management that high QWL is the result of competence in creating a meaningful product. Furthermore, competence and centrality are greatly enhanced by designing work so that employees consciously control key technical variances as close to their source as possible.

Design Recommendations. The social analysis builds the technical analysis to identify ways that key variances can be controlled by improving the fit between the technical functions and the social functions. With the information developed in the analysis, managers and employee's can implement improvements in the work process that identify and control variances at their source. Place coordination of the work at the lowest organizational level compatible with the technical and social systems, and develop organizational structures that fit the structure of the unit operations.

STS is thus s continuous management process involving four steps, and it is an iterative process. The analysis continues after improvements are implemented, resulting in an ongoing process of analysis and change.

Case Study

Once Zilog realized that the Nampa, Idaho, manufacturing facility was not merely organized differently from other plants but was much more productive, the company widened its application of the process introduced in the Idaho plant design. In fact, the 1983 recruitment brochure described Zilog's management style as a "Sociotechnical one." This diffusion of results is an important sign that the STS efforts were supported but others in the company apart from those directly using them. The STS project was extended nest to CDE, one of the first departments at Zilog's California headquarters to show interest in the STS experiment at the Idaho plant as an improvement process.

The Idaho STS organization, begun in 1978, proved to be a success in two ways. Quality results (die/water yield) exceeded by 15 to 20 percent the results of other organizations in the United Stated that build similar products, and the employee turnover of 10 percent or less was drastically lower than industry figures, which range from 50 to 100 percent annually. The questions that remained by 1980 were: Can this STS process be used in Silicon Valley; where competitive pressures are higher and loyalties lower than in Idaho? Can it deal with the high turnover and high entrepreneurial spirit of high-tech engineering, an atmosphere in which people are rewarded for being specialists? Can it work in the design industry, in a place other than a manufacturing plant? Can it work in engineering?

Those issues were important to the founder and first president of Zilog, Federico Faggin. In conversation with one of the authors, late in 1979, Faggin said, "you know, those STS results in Idaho are great from an S/C manufacturing area of the company; that's our life blood, we have to produce high-quality product. But where this sociotechnical process would have even greater value is with the people who design and create the new devices. " He had two reasons for wanting to extend the STS process to design. First, engineers will typically create just to create; Faggin wanted to help them create something that was useful to other people and therefore matched the market need. Second, if the people who were designing the new generation of microprocessors could be sensitive to what the key manufacturing variances were, the company could build a product less expensively with higher yields than before. Sensitivity to manufacturing would allow the manufacturing organization building the product to begin feeding back data to the design people.

At this time Zilog's director of CDE was faced with a series of challenges. He saw that the company was changing form eight- and sixteen-bit microprocessors and moving into the design of thirty-two-bit products. The complexity of the thirty-two-bit microprocessor is much greater than that of the sixteen-bit. A thirty-two-bit chip has over 1000,000 transitor, which is more than five times the 17,000 transitors on one sixteen-bit microprocessor. Complex chips used to have only a single function. It is not uncommon now for a complex chip to integrate the functions of what used to be three chips. The length of time needed to design and develop the eight-and sixteen-bit microprocessors was typically a year or a year and a half. The new thirty-two-bit processors require three or four years of product development. The CDE director realized that a chip-development project that used to require only a design engineer, a layout designer, and an architect was now going to require a dozen to fifteen people.

The other problem he faced was his organization. In late 1979, CE was organized functionally with fewer than a hundred employees. There were separate groups for architecture, logic, and circuit design, layout design, product planning, applications, and documentation. More than 80 percent of the people had college degrees. Of those people who had degrees, at least two thirds had an advanced degree an MS or a Ph.D. The special qualifications of these employees had shaped the functional nature of the CDE organization. This functional division was marked by conflict and friction among the various groups in CDE.

Functional specialization among design workers in widespread in Silicon Valley companies. Engineers are an elite caste with individual star performers. Layout specialist, although not an elite group, have high wages, This division of individual engineering stars and a clannish underclass of layout designer does not encourage commitment to the organization or cooperation in the design of integrated circuits (Ics). Most of the companies in the Silicon Valley have been organized in this functional way to recognized and support other types of design specialists because demand for design people is high. On any Sunday, Bay Area newspapers carry full sections of ads for design engineers, test engineers, and system architects; there is high turnover in these jobs, consistent with the number of start-up companies in the Valley. People leave one company for another in quest of becoming millionaires; People in these design specialties are often hired like players in professional sports- a hole company can be built around one of them.

Differences in background and training distinguish design engineers from layout designers, Design engineers are a sensitive group - they know how good they are, and they know what they are worth. Many of them of not mind saying exactly what they feel. Throughout their education and training, they have been rewarded fro being the best specialist. Layout designers, however, generally do not have a college education. They produce in graphics form the specific circuits created by the design engineers. Because they work in the last step of the design process, they often take the blame for the engineers' inattention as well as their won mistakes. Layout people often feel like second-class citizens. To counteract high turnover, layout people are highly paid; in this ways, they are rewarded for being specialists in their particular field.

In early 1908, when the sociotechnical analysis in CDE began, the circuit-layout function was overlooked by management planners. Figure 1 shows the original organization chart. Although the circuit-layout group consisted of fifteen designers reporting to a supervisor, who in turn reported to a senior manager in charge of IC design, it was not known in Zilog's rudimental organization charts.

CAD Technology and Layout Design. The layout function in Zilog had recently undergone some mechanization through the introduction of CAD. CAD technology was developed for application in the S/C industry during the 1970's, and these efforts to standardize the layout process were successful. Using CAD technology, simple, low-performance, standardized chips can be laid out for masks in regular, repeatable arrays easily and efficiently. The two best-known CAD packages for layout are the Applicon and the CAMA. Both are widely used in S/C layout processes in Silicon Valley. / The two systems are essentially similar in that they permit the layout designer to sketch the arrangement of devices and interconnecting lines on the screen of a video-display terminal (VDT) instead of on a drafting board or light table. As with other computer-based graphic technologies, the layout lines electronically sketched can be adjusted, moved, tilted and erased easily and at will. CAD packages also permit copying or reproducing a sketch (a line or a whole subcircuit) in any other location and in any numbers else where on the chip.

CAD technology had three primary benefits: It eliminated the digitizing step: it allows comparison of several solutions, to permit a tighter layout in less time it permits faster editing and correction of layout drawings. In addition, Applicon will recognize as distinctive the set of hand-drawn symbol commands introduced by each operator. Thus, all operators can customize their circuit-layout commands to the machine, allowing retention of their personal drawing style (the way they use the stylus on the tablet). The dictionary of commands for each layout designer is retained as a part of the data for the part of the chip he or she has worked on. Should operators use the data created by others, they can load their own dictionary of command strokes over those of a predecessor without deleting the original commands. It takes about two months for another wise experienced layout designer to develop a working skill with Applicon.

Drawbacks also exist in the application of CAD technology. Applicon is said by some to reduce the need for careful preplanning, which was the hallmark of a good layout designer working with a light table and Mylar drawings. With that earlier technology, patient preplanning prevented much correcting and erasing. Also, some layout designers report tat by using CAD packages they have had to give up some of the artistic control that was possible by working with pencil on paper or Mylar. They report feeling less identified with the results of their work (the drawings) when they design layouts with CAD. Applicon's unique dictionary of command strokes allows the designer to have some control over the work process, but it apparently does not replace the direct identification that designers associate with their own drawings. The net effect of CAD in S/C circuit layout therefore is a mechanization of tasks without extension of the designer's individual commitment to the product. STS was considered by Zilog's management as a way of understanding the needed integration of CAD technology into the design of complex products that required more designer commitment than ever before.

At first, the CAD required a shake-down. Systems crashed were frequent, and with the reliance of all VDT's on a single CAD central processing unit (COU), a crash would bring all operators to a standstill. The earliest CAD system installed at Zilog was not only unreliable but also too small for the work to be done. If additional VDT's were installed so that operators could be added to work on a design project, the response times were annoyingly slow to the layout designers. And if large segments of an IC product were called for, the memory available to the CAD CPU was often insufficient, which caused additional frustration. Finally, with this initial version of Applicon, a pattern-generator (PGP tape had to be created on the CAD CPU, which converted the Applicon data to a form used to manufacture masks. Because this conversation required considerable CPU time to complete, the tapes were generated once a week, usually late at night o on weekends, in order to maximize the time during which layout designers could use the CAD system. The design engineers complained about the bottleneck caused by this batch-mode processing of CAD data. Once these initial problems were identified and technical solutions (including the replacement of the early CPU with an improvement one) were implemented, the problems of the organization of the CAD system became clear.

The layout supervisor was the person in the group most knowledgeable about Applicon, and she trained the payout designers on its use. She controlled the assignment of work to CAD and the assignment of layout designers to terminals. She also operated the CA CPU for departmental work (such as creating PG tapes) after hours. The supervisor, and her later replacements, attempted to act as a buffer between the layout group and the design engineers. The supervisor would request engineers to route their layout-requiring work though her. She, in turn, assigned CAD work to her subordinates, usually according to their skills and their availability. Layout designers could thus be assigned to a different project each day, and they might have no connection with or understanding of the progress being made on a given project.

This arrangement proved unsatisfactory for the engineers, who complained what layout provided poor support. Engineers reported having more contact with layout than with any other group except for their own, yet these contacts were often frustrating. Engineers saw layout designers as unwilling to take direction from them and as being reluctant or perhaps unable to complete their work within the schedule.

Half of the layout designers reported frequent contact with engineers and half reported no contact with them at all. From the layout designers' point of view, many (but not all) of the engineers created an adversarial climate by considering layout people as merely the implementers of their designs and not the independent contributors that the payout people felt they were. Engineers were seen as blaming layout for slipping schedules when he fault often lay in the circuit designs that the engineers created. Turnover of layout designers at 50 percent was high at that time, especially among the new employees who knew nothing of the days before the introduction of CAD. The company and its layout group began to earn a poor reputation among potential layout recruits because of the stressful working climate and poor and inadequate CAD equipment.

The STS Process. The director of CDE felt that the whole organization rested on his shoulders. He took pride in calling himself a benevolent dictator. He liked getting in and doing the coordination and making the decisions. But he said, "I'm not going to be able to handle this in the future. If we do take on more projects, I'm never going to be able to leave here. I'm going to have all the integrating and coordinating mechanisms among all of these guys at the same time … I'll be coming in at seven in the morning and going home at seven at night." He had been doing some reading on matrix management and felt that he might consider some form of that approach. Another Zilog manager had strong views about project management and had discussed that approach with the CDE director. The director also knew about the good results in the Idaho manufacturing plant, and the company's president had talked to him about what was happening there. The president had done right kind of encouragement, but which course to take was now the director's responsibility.

The director was given an overview of STS analysis and design by an external consultant (Taylor). He and his staff asked questions, particularly whether SS analysis had ever been done in an engineering organization. The consultant did not think so nut mentioned that it had been done in a number of organizations other than manufacturing plants- specifically, offices and hospitals. Tow of the director's key engineering managers attended an STS seminar presented by UCLA. These two managers, after returning from the course, felt good about this approach. In the meantime, the director of CDE spent time with the manager of the Idaho plant, talking through philosophically and conceptually what STS analysis was. By July 1980, the CDE director had decided to use STS analysis to aid in the development of an appropriate organizational design.

After that, events followed in quick succession. A project consultant was hired. A steering committee of Zilog top management people was selected to make certain that the project was supported. Volunteers for an STS design team composed of CDE employees from each level of the hierarchy and from each functional group were requested by CDE management, who selected ten people from among the volunteers. The design teams' charter was to complete the STS analysis while meeting periodically with the steering committee to report on current progress and what they had learned and to identify the support they needed to continue with the progress. The STS design team worked under the guidance of the internal consultant (Gustavson) with advice from the external consultant (Taylor).

Each person on the STS design team was a representative of a group within the organization and was expected to take information back to that group. The STS group also called general meetings of CDE at which they explained their activities. Minutes of the STS design group were also published. Small group meetings were the responsibility of each member of the STS design team. Both analysis and feedback to co-workers became an educational process to help those people (especially layout designers) understand their role in the larger process. The members of the design group were excited because they were experiencing something new. They wanted to share it with other people. Bit, in retrospect, this communication was not as effective or as complete as intended. Considerable skepticism that anything could or would improve was voiced by those outside the STS group. The STS jargon ("mission" "variance") used by the group also alienated some co-workers.

The STS process that the team followed was divided into five phases: systems scan, technical analysis, social analysis, design recommendations, and implementation of design.

The first things the STS design team worked on in the systems scan were the mission statement and the philosophy statement. The ides of the scan was to state clearly the organization's purpose, its product, what was outside the organization, what was inside, and its boundaries (both physical and technological)/ They also created a statement of the values held throughout the organization. The scan of CDE was begun early and continued over the life of the STS design project. From the scan process, the team developed an understanding of both the external; and the internal environment. If the UCLA training is counted, this process took one and a half years before implementation.

The scanning phase did not always go smoothly. The mission statement changed many times; coming to a consensus regarding the mission of CDE was a difficult task. The mission statement finally agreed on for CDE was "to be the leader at developing and supporting IC products." There were also a lot of battles over the philosophy. Originally the design team arrived fairly readily at what it felt was a meaningful list of value statements. When this list was taken to the steering committee it was readily approved. The design group soon discovered, however, that the committee's value system was different from its own, which caused some problems. For instance, one value on the list was open communications; yet, within a week of steering committee approval, the layout designers pointed out that their supervisor had been replaced in a single evening without any advance warning to them. Such difference were resolved as the steering committee began to live seriously by the values they expressed or approved.

CDE viewed Zilog as being driven by technology and not markets. This research and development (R&D) emphasis was a reflection of competition in product development industry wide. CDE did not see itself coming out with someone else's product later or being a manufacturing producer as such. The CDE group wanted to be able to so with subsequent products what they had done with their first major product. That first product (the z-80 microprocessor) had become an industry standard, the CDE wanted to repeat that performance. They were hungry for that success. Through the new plant in Idaho. This company had a manufacturing organization that was willing to work with and support R7D. CDE saw that the interfaces were there and hoped the marketing support was also there. Many managers in the larger organization, however, did not share this view. The dominant management view emphasized the importance of markets and customer preference. But CDE saw Zilog not as a marketing company or as a manufacturing company but as a design company. In this view, marketing would go out and try to find a place for products that CDE invented and manufacturing would make them.

In reality, therefore, the company had three different views of itself. When the STS design team came up with its mission statement and went to the steering committee (which was made up of representatives from marketing, manufacturing, and upper management), the response was "You guys go back and work on it." Although the STS group felt that the members of the steering committee were not clear about what the mission was themselves, they worked on the mission statement sporadically throughout the course of the project. A mission statement that addressed state-of-the-art- products and emphasized the market was finally drafted in late 1981, after the technical analysis and social analysis were completed. To write this draft, the design team and top CDE management, as well as representatives of the marketing and manufacturing division, went on a three-day retreat near Monterey California, during which they developed the mission statement and philosophy. Off-site meeting such as this one are useful for resolving difference among groups.

For the engineers on the STS team, the technical-system analysis was clearly a valuable part of the STS process. They liked to analyze and to discuss the idea among themselves, as well to examine the technical variances that had to be controlled. In the technical analysis they began assessing how the current system was operating. The twelve key variance they identified were clustered as follows:

- Quality of product
    - Quality/organization of engineering specification varies
    - Quality of logic/circuit schematics information varies
    - Quality of composite plan varies
    - Quality of composite layout information varies
- Timeliness of product
    - Quality of project schedule varies
    - Time to complete logic/circuit design varies
    - Timeliness of composite layout information varies
    - Timeliness of finished document varies
- Other factors (such as market acceptance)

- Customer needs incorrectly/inadequately defined
- Quality of concept in terms of manufacturability varies
- Extent and number of features affecting constraints on chip size varies

In examining the current control of these key variances, the STS team became interested in receiving information form outside their closed system and in understanding what was going on in the rest of the company. Although they said that marketing did not provide any information to them and they felt that marketing had an exaggerated view of its own importance to the company, they also began to realize the importance of having marketing accept whatever they were doing. They concluded that "if a product is conceived and what we do develop is different [from] what the marketplace wants three years from now… we aren't going to succeed or survive. How do we get the market data? How do we do it now?" They decided that CDE did need to work with marketing people. The STS design team also began to realize that in designing a product they had to understand the manufacturability of that product. A representative of the test engineers (who write test programs and design test hardware that manufacturing must use) sat in the STS design team. His people were obviously interested in manufacturability. In addition, the layout people on the design team began to say to the engineers, "If I had known what you wanted earlier in the work process, I would have been able to do a lot better. My frustration has been that I really don't know what this product is supposed to look like in the end." The layout designers in the CDE department were no different from the operators on an assembly line who do not know where the product is coming from or where it is going. The members of the STS team also began to see the value of product engineers in helping the manufacturing people to increase yields.

In summary, the STS team identified the key variances of customer needs, market needs, the timeliness of getting new designs to the marketplace, manufacturability, and quality considerations. The non-engineering members of the team also began to understand that the number of features designed into an IC were going to effect the size of the chip, which was also going to affect whether it could be tested and whether it could be economically manufactured.

Benefits of the technical analysis were clarifying the product of the design system and the key variances (and how those variances were controlled); given people a common language, the language of the product, to unify their communication and to bridge the gaps between their separate language of specialization; using specialists to educate the design team about other technical functions; and beginning to remember and use the analysis because it was written down.

The social-system analysis focused on the logic and circuit designers because they were the ones who lived with the IC project for the longest period of the time and were most involved with control of the key variances. The STS team collected data on who talked to whom about what kinds of issues from every employee in the CD organization. Several findings emerged. Significantly, manufacturing was hardly mentioned. This omission can be explained in part because new chips usually involve new manufacturing process that are also under development. But nevertheless it remains that designers are often too busy to look at future products with manufacturing. Product engineers in the manufacturing area were also not mentioned in the interviews. Product engineers were trying to increase the product yield, and they were also supposed to know the most about what was going wrong with the product. Product engineers were an organizational invention, intended to span the boundaries between design engineering and manufacturing; yet they were never reported to be in touch with the group of design engineers. In general, respondents reported that managers were genuinely concerned about people and were accessible. All groups interviewed reported a high degree of social contact with peers in their own and other CDE units. Most individuals said they received positive support from their own units, but engineers said that layout provided poor support. Many respondents mentioned that most people talked about setting schedules but that few talked about meeting them. Little contact was reported with corporate staff. Company policy in the areas of compensation, performance evaluation, and career planning was criticized. The STS team began to realize that the social system was not just a group of people who liked one another. The analysis helped them to understand how they could control key variances (particularly those dealing with timeliness) and how members of CDE could keep one another informed about factors that were important in improving the results of their work.

In the meantime, the CDE organization had grown from about 60 to 150 people, including new people and new managers brought in for technical reasons. Many of these people, who were not philosophically aligned with the design values in that they agreed with blurring of caste and functional differences, felt somewhat threatened about what their positions would be after the recommendations were developed.

In fact, as recommendations did begin to emerge, other individuals and groups began to feel threatened. The CDE director himself realized that his management style was at odds with the emerging recommendations. As noted above, he jokingly referred to himself as a "benevolent dictator," which meant that he knew that he wanted the best for his employees while producing the best for the company. The theory of STS joint optimization was therefore an acceptable way to approach organizational improvement. However, although the proposed organizational failed to meet his individual needs, he was willing to support the recommendations his STS design team was producing. Meanwhile, the layout group, with its third supervisor in a year, was hearing from its two STS team representatives that some changes were likely within their organization. Yet the layout manager told the same group that he did not know of any likely changes. In part, he must have been trying to deal with poor morale by assuring them that things were stable and becoming better rather than that things were becoming even more turbulent. He was also reflecting the anxieties of several members of his layout group who felt that they would miss the security of their own group if they were permanently assigned to work with a design engineer - one of the recommendations made by the STS team.

The social analysis was completed buy the end of the summer in 1981. It then took four to five months before recommendations for change were presented to CDE. After the STS design team generated its first, second, and third choices for a design, the consultants often met off site with the top management of CDE, working on the implications of the recommendations. In the recommendation finally chosen, four design teams were formed, each of which included people who possessed all of the skills required for the production of one major IC product. Each team had responsibility for both the design and the support (with marketing and manufacturing) of their product.

In the new CDE organization, layout designers and engineers, with most of the skills required to create a manufacturable IC design, constituted a product team. The physical move of most of the company, including CDE, to a new location in January 1982 provided the "unfreezing" necessary for the new organization of CDE to be implemented, With this new approach, most of the drawbacks of CAD technology and its use were expected to be eliminated. In this design, CAD technology had been adopted for the purpose of the CDE system and not merely for maximizing use of the technology itself. Layout designers and engineers now worked closely together, and their adversarial relationship became a thing of the past. Layout designers could understand the whole process, and they could identify with a single product or family of related products. Additionally, engineers were hired to learn CAD-based layout techniques, which further improved relations with in the product-design teams and improved layout effectiveness by shortening the communication links between circuit design and layout. Design engineers often acted as quality inspectors on the layouts of their circuits, and, by doing some of their own layout and circuit design, they inspected their won work. The Applicon hardware and software were operated and maintained by organizational unit separate from layout design, which, in addition, had responsibility for the creation of simulation programs (called CAD programs) for testing of confirming the logic and circuit designs prior to layout.

The layout designers were expected to develop a set of ground rules for using Applicon during prime time. As this plan was to be implemented, one layout designer would create the mask design, and a colleague would correct and update it later that day. In this way, the layout designers were able to control the CPU space available for the most urgent jobs. Layout designers had their own individual workspace and desks away from the Applicon terminals, but within the area dedicated to their product team. This space was to be used as either a quiet area to plan subsequent tasks or as a place to meet and discuss the work with their colleagues. IN this way, the flextime arrangement used by the layout designers permitted a substantial overlap in their work hours without a conflict over using the Applicon VDT assigned to tem. A layout designer could, for example. Come in at 8:00 in the morning and work at the VDT until 2:30. The layout colleague assigned to that same terminal could come to work at noon and spend those tow and a half hours until the VDT became available in his or her individual work space, planning the work to be done with e Applicon that afternoon and evening.

Each product team was to have the skills in architecture, logic and circuit deign, and layout design, test engineering, and leadership that it needed to bring to manufacturing. In actual practice, each of the four teams has an architect on it, and several teams include test engineers, Six months before the completion of the design transfer to manufacturing, a product engineer or two joins each of these product-design teams and becomes part of it, When the product moves into manufacturing, the team moves into the manufacturing and stay until the manufacturing people have the information and knowledge to begin testing out and manufacturing the product. As a new chip begins to be manufactured, a test engineer stays in manufacturing while the rest of the design group goes back and starts work on a new product. Unlike the usual design team the S/C and computer industries, these teams do no break up. Instead, there is continuity in team process for supporting past Ics and developing new ones.

This organization is based on the realization that the product of CSE is information - information that manufacturing uses to manufacture and test the product and that marketing uses to sell the product. The technical writers are supposed to be part of this organization, although they are not yet. As the product is being produced, the role of technical writer is to obtain information from eh engineers and to train new customers in use of the product. In addition, a separate strategic marketing group was created in the marketing department to perform two functions: helping to create the original concepts for future projects and helping to introduce those products into the marketplace.

The difference e between specialists and generalists was a major issue with which the new unit design contended. Some people thought that one of the drawbacks of this proposed organization was that it would reduce the depth of technical-skill specialties forcing all team members to become multiskilled. They also thought that when the specialty -based work groups were disbanded, the lack of proximity and regular group meetings could drastically reduce (if not eliminate) the passing of hints and tricks among peers. This problem was addressed by forming technical-affinity teams, which formalized a structure for each of the technical-skill categories: test engineering, product engineering, logic and circuit design, and layout. Each affinity team was expected to hold a meeting at least once a month during which the members would upgrade one another's skills. People could share information and stay up to date. The affinity-group solution had not been going as well as desired, mainly because of an absence of interest on the part of layout designers in meeting with layout designers from other teams. Most prefer working in teams with engineers after they make the change rather than in a centralized organization.

The teams in CDE, averaging about ten people each, have leaders. Team leaders have responsibility for work-group processes, salvation of group member, feedback on group performance, and group planning, team leaders negotiate resources on behalf of the team, and product development, provide direction and integration. manage external boundaries, and facilitate activities within the team. Team leadership can be a rotating task; the same people do not have to continue to be team leaders or team administrators, although in actuality they have done so. Members and leaders are evaluated on skill and direct contribution to design tacks. Leadership and other social skills are not linked to the appraisal system.

The company had provided team skills training sessions that anyone can attend. In the beginning, the team members and leader needed skills for working in groups, and a half day of training each month for a year to acquire skills was planned - not only for those people assigned as team leaders but for members as well. Despite this dedication to the idea of training, both leadership and group-process skills have-not come up to their required levels.

Impact on Organizational Effectiveness. The performance measures used by CDE prior to the STS study included employee turnover, schedules (sometime but no always set by engineers for layout designers) met, product -release dates met, self-assessment of engineering quality (especially innovation), and market acceptance of products designed. Such measures as turnover are often contaminated by multiple but undefined effect (for example, being attributed both to dissatisfaction within the company and to the many attractions outside the company) and are thus suspect as indicators of organizational change.

Other traditional measures such as product release or product acceptance are too long term or coarse to provide help for self-correction as the changes unfold.

Following the STS study, the managers in CDE have begun to use additional measures. These include tracking the unit performance to schedule on a weekly basis; tracking product schedules on a finer, more detailed basis than before; and measuring initial product performance.

Turnover is also used even though it remains an indicator of external attractions and internal frustrations. Since the new organization was introduced, turnover has been about 10 percent for layout designers, which is lower than for similar organizations in the Valley. Layout designers are feeling committed to their group, and they are more concerned than they were previously with when the products come out and whether they can be manufactured the first time around. Evidently for layout designers the internal attractions in CDE are outweighing the external ones, engineers, however, do not present such a sanguine picture. Nearly one third of the design engineers in CDE left the company within sex months after the STS reorganization. The reasons given in exit interviews were varied. Some wanted to join start-up companies as the economy turned up. Often these engineers left the S/C industry and IC design to enter the computer industry, leaving IC design to younger colleagues. Others who left said that they did so because they sis not enjoy the managerial responsibilities of working with others. Many have been replaced with engineers who do enjoy close working relationships.

Meeting schedules is a measure that is taken more seriously by CDE employees now that in the past. In particular, people in the design team note and discuss the short-term scheduled releases from one design step to another. Because payout designers are involved in decisions affecting their schedules, they are more likely than before to "own" those decisions and are more willing to act in new ways to meet schedules. Despite this realistic view of timeliness, the schedules are slipping. It seems that the complex nature of the current IC products is such that even the CDE managers do not know enough to accurately estimate completion times. This poor ability to schedule is even more frustrating now those schedules are important to employees.

Measurements of layout productivity have been introduced in an attempt to create some short-term schedule goals. This measure is a daily count, by designer, of the number of transistors drawn, Layout designers can say that although this transistor count is a precise measure, readily available from the Applicon technology, it may prove to be merely a measures of average Applicons out put rather than an accurate indicator of the work done by a designer on a given day. Despite voicing this reservation, the layout designers are motivated to achieve good schedule performance and are thus interested in measures that may help them do so.

Product performance at "first silicon" is a new end-result measures that CDE intends to use. This measure will evaluate whether the product works as expected when it is manufactured or fails this first test. This indicator is important for assessing the care taken in checking the internal logic of IC circuit and layout design as well as for assessing the manufacturing ability of the resulting chips. It will determine whether the design needs substantial rework or if up to six months can be saved by avoiding the usual but onerous task. The product teams are oriented to design with this goal of "first silicon" in mind.

CDE management undertook an informal assessment of the new product-team organization in June 1983, more than a year after its implementation. Ten of the Forty members constituting the CDE design staff and most of the CDE mangers met to review their experience with the new unit organization. They discussed the communications within the teams, both in informal and formal meetings; communications between teams; and communications among people with the same skills. They commented on the time and quality aspects of the CDE style of decision making by consensus. They also listed issues affecting morale in the teams and their own feelings about these issues.

Nearly all those involved in this informal assessment expressed strong positive feelings. Only one of the sixteen people had little to say. Fully three quarters reported that morale was higher because of increase communication and understanding within the teams. Among the factors mentioned as enhancing team morale were member support for one another, increased ownership of decisions made by the group (especially by layout designers), and increased awareness of and learning about the total design process and its progress.

Half of the respondent's also expressed mixed feelings and, in some cases, frustration with some of the effects of the new structure. Mangers complained, for example, that decision making by consensus removed the ability to simply dictate decision to subordinates or that it took too long (in an industry where time is always short), even though it led to the ownership of decisions as a positive aspect. Some engineers questioned the quality of decisions made y a group because the "best" idea might not always be the one accepted. Engineering specialist commented that they had difficulty obtaining layout support from other design teams when they needed it. Meetings that lasted too long or that did not concern them were mentioned as drawbacks by some layout designers. Mangers, engineers, and layout designers all commented that the product team structure interfered with close professional relationships among people with similar skills and formal training and that the affinity teams had not worked out as well as they wanted.

A telling comment by manger outside CDE was that despite the fact that the STS analysis and design process took a long time and many man-hours to complete, its usefulness is more essential for the current design projects (such as the thirty-two-bit microprocessor), which require a team structure that for the more simplified projects of the past. He continues that the one-person (or master-slave) organization that worked for earlier generations of products would simply not be appropriate today. He concluded that it was unfair to compare the performance of the new organization, with it multi person, multiskilled, product orientation, to past arrangements over time during which IC products have changed so much.

What was Learned? The changed in structured from a functional, specialty-based organization to a product-oriented mutliskilled organization has been a powerful educational experience. The relationships among people have changed to fit the form, and the old, adversarial relationships between specialties have been greatly reduced. At the same time, however, the relationships among people with the same specialty background have deteriorated because of the structural change. An important activity, therefore, is to constantly reinforce the supporting structures, such as the affinity teams, to make certain they continue and succeed.

What could be done differently? If the project could be repeated, training in leadership and team skills would be more strongly emphasized earlier in implementation and continued as apart of doing business. In addition, CDE would attend to short-term performance measurements, based on the key variances identified in the technical analysis, as well as the long-range measures based on goals and mission. Planning for measurement would include consideration of formal indicators of social performance within and between teams. Team members would be involved in the creation of these measures as well as in their use. Finally, the values stated in the mission and philosophy of CDE would be tested and shaped early in the process to assure the department that these were living guidelines and CDE's real focus.

Would CDE implement the same technologies and structures for the creation of the current generation of IC products? CAC technology has proved to be useful and would be retained. Applicon has features, in the version currently used by CDE that provide advantages over the systems. The multiskilled, product-oriented teams permit the creation of complex and large IC products. The use of permanent teams rather than the temporary task forces of the more usual matrix-type organization permits an identification with products and their follow-through and would be continues. Finally, the inclusion of both layout designers and design engineers intense team has proved to be an appropriate structure within which to apply the Applicon technology. The CDE decision to recruit young engineers for the teams to learn to design layout on CED technology in addition to designing the circuit themselves had been a powerful initial validation of this approach in CDE. This team orientation is also used strategically to recruit new employees. The company's description of this organizational feature in its recruitment brochure is proof of its commitment to this idea.