CHAPTER 36

Aligning Technological and Organizational Change

ANN MAJCHRZAK
NAJMEDIN MESHKATI
University of Southern California

Handbook of Industrial Engineering: Technology and Operations Management, Third Edition.
Edited by Gavriel Salvendy

1. INTRODUCTION

The installation of new technology, especially technology involving computers or microprocessors, virtually always involves some change to the organization and its members. Thus, the effective management of technological change must include the effective management of organizational change as well.

In this chapter, conclusions are presented from the literature and recent work by the authors concerning effective management of simultaneous change in technology and organizational design. The objective of this chapter is to impart to the practicing engineer the following four points:

1. There are clear relationships between technological and organizational changes.
2. Introduction of technological change is tantamount to introduction of a technological, organizational, and people (TOP) change.
3. In order to ensure that the full range of TOP options available to any organization is considered in the selection of any single set of TOP changes, the engineer as technology planner must strive to understand the entire set of anticipated TOP changes prior to implementing new technology.
4. Planned change strategies must be thoughtfully applied to facilitate successful progress through the TOP changes.

Technologies of primary interest here are computer-automated production and information technologies because these have received the most research attention in the last decade. Production technologies include computer-automated manufacturing (CAM) and computer-integrated manufacturing (CIM) and their component technologies such as flexible manufacturing cells (FMC), automated guided vehicles, and computer numerical control (CNC) machines. Information technologies include manufacturing resource planning (MRP), computer-aided design (CAD), computer-aided engineering analysis, electronic mail, collaborative technologies, transaction processing technologies such as enterprise resource planning (ERP) systems, supply chain management systems, and electronic commerce.

2. WHY THE TOPIC IS CRITICAL TO INDUSTRIAL ENGINEERS

2.1. Failures of Implementation of New Technology

Accumulated evidence indicates that the implementation of computer-automated technology has not achieved as much success as originally anticipated. The American Production and Inventory Control Society and the Organization for Industrial Research have estimated the failure rate of these technologies to be as high as 75% (Works 1987). In a study in which 55 managers in 41 organizations supplying or using CAM were interviewed, half of the CAM installations were reported as failures (Ettlie 1986). In a study of 95 flexible manufacturing systems in the United States and Japan, the FMSs in the United States were found to be so ineffectively used as to yield little of the flexibility had been achieved in Japan (Jaikumar 1986). Kalb (1987) reports a 30–70% failure rate of computerized manufacturing technologies. One new product-development manager of a large computer manufacturer reported that "Inadequately implemented new technologies cost our plants up to $1 million a day in unexpected losses." A major study of 2000 U.S. firms that had implemented new office systems revealed that at least 40% of these systems failed to achieve the intended results (Long 1989). Gibbs (1994) reports that for every six new large-scale software systems that are put into operation, two others are cancelled, with the average software development project overshooting its schedule by half. The Standish Group in 1995 reported that only 16% of information systems projects were judged to be successful, with 31% outright cancelled (*Wall Street Journal* 1998b). The Standish Group conducted another survey in 1997 of 360 information system professionals and found that 42% of corporate information technology projects were abandoned before completion and 33% were over budget or late (*Computerworld* 1997).

Examples of these failures abound. For example, after spending more than $17 million on a long-anticipated overhaul of Los Angeles's computerized payroll system, the city controller scrapped it (*Los Angeles Times* 1999). The London Ambulance Service computer-aided dispatch system deployed in 1992 was intended to provide an automatic vehicle-locating system, telephone call processing, and allocation buttons for crew to report on current status. The system was pulled because crews couldn't accurately indicate their status and dispatchers couldn't intervene to get the crews to the needed locations (Flowers 1997). The State of California cancelled deployment of an automated child-support system for automatically tracking parents across counties who do not have primary custody of their children after spending $100 million (*Los Angeles Times* 1997). Fox Meyer, once a $5 billion drug-distribution company, was unable to process the huge volume of orders from pharmacies after installing a $65 million ERP system. As a result, it filed for bankruptcy in 1996, was bought in 1997 for just $80 million, and filed a $500 million lawsuit against Andersen Consulting, the implementers of the ERP system (*Information Week* 1998; *Wall Street Journal* 1998b). Oxford Health Plans lost $363 million in 1997 when their new claims-processing system delayed claims processing and client billing (*Wall Street Journal* 1998a; Champy 1998). Computer systems were blamed for delaying the scheduled opening of the first deregulated electricity market in the United States (*Information Week* 1997). Hershey, the nation's largest candy maker, installed a $110 million ERP system in July 1999. Glitches in the system left many distributors and retailers with empty candy shelves in the season leading up to Halloween (*Wall Street Journal* 1999). Whirlpool reported that problems with a new ERP system and a high volume of orders combined to delay shipments of appliances to many distributors and retailers.

These failures are expensive. In an internal document of September 15, 1997, the information systems research firm MetaFax calculated an average yearly loss of $80 billion from a 30% cancellation rate and a $59 billion loss from a 50% over-budget rate. In 1997 alone (before the Y2K inflated IT expenditures), companies spent $250 billion on information technology; a 30–70% failure rate clearly means that billions of dollars are spent with disappointing results (*Wall Street Journal* 1998b). Aside from a disappointing return on investment, the impacts of failed technology investments include:

- Harm to the firm's reputation (where poor implementation gets blamed on the technology vendor or designer)
- Broken trust (where workers are unwilling to go the extra mile the next time)
- Reduced management credibility (because management can't deliver on promises)
- Slower learning curve (leading to crisis management as problems increase with implementation rather than decrease)
- Reduced improvement trajectory (since there is no time to explore opportunities for new technology or new business opportunities for existing technology)

2.2. Why These High Failure Rates?

In one of the first major studies on this problem of implementation, the Congressional Office of Technology Assessment concluded: "The main stumbling blocks in the near future for implementation of programmable automation technology are not technical, but rather are barriers of cost, organization of the factory, availability of appropriate skills, and social effects of the technologies" (OTA 1984, p. 94). A few years later, the Manufacturing Studies Board of the National Research Council conducted a study of 24 cases of the implementation of CAM and CIM technologies and concluded: "Realizing the full benefits of these technologies will require systematic change in the management of people and machines including planning, plant culture, plant organizations, job design, compensation, selection and training, and labor management relations" (MSB 1986). In a 1986 Yankee Consulting Group marketing survey of CAM and CIM users, the users reported that 75% of the difficulties they experienced with the technologies could be attributable to issues concerned with planning the use of the technology within the context of the organization (Criswell 1988).

Recent evidence continues to support the conclusion that a significant component of the complexity of technological change lies in the organizational changes often experienced. C. Jackson Grayson, Jr., then Chairman of the American Productivity and Quality Center in Houston, Texas, analyzed the 68 applications for the Malcolm Baldrige National Quality Award for 1988 and 1989 and found that a major reason for failing to meet the examination criteria was the neglect of and failure to integrate human and organizational aspects with technology investments (Grayson 1990). Peter Unterweger of the UAW Research Department, after extensive case study visits in the United States and abroad, concluded that the successes of technological implications can be attributable to: (a) hardware playing a subordinate role to organizational or human factors and (b) developing the technical and organizational systems in step with one another (Unterweger 1988). In a study of 2000 U.S. firms implementing new office systems, less than 10% of the failures were attributed to technical failures; the majority of the reasons given were human and organizational in nature (Long 1989). The MIT Commission on Industrial Productivity concluded from their extensive examination of the competitiveness of different American industries: "Reorganization and effective integration of human resources and changing technologies within companies is the principal driving force for future productivity growth" (Dertouzos et al. 1989). More recently, in a 1997 survey by the Standish Group of 365 IT executive managers, the top factors identified in application development project failures were poor management of requirements and user inputs (*Computerworld* 1998a). The 1997 MetaFax survey found the reasons for IS failures to include poor project planning and management. In a 1998 *Computerworld* survey of 365 IT executives, the top factors for software development project failures were the lack of user input and changing requirements (*Computerworld* 1998a). A careful study of six failures of information technology projects found that those projects that devoted more effort to the technology rather than to the organizational issues (such as awareness, training, and changes to organizational procedures) were more likely to fail (Flowers 1997). In short, these failures can be attributed to the inadequate integration of technical with social and organizational factors during the introduction of the technological change, called sociotechnical or TOP (for Technology, Organization, and People) integration. This recognition has led *The Wall Street Journal* to write: "What's emerging here is a search for a better balance between manpower and computer power" (1998b, p. 1).

Several cases of failures directly attributable to poor alignment of technology and organizational change can be cited. In one such example (Ciborra and Schneider 1990), a U.S. aircraft instruments plant implemented a computerized MRP system. Ten months into the implementation process, none of the expected gains in efficiency had materialized, despite clearly defined goals and plans, a sound economic evaluation, and a structured implementation plan. The major problem was that there was so much emphasis on following the rules created by the MRP system that clerks often hesitated to override the system's commands even when they knew that the commands did not make sense. Even useful localized innovations with the system, such as shortcuts and new rules of thumb, remained private know-how because localized practices were not sanctioned by management. Learning from mistakes was limited because effective job performance for the system designers was measured by adherence to best technical practice, not to shop-floor reality, and thus the system designers were not willing to have their competence questioned.

As another example, in 1997 Chrysler Financial tossed out a sophisticated financial package bought for the company's financial team. The problem was that the system was incompatible with the company's e-mail system. So the company adopted a less sophisticated approach that was more closely aligned with the way the financial staffers worked: instead of monitoring dealer activity with a 100% computerized system, the company instructed clerks to obtain information from dealers the old-fashioned way—over the phone—and enter the information quickly to make it available to financial staffers who wanted to know which dealers were moving a lot of cars or taking bad loans. According to the project director, the purely computerized solution would have cost many millions of dollars more and taken years to install, but "by adding some people into the equation, we could get 95% of what we needed" and take only 90 days to set it up (*Wall Street Journal* 1999, p. A26).

Another example of how advanced technology without correct organizational alignment in the automotive industry failed is presented by *The Economist:*

> [T]he giant Hamtramck plant in Detroit, which makes Cadillacs, is just five years old and heavily automated but ranks among the least competitive plants in the United States. Hamtramck is typical of GM's early efforts to beat the Japanese by throwing truckloads of cash into a new technology. Hamtramck had what is politely called a "very rough start-up". Its robots ran wild. Although the problems have now largely been tamed, GM learnt in a joint venture with Toyota that what really mattered in manufacturing was people. (*Economist* 1990).

As another example, British Airways put in a system at airport gates in which the screen was mounted horizontally, low on a desktop. Ticket agents looked down when checking in passengers; as a result, passengers saw only the top of the agent's head. The consultant on the project reported that they did this deliberately so there would be less eye contact and less schmoozing and the lines would be shorter. However, after installation, passengers complained; apparently fliers are naturally anxious and often need a little schmoozing, according to the consultant. The airline moved the screens to eye level (*Computerworld* 1998b).

Similarly, according to a survey of the artificial intelligence industry by *The Economist,* blind introduction of computers in the workplace by an American airline (which prefers to remain nameless) proved that people do not like taking orders from a machine when an expert system was installed to schedule the work of maintenance engineers (*Economist* 1992). The engineers simply rejected the system's plans and the computer system had to be withdrawn. But when, after suitable delay, the airline reintroduced more or less the same system for engineers to use when and if they wanted, it was much better received.

A final example of a project devoting too much attention to the technology side and too little to the organizational side is the London Ambulance system failure. In the formal inquiry on the failure, it was noted that the initial concept of the system was to fully automate ambulance dispatching; however, management clearly underestimated the difficulties involved in changing the deeply ingrained culture of London Ambulance and misjudged the industrial relations climate so that staff were alienated to the changes rather than brought on board. (Flowers 1997).

While much of this information supporting the important role of aligning technology and organizations is anecdotal, there have been several econometric studies of larger samples supporting this claim. A growing body of literature has established strong empirical links among such practices as high-involvement work practices, new technologies, and improved economic performance (MacDuffie 1995; Arthur 1992). Pil and MacDuffie (1996) examined the adoption of high-involvement work practices over a five-year period in 43 automobile assembly plants located around the world, their technologies (ranging from highly flexible to rigidly integrated), and their economic performance and found that the level of complementary human resource practices and technology was a key driver of successful introduction of high-involvement practices. Kelley (1996) conducted a survey of 973 plants manufacturing metal products and found that a participative bureaucracy (i.e., group-based employee participation that provides opportunities to reexamine old routines) is complementary to the productive use of information technology in the machining process. Osterman (1994) used data on 694 U.S. manufacturing establishments to examine the incidence of innovative work practices, defined as the use of teams, job rotation, quality circles, and total quality management. He found that having a technology that requires high levels of skills was one factor that led to the increased use of these innovative work practices.

To conclude, it should be clear that technological change often necessitates some organizational change. If both organizational and technological changes are not effectively integrated and managed to achieve alignment, the technological change will fail.

3. WHAT ARE THE STUMBLING BLOCKS TO ALIGNMENT?

If the benefits of aligning technology and organizational design are so clear, why isn't it done? We suggest that there are many reasons.

3.1. The Future of Technology Is Probabilistic

The technology S curve has been historically documented as describing technology change over the years (Twiss 1980; Martino 1983). The curve, plotted as the rate of change of a performance parameter (such as horsepower or lumens per watt) over time, has been found to consist of three periods: an early period of new invention, a middle period of technology improvement, and a late period of technology maturity. The technology S curve, however, is merely descriptive of past technology changes. While it can be used for an intelligent guess at the rate of technology change in the future, technology change is sufficiently unpredictable that it cannot be used to predict precisely when and how future change may occur. Fluctuating market demand and/or novelty in the technology base exacerbate the challenge. For example, at Intel, typically at least one third of new process equipment has never been previously used (Iansiti 1999). This probabilistic nature of the technology makes creating aligned technology and organizational solutions difficult because it cannot be known with any certainty what the future organizational-technology solution is likely to be over the long term.

In his study of six information technology project failures, Flowers (1997) concluded that the unpredictability of the technology is a primary complexity factor that contributes to project failure. The more that the technology is at the "bleeding" edge, the greater the complexity. Avoiding overcommitment to any one technology or organizational solution, avoiding escalationary behavior where more resources are thrown at the solution-generation process without adequate checks and balances, and maintaining project-reporting discipline in the face of uncertainty are suggested ways of managing the inherent probabilistic nature of technology.

3.2. Some Factors Are Less Malleable Than Others

A series of research studies on the process by which technologies and organizations are adapted when technologies are implemented into an organization have shown that adaptations of both technologies and the organization can occur (Barley 1986; Contractor and Eisenberg 1990; Orlikowski and Robey 1991; Orlikowski 1992; Giddens 1994; Rice 1994; Orlikowski et al. 1995; Rice and Gattiker 1999). However, in reality, some adaptations are less likely to occur because some of these factors tend to be less malleable (Barley 1986; Johnson and Rice 1987; Poole and DeSanctis 1990; Orlikowski 1992; DeSanctis and Poole 1994; Orlikowski and Yates 1994). One of these factors is the existing organizational structure. For example, Barley (1986) found evidence that one factor that tends to be less malleable is the existing power structure in the organization. Barley found that when a medical radiation device was installed into two separate hospitals, the work changed in accordance with the organizational structure, not vice versa. That is, in the hospital where the radiologists had more power in the organizational structure than the technicians, the rift between the two jobs became greater with the new technology. In contrast, in the hospital where technicians and radiologists were not separated hierarchically, the technology was used to share knowledge between the two. Another factor often found to be less malleable is what DeSanctis and Poole (1994) refer to as the "technology spirit," which they define as the intended uses of the technology by the developer or champion who influenced the developer. If the spirit is intended to displace workers, then this spirit is unlikely to be changed during implementation. Research contradicting this assertion has been conducted recently, however (Majchrzak et al. 2000). Moreover, Tyre and Orlikowski (1994) have found that malleability may be temporal, that is, that technologies and structures can be changed, but only during windows of opportunity that may periodically reopen as the technology is used. In their study, the authors found these windows to include new rethinking about the use of the technology or new needs for the technology that were not originally envisioned. These windows did not stay open for very long; thus, over the long term, some factors may have appeared to be less malleable than others.

In sum, then, a stumbling block to integrating TOP is determining which facets of TOP are malleable to facilitate the alignment; when one facet is not malleable, that puts additional pressure on the remaining facet to conform—a pressure that may not be achievable.

3.3. Alignment Requires a Cross-Functional Definition of the Problem

For a solution to be sociotechnically aligned, changes may be needed in all aspects of the organization, not just that which is under the purview of the industrial engineer or even the manufacturing manager. Changes may be required in the material-handling organization (which may not report to the manufacturing department), the purchasing department, or the human resources department. For example, Johnson and Kaplan (1987), in their study of just-in-time manufacturing, found that those departments that made changes in the incentive systems (a responsibility outside that of the manufacturing manager) were less likely to have implementation problems than companies that did not make such changes. This cross-functional nature of aligned solutions creates the problem that because the solution touches on everyone's responsibilities, it is essentially no one's responsibility (Whiston 1996). Thus, unless an organizational structure is created to explicitly recognize the cross-functional nature of the alignment, a single function—such as the industrial engineer—cannot create the alignment. As a result, resolving a cross-functional problem with a single function becomes difficult, if not impossible.

3.4. Alignment Is Context Specific and Nonrepeatable

A solution that achieves alignment between technology and organization is typically so context specific that it is not likely to be repeatable in its exact form for the next alignment problem that comes along. This is because of the many factors that must be considered in deriving a technology-organization solution. For example, the global introduction of a new technology product typically now requires some modification in each context in which it is introduced either because of the different needs of customers or different service or manufacturing environments (Iansiti 1999) As another example, altering even one technology factor, such as the degree to which the technology can diagnose its own failures, creates the need to change such organizational factors as the amount of skills that workers must have to operate the technology (Majchrzak 1988). As another example, human supervisory control of automated systems—such as is seen in an oil and gas pipeline control center—involves fault diagnosis, error detection and recovery, and safe handling of rare, critical, and nonroutine events and incidents; these activities require very specific system-dependent sets of skills and teamwork (Meshkati 1996).

This context-specific nature of technology-organization solutions contradicts the desire of many managers today to use "cookie cutter" or repeatable solutions, believing that such solutions will cost less than solutions tailored to each site (Jambekar and Nelson 1996; Kanz and Lam 1996). In addition, Kahneman et al. (1982) have found that the judgments of people in conditions of uncertainty are governed by the availability heuristic (or bias), whereby people judge the likelihood of something happening by how easily they can call other examples of the same thing to mind. If they have no other examples, they will create connections between examples, even though the connections are tenuous. As a result, they will believe that they have a repeatable solution even though one is not warranted.

For example, when globally implementing ERP systems, managers have a choice whether to roll out a single standardized ERP solution worldwide or to allow some issues (such as user interface screens or data structures) to have localized solutions. Forcing a single standardized implementation world-wide has been the preferred strategy in most implementations because it minimizes the complexity and resources required to accommodate to localized modifications (Cooke and Peterson 1998). However, implementers at Owens-Corning believe that part of their success in their global ERP implementation was attributable to allowing localized solutions, even though it was slightly more complicated in the beginning. They believe that allowing field locations to tailor some aspects of the ERP system not only ensured the buy-in and commitment of field personnel to the ERP project, but also ensured that the ERP system met each and every field location's particular needs.

Thus, another stumbling block to alignment is that alignment solutions are best construed as nonrepeatable and highly contextual—a concept that raises management concerns about the resources required to allow such contextualization.

3.5. Alignment Requires Comprehensive Solutions That Are Difficult to Identify and Realize

A solution aligned for technology and organization is a comprehensive one involving many factors. Today it is widely believed that in addition to strategy and structure, an organization's culture, technology, and people all have to be compatible. If you introduce change in technology, you should expect to alter your corporate strategy to capitalize on the new capabilities, alter various departmental roles and relations, add personnel with new talents, and attempt to "manage" change in shared beliefs and values needed to facilitate use of the new technology. (Jambekar and Nelson 1996, p. 29.5)

Despite this need for integration, Iansiti (1999) charges that "technology choices are too often made in scattershot and reactive fashion, with technology possibilities chosen for their individual potential rather than from their system-level integration." Iansiti specifically suggests that only when there is a proactive process of technology integration—"one comprising a dedicated, authorized group of people armed with appropriate knowledge, experience, tools, and structure"—will results be delivered on time, lead times be shorter, resources be adequately utilized, and other performance measures be achieved. In a study of reengineering efforts, Hall et al. (1993) argue that many attempts at reengineering have failed because of a focus on too few of the factors needing to be changed. Instead, for reengineering to work, fundamental change is required in at least six elements: roles and responsibilities, measurements and incentives, organizational structure, information technology, shared values, and skills.

Thus, another stumbling block to alignment is the need to consider all these factors and their relationships. For many managers and industrial engineers, there are too many factors and relationships; as a result, it is far easier to focus mistakenly on only one or a few factors.

3.6. Alignment Involves Long Planning Cycles, Where Observable Results and Knowing Whether You Made the Right Decisions Take Awhile

Years ago, Lawrence and Lorsch (1967) helped us to recognize the importance of the time horizon of feedback from the environment in determining whether strategic and organizational decisions are the right decisions. In their research, they found that some departments had very quick time horizons, such as a manufacturing department that is structured and oriented to obtaining quick feedback from the environment. In contrast are departments with longer time horizons, such as a research and development department, in which the department is organized to expect feedback about their work over a much longer time period. Lawrence and Lorsch further found that these different time horizons of feedback created different needs for organizational structures, performance-monitoring systems, and personnel policies. The technology-development process can be characterized as one that has a long planning cycle so that the time horizon of feedback may be months or years. For example, the average CIM implementation may take up to 3 years to complete; while the implementation of a large ERP system takes at least 18 months. As a result, managers and engineers need to make decisions about the design of the technology-organization solution in the absence of any data from the field. While some of these decisions may be changed later if data from the field indicate a problem in the design, some of these decisions are changeable only at great cost. This creates a bias toward conservativeness, that is, making decisions that minimize risk. As a result, only those factors that decision makers have historical reason to believe should be changed are likely to be changed, increasing the probability of misalignment. Thus, another stumbling block to achieving alignment is the long planning cycle of technology-organizational change, which tends to create a bias against change because learning whether planning decisions are the right ones.

3.7. Alignment Involves Compromises

Given the many factors involved in deriving an aligned solution and the many functions affected by an aligned solution, the final aligned solution is unlikely to be an idealized solution. Rather, the final solution is likely to be the outcome of a series of negotiations among the relevant parties. For example, a labor union may not want to give up the career-progression ladder provided by specialized jobs and embrace cross-functional teamwork; management may not want to give up the decision-making control they enjoy and embrace autonomy among the teams. The process of negotiating these different positions to result in some amicable compromise may be difficult and frustrating, adding to the challenges imposed by alignment.

Information technology, because it tends to break down organizational barriers, turfs, and layers, could face opposition from individuals entrenched in the companies' hierarchy. For example, production planning, inventory control, and quality control will increasingly be under the control of front-line employees, and this will pose a major threat to low-level supervisors and middle managers (Osterman 1989) and may even lead to their extinction (Drucker 1988).

4. HOW CAN TECHNOLOGY PLANNERS PURSUE ALIGNMENT DESPITE THESE DIFFICULTIES?

The difficulties identified in Section 3 are real difficulties not likely to go away with new managers, new technologies, new industrial engineering skills, new organizational designs, or new motivations. Therefore, industrial engineers must identify ways to move past these difficulties. This means taking the difficulties into account when pursuing alignment, rather than ignoring them. Effort then is not spent on reducing the difficulties per se, but on managing them so that alignment can still be achieved. Below we propose several ways of pursuing alignment in ways that allow technology planners to move past the difficulties.

4.1. Focus Alignment on Business Purpose, Driven by Competitive Need, Not as a Technology Fix to a Localized Problem

The impact of the difficulties identified in Section 3 is often experienced as resistance to change. Managers argue against a technology; workers refuse to intervene to fix the technology; industrial engineers focus solely on the technology, refusing to consider work and job changes. This resistance to change is often a sign that the justification for the technology is weak. Weak justifications are those where the need for the technology is not driven by competitive advantage pursued by the firm. Porter (1985), Schlie and Goldhar (1995), Pine (1993), Goldman et al. (1995), and D'Aveni and Gunther (1994), among others, have emphasized the need for technology choices to be driven by the competitive advantage being pursued by the firm. Yet, as pointed out by Kanz and Lam (1996), traditional strategic management rarely adequately ties technology choices to strategic choices because of a lack of understanding of how technology choices are different from other types of strategic choices (such as new products or cost-cutting strategies). In a two-year study involving over 300 major firms, they found that while 50 executives believed their firms tied improvements in their IT infrastructure to a business strategy, only 10 firms were found to be doing so after a formal assessment. Moreover, while 190 executives believed their overall corporate strategies were driving the methodology for implementing their business plans, less than 20 strategies were actually doing so. The remainder were constrained by limitations in either organizational or IT culture and design (Sweat 1999).

Schlie (1996) offers specific suggestions for identifying how technology choices should be driven by competitive firm needs. He adopts Porter's (1985) strategic planning framework, which suggests that competitive advantage can be derived at any point along a firm's value chain (e.g., inbound logistics, outbound logistics, marketing/sales, procurement, R&D, human resource management, or firm infrastructure). For the point on the value chain that the firm decides to have a competitive advantage, that advantage can be achieved either through cost leadership (i.e., low cost, low price) or differentiation (i.e., uniqueness to the customer). Using this framework, Schlie (1996) suggests that firm management should first decide where in the value chain they will compete, and then how they will use technology to facilitate achieving their competitive advantage. In communicating this to plant personnel, then, justification of both the strategic choices as well as how technology helps the strategic choices is required. Schlie cautions, however, that some technologies can only be adequately justified for some of these strategic choices. He uses as an example the advanced manufacturing technologies CAM and CIM, pointing out that the contribution of these technologies to the competitive advantage of low cost is ambiguous and situation specific. Yet when firms justify their technology expenditures based on direct labor savings, that is precisely what they are suggesting. Thus, difficulties of alignment will not be overcome if the justification for the technology expenditure is suspect from the outset.

While there are many other strategic planning frameworks for integrating technology design choices with strategic choices (e.g., Burgelman and Rosenbloom 1999; Leonard-Barton 1995), the purpose here is not to elaborate the frameworks but to emphasize the need for the technology design choices to be driven by a business strategy—regardless of the framework used—and not by reactive problem solving.

4.2. Recognize the Breadth of Factors and Their Relationships That Must Be Designed to Achieve Alignment

It is apparent from Section 2.2 that the high failure rates of new technologies are due to the lack of alignment among technology and organizational factors. What are these factors? The U.S. industry's initiative on agile manufacturing (documented in Goldman et al. 1995) identified a range of factors, including the production hardware, the procurement process, and the skills of operators. The National Center for Manufacturing Sciences created a program to promote manufacturing firms to assess themselves on their excellence. The assessment contained 171 factors distributed across 14 areas ranging from supplier development to operations, from cost to flexibility, from health and safety to customer satisfaction. In a five-year industry–university collaborative effort funded by the National Center for Manufacturing Sciences, 16 sets of factors were identified that must be aligned (Majchrzak 1997; Majchrzak and Finley 1995), including:

- Business strategies
- Process variance-control strategies
- Norms of behavior

- Strategies for customer involvement
- Employee values
- Organizational values
- Reporting structure
- Performance measurement and reward systems
- Areas of decision-making authority
- Production process characteristics
- Task responsibilities and characteristics
- Tools, fixtures, and material characteristics
- Software characteristics
- Skill breadth and depth
- Information characteristics
- Equipment characteristics

Within each set, 5–100 specific features were identified, with a total of 300 specific design features needing to be designed to create an aligned organizational-technology solution for a new technology. In this five-year study, it was also found that achieving alignment meant that each of these factors needed to be supportive of each other factor. To determine whether a factor was supportive of another factor, each factor was assessed for the degree to which it supported different business strategies, such as minimizing throughput time or maximizing inventory turnover. Supportive factors were then those that together contributed to the same business strategy; inversely, misaligned solutions were those for which design features did not support similar business strategies.

Recognizing this range of factors and their relationships may seem overwhelming; but it can be done. The cross-functional teams and use of CAD technologies for developing the Boeing 777 aircraft present an excellent example of alignment. In designing the 777, Boeing created approximately 240 teams, which were labeled ‘‘design-build teams.’’ These teams included cross-functional representatives from engineering design, manufacturing, finance, operations, customer support, maintenance, tool designers, customers, and suppliers (Condit 1994). To communicate part designs, the teams used 100% digital design via the 3D CAD software and the networking of over 2000 workstations. This allowed the suppliers to have real-time interactive interface with the design data; tool designers too were able to get updated design data directly from the drawings to speed tool development. In addition, the CAD software's capability in performing preassembly checks and visualization of parts allowed sufficient interrogation to determine costly misalignments, interferences, gaps, confirmation of tolerances, and analysis of balances and stresses (Sherman and Souder 1996). In sum, the technology of CAD was aligned with the organizational structure of the cross-functional teams.

4.3. Understand the Role of Cultures in Alignment

Culture affects alignment by affecting the change process: changes that support the existing culture are easier to implement successfully than changes that cause the culture to change. At least two types of culture must be considered in designing a technology-organization solution: the national culture of the country and the culture of the organization.

According to Schein (1985), organizational culture is ‘‘a pattern of basic assumptions—invented, discovered, or developed by a given group as it learns to cope with its problems of external adaptation and internal integration—that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems.’’ Kotter and Heskett (1992, p. 4) contend that organizational culture has two levels that differ in terms of their visibility and their resistance to change:

> At the deeper and less visible level, culture refers to values that are shared by the people in a group and that tend to persist over time even when group membership changes. . . . At the more visible level, culture represents the behavior patterns or style of an organization that new employees are automatically encouraged to follow by their fellow employees. . . . Each level of culture has a natural tendency to influence the other.

Operationally, organizational culture is defined as a set of shared philosophies, ideologies, values, beliefs, expectations, attitudes, assumptions, and norms (Mitroff and Kilmann 1984). Cultural norms are the set of unwritten rules that guide behavior (Jackson 1960). Use of this concept allows the capturing of those dimensions of organizational life that may not be visible in the more rational and mechanical aspects of the organization.

Cultures can be characterized not only by their focus but also by their strength (O'Reilly 1989; Beyer 1992). Strong cultures exert greater conformity on organizational members than weak cultures. The stronger the culture, then, the more difficult it will be to implement a technology-organization alignment that contrasts with that culture. For example, if a knowledge-management repository is installed, workers are unlikely to contribute to the repository if there is a strong culture that encourages independence and heroism (Davenport 1994) Thus, in designing a technology-organization solution, the existing culture of the organization should be carefully considered and, if possible, used to foster the solution.

National culture, according to anthropologists, is the way of life of a people—the sum of their learned behavior patterns, attitudes, customs, and material goods. According to Azimi (1991), the culture of a society consists of a set of ideas and beliefs. These ideas and beliefs should have two principal characteristics or conditions: first, they should be accepted and admitted by the majority of the population; and second, the acceptance of these beliefs and ideas should not necessarily depend upon a scientific analysis, discussion, or convincing argument. Also, national culture, in the context of technology transfer and utilization, could operationally be defined as the "collective mental programming of peoples' minds" (Hofstede 1980a).

National culture affects not only the safety but also the success and survival of any technology. National cultures differ on at least four basic dimensions: power distance, uncertainty avoidance, individualism-collectivism, and masculinity-femininity (Hofstede 1980b). Power distance is the extent to which a society accepts the fact that power in institutions and organizations is distributed unequally. It is an indication of the interpersonal power or influence between two entities, as perceived by the less powerful of the two (BCAG 1993). Uncertainty avoidance is the extent to which a society feels threatened by uncertain and ambiguous situations. It also refers to attempts to avoid these situations by providing greater career stability, establishing more formal rules, not tolerating deviant ideas and behaviors, and believing in absolute truths and the attainment of expertise. Individualism is characterized by a loosely knit social framework in which people are supposed to take care of themselves and their immediate families only, while collectivism is characterized by a tight social framework in which people distinguish between in-group and out-group; they expect their in-group members (e.g., relatives, clan, organization) to look after them, and in exchange they owe absolute loyalty to the group. The masculinity dimension expresses the extent to which the dominant values in a society are "masculine," as evidenced by decisiveness, interpersonal directness, and machismo (Johnston 1993). Other characteristics of masculine cultures include assertiveness, the acquisition of money and material goods, and a relative lack of empathy and reduced perceived importance for quality-of-life issues. This dimension can also be described as a measure of the need for ostentatious manliness in the society (BCAG 1993). Femininity, the opposite pole of this continuum, represents relatively lower assertiveness and greater empathy and concern for issues regarding the quality of life.

The four cultural dimensions discussed above also have significant implications for most complex technological systems' performance, reliability, and safety. For instance, according to Helmreich (1994) and Helmreich and Sherman (1994), there is evidence that operators with high power distance and high uncertainty avoidance prefer and place a "very high importance" on automation. Furthermore, it is known that the primary purpose of regulations is to standardize, systematize, and impersonalize operations. This is done, to a large extent, by ensuring adherence to (standard and emergency) operating procedures. On many occasions it requires replacing operators' habits with desirable intentions that are prescribed in procedures or enforced by regulations. However, according to several studies, an operator's culturally driven habit is a more potent predictor of behavior than his or her intentions, and there could be occasions on which intentions cease to have an effect on operators' behavior (Landis et al. 1978). This fact places in question the effectiveness of those regulations and procedures that are incompatible with operators' culturally driven habits.

A major, though subtle, factor affecting the safety and performance of a technological system is the degree of compatibility between its organizational culture and the national culture of the host country. It is an inevitable reality that groups and organizations within a society also develop cultures that significantly affect how the members think and perform (Schein 1985).

Demel (1991) and Demel and Meshkati (1989) conducted an extensive field study to explore how the performance of U.S.-owned manufacturing plants in other countries is affected by both the national culture of the host country and the organizational culture of the subsidiary plant. A manufacturing plant division of a large American multinational corporation was examined in three countries: Puerto Rico, the United States, and Mexico. Hofstede's (1980a) Values Survey Module for national culture and Reynolds's (1986) Survey of Organizational Culture were administered. Performance measures (i.e., production, safety, and quality) were collected through the use of secondary research.

The purpose of this investigation was threefold:

1. To determine whether there were any differences among the national cultures of Puerto Rico, the United States, and Mexico
2. To find out whether there were any differences between the organizational cultures of the three manufacturing plants

3. To establish whether there was any compatibility between the organizational culture of the plants and the national culture of the three countries, and examine whether the compatibility (or incompatibility) affected their performance in terms of production yields, quality, safety, and cycle time

Although the results of this study indicate that there are differences among the national culture dimensions of Puerto Rico, the United States, and Mexico, no significant differences were found between the organizational cultures of the three plants. This may be due to selection criteria, by which candidates, by assessment of their behavioral styles, beliefs, and values, may have been carefully screened to fit in with the existing organizational culture, Additionally, socialization may have been another factor. This means that the company may have had in-house programs and intense interaction during training, which can create a shared experience, an informal network, and a company language. These training events often include songs, picnics, and sporting events that build a sense of community and feeling of togetherness. Also, the company may have had artifacts, the first level of organizational culture, such as posters, cards, and pens that remind the employees of the organization's visions, values, and corporate goals and promote the organization's culture.

Therefore, it seems that a ''total transfer'' has been realized by this multinational corporation. Because these manufacturing plants produce similar products, they must obtain uniform quality in their production centers. To gain this uniformity, this company has transferred its technical installations, machines, and organization. Moreover, to fulfill this purpose, the company chooses its employees according to highly selective criteria. Notwithstanding, Hofstede's research demonstrates that even within a large multinational corporation known for its strong culture and socialization efforts, national culture continues to play a major role in differentiating work values (Hofstede 1980a).

There are concepts in the dimensions of organizational culture that may correspond to the same concepts of the dimensions of national culture:

The power distance dimension of national culture addresses the same issues as the perceived oligarchy dimension of organizational culture. They both refer to the nature of decision making; in countries where power distance is large, only a few individuals from the top make the decisions. Uncertainty avoidance and perceived change address the concepts of stability, change, and risk taking. One extreme is the tendency to be cautious and conservative, such as in avoiding risk and change when possible in adopting different programs or procedures. The other is the predisposition to change products or procedures, especially when confronted with new challenges and opportunities—in other words, taking risks and making decisions. Uncertainty avoidance may also be related to perceived tradition in the sense that if the employees have a clear perception of ''how things are to be done'' in the organization, their fear of uncertainties and ambiguities will be reduced. An agreement to a perceived tradition in the organization complements well a country with high uncertainty avoidance. Individualism–collectivism and perceived cooperation address the concepts of cooperation between employees and trust and assistance among colleagues at work. In a collectivist country, cooperation and trust among employees are perceived more favorably than in an individualist country.

The perceived tradition of the organizational culture may also be related to individualism-collectivism in the sense that if members of an organization have shared values and know what their company stands for and what standards they are to uphold, they are more likely to feel as if they are an important part of the organization. They are motivated because life in the organization has meaning for them. Ceremonies of the organizational culture and rewards given to honor top performance are very important to employees in any organization. However, the types of ceremonies or rewards that will motivate employees may vary across cultures, depending on whether the country has a masculine orientation, where money and promotion are important, or a feminine orientation, where relationships and working conditions are important. If given properly, these may keep the values, beliefs, and goals uppermost in the employees' minds and hearts.

Cultural differences may play significant roles in achieving the success of the corporations' performance. The findings of this study could have important managerial implications. First, an organizational culture that fits one society might not be readily transferable to other societies. The organizational culture of the company should be compatible with the culture of the society the company is transferring to. There needs to be a good match between the internal variety of the organization and the external variety from the host country. When the cultural differences are understood, the law of requisite variety can then be applied as a concept to investigate systematically the influence of culture on the performance of the multinational corporations' manufacturing plants. This law may be useful for examining environmental variety in the new cultural settings. Second, the findings have confirmed that cultural compatibility between the multinational corporations' organizational culture and the culture of the countries they are operating in plays a significant role in the performance of the corporations' manufacturing plants.

Therefore, it can be suggested that the decision concerning which management system or method to promote should be based on specific human, cultural, social, and deeply rooted local behavior patterns. It is critical for multinational corporations operating in different cultures from their own to ensure and enhance cultural compatibility for the success of their operations. As a consequence, it can be recommended that no organizational culture should be transferred without prior analysis and recommendations for adjustment and adaptation to the foreign countries' cultures and conditions. This research has given a clear view of the potential that currently exists for supervising and evaluating cultural and behavioral aspects of organizations as affected by their external environment and their relationship to the performance of the organizations. Culture, both national and organizational, will become an increasingly important concept for technology transfer.

Results showed that while there were differences between the national cultures of the three countries, there were no significant differences between the organizational cultures of the three manufacturing plants. It is noteworthy that the rank order of the performance indicators for these plants was in exact concordance with the rank order of the compatibility between the organizational culture and the national culture of the host country: Mexico had the highest overall cultural compatibility and the highest performance; Puerto Rico had high overall compatibility and the next-highest overall performance; and the United States had the lowest cultural compatibility and the lowest overall performance.

Meshkati has recently studied the concept of a "safety culture." Nuclear reactor operators' responses to nuclear power plant disturbances is shown in Figure 1 (Meshkati et al. 1994, adapted from Rasmussen 1992). The operators are constantly receiving data from the displays in the control

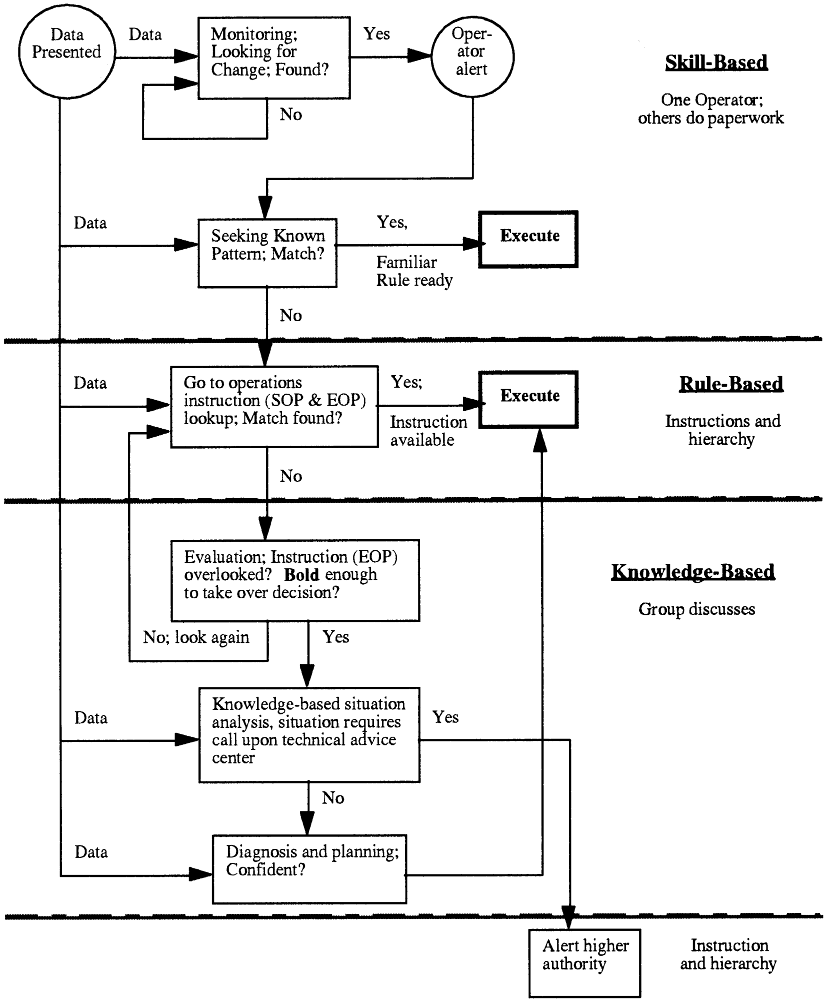

Figure 1 Model for Nuclear Power Plant Operators' Responses to Disturbances. (Adapted from Rasmussen 1992)

room and looking for change or deviation from standards or routines in the plant. It is contended that their responses during transition from the rule-based to the knowledge-based level of cognitive control, especially in the knowledge-based level, are affected by the safety culture of the plant and are also moderated or influenced by their cultural background. Their responses could start a vicious cycle, which in turn could lead to inaction, which wastes valuable time and control room resources. Breaking this vicious cycle requires boldness to make or take over decisions so that the search for possible answers to the unfamiliar situation does not continue unnecessarily and indefinitely. It is contended that the boldness is strongly culturally driven and is a function of the plant's organizational culture and reward system and the regulatory environment. Boldness, of course, is also influenced by operators' personality traits, risk taking, and perception (as mentioned before), which are also strongly cultural. Other important aspects of the national culture include hierarchical power distance and rule orientation (Lammers and Hickson 1979) which govern the acceptable behavior and could determine the upper bound of operators' boldness.

According to the International Atomic Energy Agency, two general components of the safety culture are the necessary framework within an organization whose development and maintenance is the responsibility of management hierarchy and the attitude of staff at all different levels in responding to and benefiting from the framework (IAEA 1991). Also, the requirements of individual employees for achieving safety culture at the installation are a questioning attitude, a rigorous and prudent approach, and necessary communication. However, it should be noted that other dimensions of national culture—uncertainty avoidance, individualism–collectivism, and masculinity–femininity—while interacting with these general components and requirements, could either resonate with and strengthen or attenuate safety culture. For instance, the questioning attitude of operators is greatly influenced by the power distance, rule orientation, and uncertainty avoidance of the societal environment and the openness in the organizational culture of the plant. A rigorous and prudent approach that involves understanding the work procedures, complying with procedure, being alert for the unexpected, and so on is moderated by power distance and uncertainty avoidance in the culture and by the sacredness of procedures, the criticality of step-by-step compliance, and a definite organizational system at the plant. Communication which involves obtaining information from others, transmitting information to others, and so on, is a function of all the dimensions of national culture as well as the steepness and rigidity of the hierarchical organizational structure of the plant.

The nuclear industry shares many safety-related issues and concerns with the aviation industry, and there is a continuous transfer of information between them (e.g., EPRI 1984). Cultural and other human factors considerations affecting the performance of a cockpit crew are, to a large extent, similar to those affecting nuclear plant control room operators. Therefore, it is worth referring briefly to a fatal accident involving a passenger airplane in which, according to an investigation by the U.S. National Transportation Safety Board (NTSB 1991), national cultural factors within the cockpit and between it and the air traffic control tower contributed significantly to the crash. Avianca flight 052 (AV052) (Avianca is the airline of Colombia), a Boeing 707, crashed in Cove Neck, New York, on January 25, 1990, and 73 of the 158 persons aboard were killed. According to the NTSB:

> The NTSB determines that the probable cause of this accident was the failure of the flight crew to adequately manage the airplane's fuel load, *and their failure to communicate an emergency fuel situation to air traffic control* before fuel exhaustion occurred. (NTSB 1991, p. 76, emphasis added)
>
> The word "*priority*" was used in procedures' manuals provided by the Boeing Company to the airlines. A captain from Avianca Airlines testified that the use by the first officer of the word "priority," rather than "*emergency,*" may have resulted from training at Boeing. . . . He stated that these personnel received the *impression* from the training that the words priority and emergency *conveyed the same meaning* to air traffic control. . . . The controllers stated that, although they would do their utmost to assist a flight that requested "priority," *the word would not require a specific response* and that *if a pilot is in a low fuel emergency and needs emergency handling, he should use the word "emergency."* (NTSB 1991, p. 63; emphasis added)

The NTSB concluded:

> The first officer, who made all recorded radio transmissions in English, *never used the word "Emergency,"* even when he radioed that two engines had flamed out, and he did not use the appropriate phraseology published in United States aeronautical publications to communicate to air traffic control the flight's minimum fuel status. (NTSB 1991, p. 75, emphasis added)

Helmreich's (1994) comprehensive analysis of the AV052 accident thoroughly addresses the role of cultural factors. His contention is that

> had air traffic controllers been aware of cultural norms that may influence crews from other cultures, they might have communicated more options and queried the crew more fully regarding the flight status. . . . The possibility that behavior on this [flight] was dictated in part by norms of national culture cannot be dismissed. It seems likely that national culture may have contributed to [the crew's behavior and decision

> making]. . . . Finally, mistaken cultural assumptions arising from the interaction of two vastly different national cultures [i.e., crew and ATC] may have prevented effective use of the air traffic control system. (Helmreich 1994, p. 282)

These conclusions have been corroborated in principle by several other studies: an operator's culturally driven habit is a more potent predictor of behavior than his or her intentions, and there could be occasions on which intentions cease to have an effect on operators' behavior (Landis et al. 1978). This fact brings to question the effectiveness of those (safety-related) regulations and procedures that are incompatible with operators' culturally driven habits.

According to Helmreich (1994):

> In a culture where group harmony is valued above individual needs, there was probably a tendency to remain silent while hoping that the captain would "save the day." There have been reported instances in other collectivist, high power distance cultures where *crews have chosen to die in a crash rather than disrupt group harmony and authority* and bring accompanying shame upon their family and in-group. (Emphasis added)
>
> High Uncertainty Avoidance may have played a role [in this accident] by locking the crew into a course of action and preventing discussion of alternatives and review of the implications of the current course of action. High Uncertainty Avoidance is associated with a tendency to be inflexible once a decision has been made as a means of avoiding the discomfort associated with uncertainty.

Moreover, the importance of the cultural factors vis-à-vis automation in the aviation industry is further highlighted by two recently published studies. Helmreich and Merritt (1998), in their study of national culture and flightdeck automation, surveyed 5705 pilots across 11 nations and report that "the lack of consensus in automation attitudes, both within and between nations, is disturbing." They conclude that there is a need for clear explication of the philosophy governing the design of automation. Most recently, the U.S. Federal Aviation Administration Human Factors Study Team issued a report (FAA 1996). The team identified several "vulnerabilities" in flight crew management of automation and situation awareness that are caused by a number of interrelated deficiencies in the current aviation system, such as "insufficient understanding and consideration of cultural differences in design, training, operations, and evaluation." They recommend a host of further studies, under the title of "Cultural and Language Differences." Moreover, they include pilots' understanding of automation capabilities and limitations, differences in pilot decision regarding when and whether to use different automation capabilities, the effects of training, and the influence of organizational and national cultural background on decisions to use automation.

4.4. Make Organization and Technology Design Choices That Encourage Innovation

The difficulties discussed in Section 3 suggest that even when a comprehensive technology-organization solution is devised, the unpredictability of the process by which technologies and organizational change unfolds will inevitably lead to unplanned events. Simply creating a portfolio of contingency plans is likely to be insufficient because contingencies to cover all unplanned events cannot be identified in advance. Thus, technology-organization solutions are more likely to be successful when they allow for innovation at the individual and group level. That is, even if careful plans have been made for everything from critical technical features for maintainability to redesigned job descriptions and performance-incentive systems, changes to these features, descriptions, and systems should be not only permitted but encouraged as personnel struggle to make the technology suit their work process.

In a careful analysis of six failed information systems developments, Flowers (1997) found that one of the main reasons for failure was an attitude in which failure, or association with failure, was likely to result in scapegoating or possible loss of employment or else have a severe effect upon the careers of the individual or individuals involved. For example, in the report of the inquiry on the failure of the London Ambulance system, the negative effect on the implementation of a senior manager was noted: the senior manager instilled a fear of failure by being very powerful, with a determination not to be deflected off course. Kelley (1996), in a survey of almost 1000 manufacturing plants, found that group-based employee participation mechanisms that supported the reexamination of old routines and taking advantage of informal shortcuts that employees had worked out on their own were complementary—especially in higher technology firms—to the productive use of information technology in the machining process.

Another example of the need for individual and group-level innovation is a recent study of the implementation of a collaborative technology to allow an interorganizational virtual (i.e., distributed across time and location) team to conceptualize and develop a new product. (Majchrzak et al. 2000). The eight-person team was encouraged to indicate the features they wanted in a collaborative technology. They asked for a central repository on a central server that could capture all types of knowledge (from text to drawings), mechanisms for cataloguing the knowledge for easy retrieval later (such as keywords, dates, author identification, and reference links to previous related entries), mechanisms for being informed when new knowledge relevant to their area of expertise was entered into the knowledge base (e.g., profiling their interests coupled with e-mail notification when an entry fit that profile), ability to link desktop applications interactively to the knowledge base (called hot links), templates for commonly captured knowledge (such as for meeting agendas, meeting minutes, action items, decision rationale), and access anywhere by anyone anytime (24 × 7 access by team members and managers). A system was developed to these specifications. Then the team was encouraged to develop a set of coordination norms for how to conduct their creative engineering design work virtually using the collaborative technology. They created a new work process that would encourage all members of the team (including suppliers and specialists) and external managers to enter all knowledge asynchronously into the knowledge base and for each member then to comment on the entries as need be. The team worked for 10 months and successfully developed a breakthrough product. What is relevant for this discussion is that while the team had the opportunity to create its own technology and work process at the outset, in the end it changed every single one of its norms and most of the ways in which it used the technology. Thus, while there was careful planning prior to the beginning of the team's work—far more planning than would normally be permitted in many organizations today—the team still found it necessary to make changes. The team was fortunate because it were encouraged and able to make those changes as they became necessary. The technology was designed sufficiently flexibly so that entries could be identified using simple searches rather than the complex navigation tools that they thought they might need. Management was sufficiently flexible that when the team asked them to stop using the technology, they obliged. The team's work process was sufficiently flexible that when asynchronous communication proved insufficient, they were able to add a ''meet-me'' teleconference line so that all future encounters could be synchronously conducted using both the collaborative technology and the teleconference capability. Thus, the team succeeded not only because there had been careful planning, but because they could also innovate their work process and the technology as problems arose.

Thus, critical to the success of technology-organization alignment is that the technology-organization solution be designed to encourage localized innovation (Johnson and Rice 1987; Rogers 1995), that is, innovation required to make a particular technology-organization solution work in a particular context with a particular set of people. Characteristics of solutions that allow localized innovation include:

4.4.1. Solutions That Enhance, Not Deskill Workers

When workers are deskilled from a technology-organization solution, they do not have the knowledge to be able to intervene when necessary, identify problems, formulate solutions, and then implement the solutions. Thus, solutions must not permit deskilling. Technologies that avoid deskilling are those that allow workers to understand what the technology is doing and how it is doing it and provide workers with ways to intervene in the process to perform the planning, thinking, and evaluation work, leaving the routine work to the technology (Majchrzak 1988). The collaborative technology used by the virtual team members described in Majchrzak et al. (2000) was entirely open, with no hidden formula, hidden menus, or hidden processing; thus, the team was able to evolve the technology to the point where they could it make useful to them. CNC machines that hide processing logic from the operators are examples of technologies that violate this principle and thus inhibit innovation.

4.4.2. Solutions Should Be Human Centered

A broader proposition than that solutions should not deskill workers is that solutions should be human centered, that is, solutions should focus on how people use information, not simply on how to design a better, faster, cheaper machine. Davenport (1994) lists guidelines for designing human-centered information systems:

- Focus on broad information types, rather than on specific computerized data.
- Emphasize information use and sharing rather than information provision.
- Assume transience of solutions rather than permanence.
- Assume multiple rather than single meanings of terms.
- Continue design and reinvention until desired behavior is achieved enterprise wide rather than stopping the design process when it is done or system is built.
- Build point-specific structures rather than enterprise-wide structures.
- Assume compliance is gained over time through influence rather than dictated policy.
- Let individuals design their own information environments rather than attempt to control those environments.

Human-centered automation initiative is a good example of the technologies that attempt to avoid deskilling of human operators (Billings 1996). Loss of situation awareness, which could have been caused by "glass cockpit" and overautomation, have been cited as a major cause of many aviation mishaps (Jentsch et al. 1999; Sarter and Woods 1997). Also, in many cases, because of the aforementioned issues, automation only aggravates the situation and becomes part of the problem rather than the solution. For example, in the context of aviation, automation is even more problematic because it "amplifies [crew] individual difference" (Graeber 1994) and "it amplifies what is good and it amplifies what is bad" (Wiener 1994). Furthermore, the automated devices themselves still need to be operated and monitored by the very human whose caprice they were designed to avoid. Thus, the error is not eliminated, only relocated. The automation system itself, as a technological entity, has a failure potential that could result in accidents. The problem arises when an automated system fails; it inevitably requires human intervention to fix it in a relatively short time. The same operators who have been out of the loop, may have "lost the bubble" (Weick 1990) with respect to cause and effect of the system failure and been deskilled, must now skillfully engage in those very activities that require their contributions to save the day (Meshkati 1996; Roberts and Grabowski 1996).

Deskilling is not necessarily limited to technical skills; blind automation tends to undermine interpersonal skills as well as encourage performance in isolated workstations and ingrains an individualistic culture in the organization. According to an analysis of high-reliability systems such as flight operations on aircraft carriers by Weick and Roberts (1993), a culture that encourages individualism, survival of the fittest, macho heroics, and can-do reactions is often counterproductive and accident prone. Furthermore, interpersonal skills are not a luxury but a necessity in high-reliability organizations.

4.4.3. Solutions That Integrate Across Processes, Not Bifurcate

Technology-organization solutions that create more differentiation between jobs hurt innovation because the problems that arise during implementation are rarely limited to an action that a single person holding a single job can solve. For example, an engineer may not have realized that by speeding up a processing step, she has added a greater queue for inspection, which, if left unresolved, will lead to quicker but more faulty inspections. To solve this problem requires that both quality control and manufacturing work together. For this reason, solutions that are focused on improvements to entire processes—that is, a process-based view of the organization—tend to be more successfully implemented than solutions that are focused on individual functions (Majchrzak and Wang 1996).

4.4.4. Solutions That Encourage Knowledge Recognition, Reuse, and Renewal

Localized innovation can be costly if the solutions themselves are not captured for later potential reuse. That is, if every single context is allowed to experiment through trial and error and generate different ways to handle the problems that arise during solution implementation, and this experimentation is done without the benefit of a knowledge base or technical staff to support knowledge transfer across contexts, the end cost of all the localized solutions can be very high. Thus, each site should have available, and be encouraged to use, a knowledge repository that describes various ways to resolve the different difficulties it is likely to encounter. Moreover, to make such a knowledge repository effective, each context should be encouraged to contribute to the knowledge repository so that future implementations can benefit from their learning (McDermott 1999). For example, a percentage of consultants' pay at Ernst & Young is determined by their contribution to the central knowledge repository (called Ernie) and the uses by other consultants made of their entries.

4.4.5. Solutions Should Decentralize Continuous Improvement

For people to engage in localized innovation, they must both be motivated to do so and have the ability to do it. Motivation can be encouraged by the provision of incentives through reward-and-recognition programs as well as by management offering a consistent message and modeling behavior that everyone should continuously improve what they do. Ability to innovate can be provided through such classic continuous improvement skills as "five whys," Pareto analysis, graphing actual vs. expected outcomes over time, and group problem-solving techniques. Finally, a cycle of continuously evolving on-site experimentation that enables technology and context eventually to "fit" should be encouraged (Leonard-Barton 1988). "Such experimentation can range from scientific investigations of new materials to beta testing a product prototype with potential customers, and from mathematically simulating product performance to studying product aesthetics via physical models" (Iansiti 1999, p. 3–55). Expecting everyone to become knowledgeable about continuous improvement techniques and then motivating everyone to use those techniques can help to encourage localized innovation.

4.5. Agree on a Change Process for Achieving Alignment

The difficulties identified in Section 3 are better managed when the process by which the technology-organization solution is designed and implemented is an orderly, known, and repeatable process.

People become anxious when they are thrust into chaotic situations over which they have no control and which affect their jobs and possibly their job security and careers (Driver et al. 1993). People are given some sense of control when they know what the process is: how decisions will be made, by whom, and when, and what their role is in the decision-making and implementation process. Sociotechnical systems design suggests the following nine steps in the design and implementation of a technology-organization solution (Emery 1993; Taylor and Felten 1993):

1. Initial scanning of the production (or transformation) system and its environment to identify the main inputs, transforming process, outputs, and types of variances the system will encounter
2. Identification of the main phases of the transformation process
3. Identification of the key process variances and their interrelationships
4. Analysis of the social system, including the organizational structure, responsibility chart for controlling variances, ancillary activities, physical and temporal relationships, extent to which workers share knowledge of each others' roles, payment system, how roles fill psychological needs of employees, and possible areas of maloperation
5. Interviews to learn about people's perceptions of their roles
6. Analysis of relationship between maintenance activities and the transformation system
7. Relationship of transformation system with suppliers, users, and other functional organizations
8. Identification of impact on system of strategic or development plans and general policies
9. Preparation of proposals for change

These nine steps have been created to optimize stakeholder participation in the process, where stakeholders include everyone from managers to engineers, from suppliers to users, from maintainers to operators. A similar process is participative design (Eason 1988; Beyer and Holtzblatt 1998), tenets of which include:

- No one who hasn't managed a database should be allowed to program one.
- People who use the system help design the infrastructure.
- The best information about how a system will be used comes from in-context dialogue and role playing.
- Prototyping is only valuable when it is done cooperatively between users and developers.
- Users are experts about their work and thus are experts about the system; developers are technical consultants.
- Employees must have access to relevant information, must be able to take independent positions on problems, must be able to participate in all decision making, must be able to facilitate rapid prototyping, must have room to make alternative technical and/or organizational arrangements, must have management support but not control, must not have fear of layoffs, must be given adequate time to participate, and must be able to conduct all work in public.

The participative design process first involves establishing a steering committee of managers who will ultimately be responsible for ensuring that adequate resources are allocated to the project. The steering committee is charged with chartering a design team and specifying the boundaries of the redesign effort being considered and the resources management is willing to allocate. The design team then proceeds to work closely with the technical staff first to create a set of alternative organizational and technical solutions and then to assess each one against a set of criteria developed with the steering committee. The selected solutions are then developed by the design and technical personnel, with ever-increasing depth. The concept is that stakeholders are involved before the technology or organizational solutions are derived and then continue to be involved as the design evolves and eventually makes the transition to implementation (Bodker and Gronbaek 1991; Clement and Van den Besselaar 1993; Kensing and Munk-Madsen 1993; Damodaran 1996; Leonard and Rayport 1997).

Both the participative design and STS processes also focus on starting the change process early. Typically, managers wait to worry about alignment after the technology has been designed, and possibly purchased. Because too many organizational and other technology choices have now been constrained, this is too late (Majchrzak 1988). For example, if the data entry screens for an enterprise resource-planning system are designed not to allow clerks to see the next steps in the data flow, and the organizational implications of this design choice have not been considered in advance, clerks may well misunderstand the system and input the wrong data, leading to too many orders being sent to the wrong locations. This is what happened at Yamaha. If the enterprise resource-planning system had been designed simultaneously with the jobs of clerks, then the need to present data flow information would have been more apparent and the costly redesign of the user interface would not have been required. Thus, starting the change process before the technology has been designed is critical to achieve alignment.

Finally, a change process must include all best practices of any project management structure, from metrics and milestones to skilled project managers and contract administration. Too often, the implementation of a technology-organization solution is not given the organizational sanction of a project and instead is decomposed into the various functional responsibilities, with the integration being assigned to somebody's already full plate of responsibilities. A project manager is needed who is responsible for the entire life cycle, from design to implementation to use, and whose performance is based on both outcome metrics (e.g., the extent to which the solution contributed to the business objectives) and process metrics (e.g., did people involved in the design find that their time was well spent?). The project manager needs to report to a steering committee of representatives from each stakeholder community, and the steering committee should hold the program manager accountable to following best-practice project-management principles such as

1. Clear descriptions of specifications and milestones that the solution must meet
2. Risk identification, tracking, and mitigation
3. Early and iterative prototyping with clear testing plans including all stakeholders
4. A formal process for tracking requests for changes in specifications

Finally, given the key role played by the project manager, the job should not be given to just anyone. While small technology-organizational solutions might be handled by an inexperienced project manager, provided there is some formal mentoring, the larger the project, the greater the need for experience. With larger projects, for example, experience is required in contract administration (e.g., devising contracts with service providers that offer them the type of incentives that align their interests with yours), coordination of distributed teams, managing scope creep, and balancing conflicts of interests. These skills are not specific to a technology; but they are specific to project management expertise. The Conference Board, for example, found that problematic enterprise resource planning installations were attributable to the use of poor project-management principles that were specific not to the technology but rather to the scale of the change required (Cooke and Peterson 1998). Thus, a planned change process is critical to the ability to overcome difficulties of alignment.

4.6. Use Decision Aids to Enhance Internal Understanding of Technology-Organizational Alignment

A final recommendation for managing the difficulties of alignment is to use computerized decision aids that have a sufficient knowledge base to offer guidance on how to align technology and organizational options under various contexts. In this way, a company can reduce its reliance on outside consultants while it iteratively strives for better and better alignment. Pacific Gas & Electric seemed to appreciate the need to take technology and organizational development in-house, according to the *Wall Street Journal* (1998b), when it decided to use a team of 300 company employees in its $200 million, four-year effort to rebuild the company's aging computer system. Big-name consulting firms were eschewed, in favor of small consulting firms, but only in supporting roles. As with any simulation package used in industrial engineering, such a decision aid should allow what-if modeling, that is, the ability to try out different technology-organizational solutions and see which are more likely to achieve the desired outcomes at the least cost. Such a decision aid should also incorporate the latest best practices on what other firms have been able to achieve when aligning their organizations and technologies. Finally, such a decision aid should help the firm to conduct a cross-functional comprehensive assessment of the current alignment state of the firm and compare it to the to-be state to identify the high-priority gaps that any new solution should resolve. In this section, we describe two decision aids, TOP Modeler (www.topintegration.com) and iCollaboration software (www.adexa.com).

4.6.1. TOP Modeler

TOP Modeler is a dynamic organization analysis, design, and reengineering tool (Majchrzak and Gasser 2000). TOP Modeler uses a flexible, dynamic modeling framework to deliver a large, well-validated base of scientific and best-practice knowledge on integrating the technology, organizational, and people (TOP) aspects of advanced business enterprises. The current focus of TOP Modeler's knowledge base is advanced manufacturing enterprises, although it can be expanded to other types of enterprises. TOP Modeler's knowledge base was developed with a $10 million, five-year investment of the U.S. Air Force ManTech program, the National Center for Manufacturing Sciences, Digital Equipment Corporation, Texas Instruments, Hewlett-Packard, Hughes, General Motors, and the University of Southern California.

Users have the choice of using TOP Modeler to evaluate their current organization or evaluate their alternative "to-be" future states. Users do this by describing their business strategies and being informed by TOP Modeler of an ideal organizational profile customized to their business strategies. Then users can describe features of their current or proposed future organization and be informed by TOP Modeler of prioritized gaps that need to be closed if business strategies are to be achieved. There are three sets of business strategies contained in TOP Modeler: business objectives, process variance control strategies, and organizational values. TOP Modeler also contains knowledge about the relationships among 11 sets of enterprise features, including information resources, production process characteristics, empowerment characteristics, employee values, customer involvement strategies, skills, reporting structure characteristics, norms, activities, general technology characteristics, and performance measures and rewards.

The TOP Modeler system has a graphical, interactive interface; a large, thorough, state-of-the-art knowledge representation; and a flexible system architecture. TOP Modeler contains a tremendous depth of scientific and best-practice knowledge—including principles of ISO-9000, NCMS's Manufacturing 2000, etc.—on more than 30,000 relationships among strategic and business attributes of the enterprise. It allows users to align, analyze, and prioritize these attributes, working from business strategies to implementation and back. The user of TOP Modeler interacts primarily with a screen that we call the ferris wheel. This screen provides an immediate, intuitive understanding of what it means to have TOP integration in the workplace: TOP integration requires that numerous different aspects of the workplace (e.g., employee values, information, and responsibilities for activities) must all be aligned around core organizational factors (e.g., business objectives) if optimum organizational performance is to be achieved.

TOP Modeler has been used in over 50 applications of organizational redesign, business process redesign, or implementation of new manufacturing technology. The companies that have used it have ranged from very small companies to very large companies, located in the United States, Brazil, and Switzerland. Some of the uses we have been informed about include:

- Use by government-sponsored manufacturing consultants (e.g., Switzerland's CCSO) to help small companies develop strategic plans for restructuring (in one case, the tool helped the consultant understand that the company's initial strategic plan was unlikely to succeed until management agreed to reduce the amount of variation that it allowed in its process).
- Use by large software vendors (e.g., EDS) to help a company decide to not relocate its plant from one foreign country to another (because the expense of closing the "gaps" created by the move was likely to be too high).
- Use by a large manufacturing company (General Motors) to decide whether a joint venture plant was ready to be opened (they decided on delaying the opening because the tool helped to surface differences of opinion in how to manage the workforce).
- Use by a small manufacturing company (Scantron) to decide whether its best practices needed improving (the tool helped the company to discover that while it did indeed have many best practices, it needed to involve the workforce more closer with the supplier and customer base, an action the company subsequently took).
- Use in a large technology change effort at a large manufacturing company (Hewlett-Packard) to help identify the workforce and organizational changes needed for the new production technology to operate correctly (resulting in a substantial improvement in ramp-up time when the new product and production process was introduced).
- Use by a redesign effort of a maintenance crew (at Texas Instruments) to determine that the team-based approach they had envisioned needed several important improvements prior to start-up.
- Use by a strategic planning committee at a large manufacturing company to identify areas of misalignment among elements of a new strategic plan (in this case between quality and throughput time).
- Use by a manufacturing division manager to verify his current business strategy, which had been given to him by his group manager. As a consequence of using TOP Modeler, he discovered that he had agreed to a business objective of new product development without having the authority over the necessary people, skills, and other resources to deliver on that objective. He went back to his group manager to renegotiate these resources.

These are just a few examples of the uses made of TOP Modeler. We believe that with a decision aid, the difficulties of achieving alignment are substantially reduced.

4.6.2. iCollaboration Tool for Technology-Organizational Realignment

Another powerful decision aid for the (intra- and interenterprise) technology-organization alignment that is currently being used by many companies in different industries is the state-of-the-art, Internet-enabled Adexa company's iCollaboration software (www.adexa.com). These manufacturing and service industries include electronics, semiconductor, textile and apparel, and automotive. Adexa tools provide a continuous and dynamic picture of a manufacturing enterprise supply chain and operational status at all times.

iCollaboration software suite enables users to dynamically address and monitor operational planning, materials management, order management and request for quotes (RFQs), strategic and operational change propagation, new product management, collaborative customer and demand planning, and customer satisfaction.

The main feature of the iCollaboration suite include:

1. An integrated/synchronized set of supply chain and operations planning tools that cover the strategic planning (facilities, products, supplies
2. Supply chain planning (sourcing, making, storing)
3. Material and capacity planner; detailed make and deliver, factory planning
4. Reactive dynamic scheduler shop-floor scheduling, dispatch lists

Figure 2 shows a conceptual architecture of Adexa iCollaboration suite and how it interfaces both intra- and interenterprise. The following is a review of some specific areas, examples, and improvements where the iCollaboration tool could help the enterprise in systematic integration of technology into an organizational setting.

4.6.2.1. Operational Planning Operational planning in this context encompasses all the activities: forecasting, demand planning, sourcing, production planning, and shipping. The strategic plan should be aligned with the tactical and operational so that every decision at all levels is consistent; any deviations should be immediately relayed and approved or rejected. The supply chain planner (SCP) and the global strategic planner (GSP) tools create strategic plans that are feasible at lower levels, thus eliminating/minimizing unnecessary monitoring. Each planner (demand, materials, production, etc.) is working from the most current plans and has visibility into what is possible, which leads to linear-empowered organizations. Every change in market demand or supply chain problem is immediately reflected and visible, allowing an optimal replan based on prevalent situations. Materials, manufacturing resources, skills, and shippers all operate in synch, thus eliminating expeditors and facilitators. The GSP, SCP, material and capacity planner (MCP), collaborative demand planner (CDP), collaborative supply planner (CSP), and collaborative enterprise Planner (CEP) tools enable

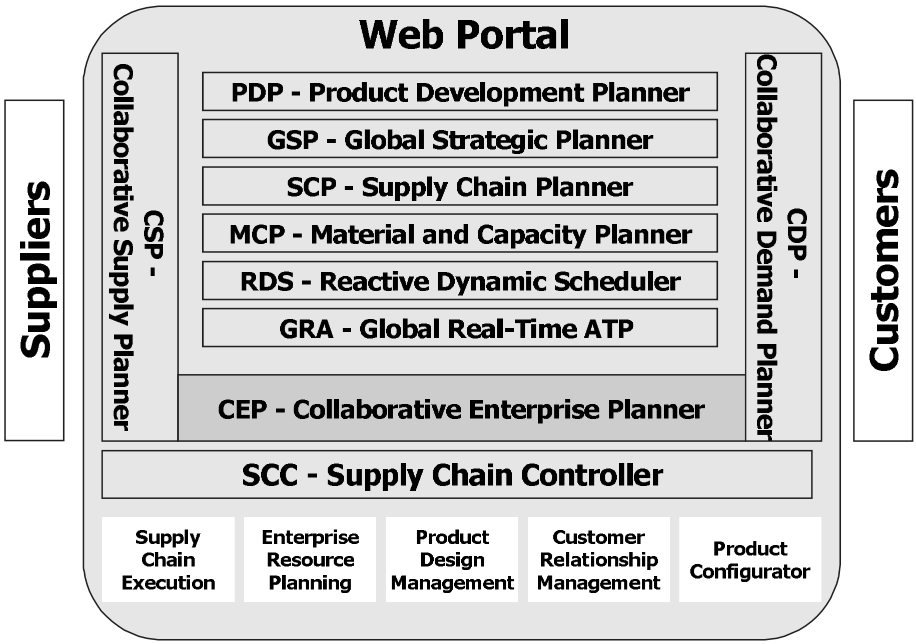

Figure 2 The Architecture of the iCollaboration Tool.

the management to align its organizations and coordinate functions (e.g., centralized vs. decentralized planning, ability to manage customer or product lines by one person or department) effectively to meet its business goals.

4.6.2.2. Materials Management The materials organization or individual responsible for raw materials, subassembly suppliers, feeder plants, and finished goods management needs full visibility into all requirements and changes as they happen. Based on the enterprise, these functions may be aligned by product family, facility, or material type. The material managers have access to the latest long-term forecasts and plans, any market changes, order status and changes, effectivities, part substitutions, and all specific rules as they apply to the vendor or supplier, and the latest company rules regards products, materials, customers, or priorities. The enterprise is thus free to align the organization to achieve lowest inventories, lowest material-acquisition costs, best vendor contracts (reduced set of reliable suppliers, quality, etc.), effective end-of-life planning, and reduced obsolescence.

4.6.2.3. Order Management and Request for Quotes (*RFQs*) An organization, which is responsible for the first line of attack on responding to RFQs, order changes, new orders, new customers, should be able to respond rapidly and accurately to delivery capability and costs. More importantly, the response should be based on the current plant loads and reflects the true deliverable lead times and capabilities.

4.6.2.4. Strategic and Operational Change Propagation As is the norm, strategies and operational activities change for various internal or external reasons. Most organizations without access to the right technology manage this change by incurring high costs in terms of additional people both to convey the message of change and to manage and monitor. Visibility and instant change propagation in either direction allow enterprises to respond only when necessary, and they are guided by a system-oriented decision so that their responses are optimal and effective immediately.

4.6.2.5. New Product Management New product development, engineering, materials, sales, and production functions require seamless collaboration. Business processes that take advantage of these functionalities can be implemented so that new product introduction is as much a part of day-to-day operations as the making and delivery of current products. There may not necessarily be a need for any special organizations or staffing to meet new product introductions. These products become akin to new demands on resources; and in fact, with the added visibility and speed of change propagation, the enterprise can develop better-quality products and more of them. This can be done because an enterprise utilizing a tool such as iCollaboration can easily try out more ideas and functions simultaneously, which increases the ability of the enterprise to ramp up production faster

4.6.2.6. Collaborative Customer/Demand Planning The CDP tool allows the customer-facing individuals to evaluate and analyze the demands by sales organizations, geography, product managers, and manufacturing and product planners to interact and control all activities seamlessly and consistent with enterprise goals of maximizing profitability and related corporate strategies. The application of this tool may result in the synchronization among the entire sales and customer relationship teams, in conjunction with customer relationship management (CRM) integration, which would produce customer satisfaction.

4.6.2.7. Customer Satisfaction Customer satisfaction, as measured by product delivery due date performance, accurate order fill rate, response to quotes, and response to changes in orders, can be significantly enhanced by creating an empowered customer facing organization that is enabled and empowered. It should be noted that this issue is one of the most critical determinants of success for today's e-commerce businesses. With the iCollaboration tools, an organization can create customer-facing organizations that may be aligned with full customer responsibility, product responsibility, order responsibility, or any combination of those. These organizations or individuals are independent, do not have to call someone, and yet are in synch with all other supporting organizations.

5. CONCLUSIONS

A review of possible decisions leaves a long list of do's and don'ts for implementing new technology. Some of the more important ones are:

- Don't regard new technology and automation as a quick fix for basic manufacturing or human resource problems; look to the firm's entire human–organization–technology infrastructure as the fix.
- Don't assume that human resource problems can be resolved after the equipment is installed; some of the problems may have to do with the specific equipment selected.

- Do expect that multiple different configurations of matches of human–organization–technology infrastructure elements are equally effective as long as the organization can undergo all the needed changes.
- Do expect to redesign jobs of operators, technical support staff, and supervisors.
- Do involve marketing staff in resources planning.
- Don't look for broad-brush deskilling for skill upgrading of the workforce with new technology; rather, some new skills will be required and others will no longer be needed.
- Don't make direct labor the prime economic target of new technology; the displacement of direct labor is only a small part of the economic benefit of the new technology.
- Do perform a training-needs analysis prior to any employee training relating to the implementation of the new technology; do expect a substantial increase in training cost.
- Do expect that the union–management relationship will change dramatically.
- Do begin facing the dilemma of changing the organizational structure to meet both coordination and differentiation needs.
- Do expect resistance; begin convincing managers and the workforce of the need for change before installing the new technology.
- Do use a multidisciplinary project team to implement any new technology in the workplace.
- Do assess and incorporate all aspects of new technology in the implementation decision making, such as social and environmental impacts.
- Do ensure a thorough understanding of the dimensions of local national culture.
- Do ascertain a determination of the extent of national culture match with those of organizational culture of the technological system (to be implemented).
- Do ensure that the effects of cultural variables on the interactions between human operators and automation in control centers of technological systems are fully considered.

The foregoing ideas concerning technology alignment with organization are of paramount importance for the companies in this emerging era of e-commerce and e-business, which is the ideal test bed for the full implementations of these ideas. The new industrial revolution being precipitated by the advent of the e-commerce phenomenon is probably the most transformative event in human history, with the far-reaching capability to change everything from the way we work to the way we learn and play. The e-commerce industry has empowered customers more than ever and has further required seamless coordination and information exchange among inter- and intraorganizational units responsible for dealing with customers and suppliers. For instance, Dell Computer, a pioneer and a harbinger of the e-commerce industry, has created a fully integrated value chain that allows for a three-way information partnership with its suppliers and customers, thereby improving efficiency and sharing the benefits across the entire chain. (*Economist* 1999). Product managers, manufacturing, and product planners need to interact and control all activities seamlessly with full transparency to the customer. This holistic approach necessitates the utmost efficiency of the entire production life cycle and eventually requires addressing all environmental impacts of e-business.

The new world order for business and industry mandates that technology implementation be comprehensive and must encourage continuous evolution and that it needs tools to help the process of implementation.

Acknowledgments

Najmedin Meshkati would like to acknowledge the contributions of his former USC graduate student and research assistant, Ms. Gail Demel, for the cross-cultural study, undergraduate student Mr. Joseph Deato for his review and analysis of the material, and Dr. Cyrus K. Hadavi of Adexa for providing insightful information on enterprise resource planning and iCollaboration.

REFERENCES

Arthur, J. (1992) "The Link Between Business Strategy and Industrial Relations Systems in American Steel Minimills," *Industrial and Labor Relations Review,* Vol. 45, No. 3, pp. 588–506.

Azimi, H. (1991), *Circles of Underdevelopment in Iranian Economy,* Naey, Teheran (in Farsi).

Barley, S. R. (1986), "Technology as an Occasion for Structuring: Evidence from Observations of CT Scanners and the Social Order of Radiology Departments," *Administrative Science Quarterly,* Vol. 31, pp. 78–108.

Beyer, J. M. (1992), "Metaphors, Misunderstandings and Mischief: A Commentary," *Organization Science,* Vol. 3, No. 4, pp. 467–474.

Beyer, H., and Holtzblatt, K. (1998), *Contextual Design,* Morgan Kaufmann, San Francisco.

Billing, C. E. (1996), *Aviation Automation: The Search for a Human-Centered Approach,* Lawrence Erlbaum Associates, Mahwah, NJ.

Bodker, S., and Gronbaek, K. (1991), ''Cooperative Prototyping: Users and Designers in Mutual Activity,'' *International Journal of Man–Machine Studies,* Vol. 34, pp. 453–478.

Boeing Commercial Aircraft Group (BCAG) (1993), ''Crew Factor Accidents: Regional Perspective,'' in *Proceedings of the 22nd Technical Conference of the International Air Transport Association (IATA) on Human Factors in Aviation* (Montreal, October 4–8), IATA, Montreal, pp. 45–61.

Burgelman, R. A., and Rosenbloom, R. S. (1999), ''Design and Implementation of Technology Strategy: An Evolutionary Perspective,'' in *The Technology Management Handbook,* R. C. Dorf, Ed., CRC Press, Boca Raton, FL.

Champy, J. (1998), ''What Went Wrong at Oxford Health,'' *Computerworld,* January 26, p. 78.

Ciborra, C., and Schneider, L. (1990), ''Transforming the Practives and Contexts of Management, Work, and Technology,'' Paper presented at the Technology and the Future of Work Conference (Stanford, CA, March 28–30).

Clement, A., and Van den Besselaar, P. A. (1993), ''Retrospective Look at PD Projects,'' *Communications of the ACM,* Vol. 36, No. 4, pp. 29–39.

Computerworld (1997), ''Workflow Software Aids App Development,'' November 3, p. 57.

Computerworld (1998a), Briefs, June 22, p. 55.

Computerworld (1998b), ''The Bad News,'' August 10, p. 53.

Condit, P. M. (1994), ''Focusing on the Customer: How Boeing Does It,'' *Research-Technology Management,* Vol. 37, No. 1, pp. 33–37.

Contractor, N., and Eisenberg, E. (1990), ''Communication Networks and New Media in Organizations,'' in *Organizational and Communication Technology,* J. Fulk and C. Steinfield, Eds., Sage, Newbury Park, CA.

Cooke, D. P., and Peterson, W. J. (1998), *SAP Implementation: Strategies and Results,* Conference Board, New York.

Criswell, H. (1998), ''Human System: The People and Politics of CIM,'' Paper presented at UTOFACT Conference (Chicago).

Damodaran, L. (1996), ''User Involvement in the System Design Process,'' *Behavior and Information Technology,* Vol. 15, No. 6, pp. 363–377.

D'Aveni, R. A., and Gunther, R. (1994), *Hypercompetition: Managing the Dynamics of Strategic Maneuvering,* Free Press, New York.

Davenport, T. (1994), ''Saving IT's Soul: Human-Centered Information Management,'' *Harvard Business Review,* March–April, Vol. 72, pp. 119–131.

Demel, G. (1991), ''Influences of Culture on the Performance of Manufacturing Plants of American Multinational Corporations in Other Countries: A Macroergonomics Analysis,'' Master's Thesis, Institute of Safety and Systems Management, University of Southern California, Los Angeles.

Demel, G., and Meshkati, N. (1989), ''Requisite variety: A concept to analyze the effects of cultural context for technology transfer,'' in *Proceedings of the 33rd Annual Meeting of the Human Factors Society.* Santa Monica, CA: Human Factors Society, pp. 765–769.

Dertouzos, M., Lester, R., Salon, R., and The MIT Commission on Industrial Productivity (1988), *Made in America: Regaining the Productive Edge,* MIT Press, Cambridge, MA.

DeSanctis, G., and Poole, M. (1994), ''Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory,'' *Organization Science,* Vol. 5, No. 2, pp. 121–147.

Driver, M. J., Brousseau, K. R., and Hunsaker, P. L. (1993), *The Dynamic Decision Maker: Five Decision Styles for Executive and Business Success,* Jossey-Bass, San Francisco.

Drucker, P. F. (1988), ''The Coming of the New Organization,'' *Harvard Business Review,* Vol. 66, January–February, 45–53.

Eason, K. (1988), Information Technology and Organizational Change, Taylor & Francis, London.

Economist, The (1990), ''Detroit's Big Three: Are America's Carmakers Headed for the Junkyard?'' April 14.

Economist, The (1992), ''Cogito, Ergo Something (Computers and human intelligence: A survey of artificial intelligence),'' March 14.

Economist, The (1999), ''Business and the Internet: The Net Imperative,'' June 26.

Electric Power Research Institute (EPRI) (1984), *Commercial Aviation Experience of Value to the Nuclear Industry,* Prepared by Los Alamos Technical Associates, Inc. EPRI NP.3364, January, EPRI, Palo Alto, CA.

Emery, F. (1993), "The Nine-Step Model," in *The Social Engagement of Social Science: A Tavistock Anthology,* E. Trist and H. Murray, Eds., University of Pennsylvania Press, Philadelphia.

Ettlie, J. (1986),"Implementing Manufacturing Technologies: Lessons from Experience," in *Managing Technological Innovation: Organizational Strategies for Implementing Advanced Manufacturing Technologies,* D. D. Davis, Ed., Jossey-Bass, San Francisco.

Federal Aviation Administration (FAA) (1996), "The Interfaces Between Flightcrews and Modern Flight Deck Systems," FAA Washington, DC.

Flowers, S. (1997), "Information Systems Failure: Identifying the Critical Failure Factors," *Failure and Lessons Learned in Information Technology Management,* Vol. 1, pp. 19–29.

Gibbs, W. (1994), "Software's Chronic Crisis," *Scientific American,* March, pp. 72–81.

Giddens, A. (1994), *The Constitution of Society: Outline of the Theory of Structuration,* University of California Press, Berkeley.

Goldman, S. L., Nagel, R. N., and Preiss, K. (1995), *Agile Competitors and Virtual Organizations,* Van Nostrand Reinhold, New York.

Graeber, R. C. (1994), "Integrating Human Factors Knowledge into Automated Flight Deck Design," Invited presentation at the International Civil Aviation Organization (ICAO) Flight Safety and Human Factors Seminar (Amsterdam, May 18).

Grayson, C. (1990), "Strategic Leadership," Paper presented at the Conference on Technology and the Future of Work (Stanford, CA, March 28–30).

Hall, G., Rosenthal, J., and Wade, J. (1993), "How to Make Reengineering Really Work," *Harvard Business Review,* Vol. 71, November–December, pp. 119–133.

Helmreich, R. L. (1994), "Anatomy of a System Accident: Avianca Flight 052," *International Journal of Aviation Psychology,* Vol. 4, No. 3, pp. 265–284.

Helmreich, R. L., and Sherman, P. (1994), "Flightcrew Perspective on Automation: A Cross-Cultural Perspective." *Report of the Seventh ICAO Flight Safety and Human Factors Regional Seminar,* Montreal, Canada: International Civil Aviation Organization (ICAO), pp. 442–453.

Helmreich, R. L., and Merritt, A. (1998), *Culture at Work in Aviation and Medicine: National, Organizational, and Professional Influences,* Ashgate, Brookfield, VT.

Hofstede, G. (1980a), *Culture's Consequences,* Sage, Beverly Hills, CA.

Hofstede, G. (1980b), "Motivation, Leadership, and Organization: Do American Theories Apply Abroad?" *Organizational Dynamics,* Vol. 9, Summer, pp. 42–63.

Iansiti, M. (1999), "Technology Integration: Matching Technology and Context," in *The Technology Management Handbook,* R. C. Dorf, Ed., CRC Press, Boca Raton, FL.

Information Week (1997), "California Targets March for Electric Utility System," December 30.

Information Week (1998), "Andersen Sued on R/3," July 6, p. 136.

International Atomic Energy Agency (IAEA) (1991), *Safety Culture,* Safety Series No. 75-INSAG-4, IAEA, Vienna.

Jackson, J. M. (1960), "Structural Characteristics of Norms," in *The Dynamics of Instructional Groups: Socio-Psychological Aspects of Teaching and Learning,* M. B. Henry, Ed., University of Chicago Press, Chicago.

Jaikumar, R. (1986), "Post-Industrial Manufacturing," *Harvard Business Review,* November–December.

Jambekar, A. B., and Nelson, P. A. (1996), "Barriers to Implementation of a Structure for Managing Technology," in *Handbook of Technology Management,* G. H. Gaynor, Ed., McGraw-Hill, New York.

Jentsch, F., Barnett, J, Bowers, C. A., and Salas, E. (1999), "Who Is Flying This Plane Anyway? What Mishaps Tell Us about Crew Member Role Assignment and Air Crew Situation Awareness," *Human Factors,* Vol. 41, No. 1, pp. 1–14.

Johnson, B., and Rice, R. E. (1987), *Managing Organizational Innovation,* Columbia University Press, New York.

Johnson, H. T., and Kaplan, R. S. (1987), *Relevance Lost: The Rise and Fall of Management Accounting,* Harvard Business School Press, Boston.

Johnston, A. N. (1993), "CRM: Cross-cultural Perspectives," in *Cockpit Resource Management,* E. L. Wiener, B. G. Kanki, and R. L. Helmreich, Eds., Academic Press, San Diego, pp. 367–397.

Kalb, B. (1987), "Automation's Myth: Is CIM Threatening Today's Management?" *Automotive Industries,* December.

Kahneman, D., Slovic, P., and Tversky, A. (1982), *Judgment under Uncertainty: Heuristic and Biases,* Cambridge University Press, New York.

Kanz, J., and Lam, D. (1996), "Technology, Strategy, and Competitiveness," in *Handbook of Technology Management,* G. H. Gaynor, Ed., McGraw-Hill, New York.

Kelley, M. R. (1996), "Participative Bureaucracy and Productivity in the Machined Products Sector," *Industrial Relations,* Vol. 35, No. 3, pp. 374–398.

Kensing, F., and Munk-Madsen, A. (1993), "PD: Structure in the Toolbox," *Communications of the ACM,* Vol. 36, No. 4, pp. 78–85.

Kotter, J. P., and Heskett, J. L. (1992), *Corporate Culture and Performance,* Free Press, New York.

Lammers, C. J., and Hickson, D. J. (1979), "A Cross-national and Cross-institutional Typology of Organizations," In *Organizations,* C. J. Lammers and D. J. Hickson, Eds., Routledge & Kegan Paul, London, pp. 420–434.

Landis, D., Triandis, H. C., and Adamopoulos, J. (1978), "Habit and Behavioral Intentions as Predictors of Social Behavior," *Journal of Social Psychology,* Vol. 106, pp. 227–237.

Lawrence, P. R., and Lorsch, J. W. (1967), *Organization and Environment: Managing Differentiation and Integration,* Graduate School of Business Administration, Harvard University, Boston.

Leonard-Barton, D. (1995), *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation,* Harvard Business School Press, Boston.

Leonard-Barton, D. (1998), "Implementation as Mutual Adaptation of Technology and Organization," *Research Policy,* Vol. 17, No. 5, pp. 251–267.

Leonard, D., and Rayport, J. (1997), "Spark Innovation through Empathic Design," *Harvard Business Review,* Vol. 75, November–December, pp. 103–113.

Long, R. J. (1989), "Human Issues in New Office Technology," in *Computers in the Human Context: Information Technology, Productivity, and People,* T. Forester, Ed., MIT Press, Cambridge, MA.

Los Angeles Times (1997), "Snarled Child Support Computer Project Dies," November 21, p. A1.

Los Angeles Times (1999), "$17 Million Later, Tuttle Scraps Computer Overhaul," p. B-1.

MacDuffie, J. P. (1995), "Human Resource Bundles and Manufacturing Performance: Organizational Logic and Flexible Production Systems in the World Auto Industry," *Industrial and Labor Relations Review,* Vol. 48, No. 2, pp. 199–221.

Majchrzak, A. (1988), *The Human Side of Factory Automation,* Jossey-Bass, San Francisco.

Majchrzak, A. (1997), "What to Do When You Can't Have It All: Toward a Theory of Sociotechnical Dependencies," *Human Relations,* Vol. 50, No. 5, pp. 535–565.

Majchrzak, A., and Gasser, L. (2000), "TOP-MODELER: Supporting Complex Strategic and Operational Decisionmaking," *Information, Knowledge, Systems Management,* Vol. 2, No. 1.

Majchrzak, A., and Finley, L. (1995), "A Practical Theory and Tool for Specifying Sociotechnical Requirements to Achieve Organizational Effectiveness," In *The Symbiosis of Work and Technology,* J. Benders, J. deHaan and D. Bennett, Eds., Taylor & Francis, London.

Majchrzak, A., and Wang, Q. (1996), "Breaking the Functional Mindset in Process Organizations," *Harvard Business Review,* Vol. 74, No. 5, September–October, pp. 92–99.

Majchrzak, A., Rice, R. E., Malhotra, A., King, N., and Ba, S. (2000), "Technology Adaptation: The Case of a Computer-Supported Inter-Organizational Virtual Team," *Management Information Sciences Quarterly,* Vol. 24, No. 4, pp. 569–600.

Manufacturing Studies Board (MSB) (1988), Committee on the Effective Implementation of Advanced Manufacturing Technology, National Research Council, National Academy of Sciences, *Human Resource Practice for Implementing Advanced Manufacturing Technology,* National Academy Press, Washington, DC.

Martino, J. P. (1983), *Technological Forecasting for Decision Making,* 2nd ed., North Holland, New York.

McDermott, R. (1999). "Why Information Technology Inspired but Cannot Deliver Knowledge Management," *California Management Review,* Vol. 41, No. 4, pp. 103–117.

Meshkati, N. (1996), "Organizational and Safety Factors in Automated Oil and Gas Pipeline Systems," in *Automation and Human Performance: Theory and Applications,* R. Parasuraman and M. Mouloua, Eds., Erlbaum, Hillsdale, NJ, pp. 427–446.

Meshkati, N., Buller, B. J., and Azadeh, M. A. (1994), *Integration of Workstation, Job, and Team Structure Design in the Control Rooms of Nuclear Power Plants: Experimental and simultation Studies of Operators' Decision Styles and Crew Composition While Using Ecological and Traditional User Interfaces,* Vol. 1, Grant report prepared for the U.S. Nuclear Regulatory Commission, (Grant # NRC-04-91-102), University of Southern California, Los Angeles.

Mitroff, I. I., and Kilmann, R. H. (1984), *Corporate Tragedies: Product Tampering, Sabotage, and Other Catastrophes,* Praeger, New York.

National Transportation Safety Board (NTSB) (1991), *Aircraft Accident Report: Avianca, the Airline of Columbia, Boeing 707-321B,* HK 2016 Fuel Exhaustion, Cove Neck, New York, January 25, 1990, Report No. NTSB-AAR-91-04, NTSB, Washington, DC.

Office of Technology Assessment (OTA) (1984), *Computerized Manufacturing Automation,* Library of Congress #84-601053, OTA. Washington, DC.

O'Reilly, C. A. (1989), "Corporations, Culture, and Commitment: Motivation and Social Control in Organizations," *California Management Review,* Vol. 31, No. 4, pp. 9–25.

Orlikowski, W. J. (1992), "The Duality of Technology: Rethinking the Concept of Technology in Organizations," *Organization Science,* Vol. 3, No. 3, pp. 398–427.

Orlikowski, W. J., and Robey, D. (1991), "Information Technology and the Structuring of Organizations," *Information Systems Research,* Vol. 2, pp. 143–169.

Orlikowski, W. J., Yates, J., Okamura, K., and Fujimoto, M. (1995), "Shaping Electronic Communication: The Metastructuring of Technology in the Context of Use," *Organization Science,* Vol. 6, No. 4, pp. 423–443.

Orlikowski, W. J., and Yates, J. (1994), "Genre Repertoire: The Structuring of Communication in Organizations," *Administrative Science Quarterly,* Vol. 39, No. 4, pp. 541–574.

Osterman, P. (1989), in *The Challenge of New Technology to Labor–Management Relations* BLMR 135. Summary of a conference sponsored by the Bureau of Labor–Management Relations and Cooperative Programs, U.S. Department of Labor, Washington, DC.

Osterman, P. (1994), "How Common is Workplace Transformation and Who Adopts It?" *Industrial and Labor Relations Review,* Vol. 47, No. 2, pp. 173–188.

Pil, F., and MacDuffie, J. P. (1996), "The Adoption of High-Involvement Work Practices," *Industrial Relations,* Vol. 35, No. 3, pp. 423–455.

Pine, B. J. (1993), *Mass Customization: The New Frontier in Business Competition,* Harvard Business School Press, Boston.

Poole, M. S., and DeSanctis, G. (1990), "Understanding the Use of Group Decision Support Systems: The Theory of Adaptive Structuration," in *Organizational and Communication Technology,* J. Fulk and C. Steinfeld, Eds., Sage, Newbury Park, CA, pp. 173–193.

Porter, M. E. (1985), *Competitive Advantage,* Free Press, New York.

Rasmussen, J. (1992), Personal communication.

Reynolds, P. D. (1986), "Organizational Culture as Related to Industry, Position and Performance," *Journal of Management Studies,* Vol. 23, pp. 333–345.

Rice, R. (1994), "Network Analysis and Computer-Mediated Communication Systems," in *Advances in Social and Behavioral Science from Social Network Analysis,* L. Wasserman and J. Galaskiewicz, Eds., Sage, Newbury Park, CA, pp. 167–203.

Rice, R., and Gattiker, U. (1999), "New Media and Organizational Structuring of Meaning and Relations," in *New Handbook of Organizational Communication,* F. Jablin and L. Putnam, Eds., Sage, Newbury Park, CA.

Roberts, K. H., and Grabowski, M. (1996), "Organization, Technology, and Structuring," in *Handbook of Organization Studies,* S. R. Clegg, C. Hardy, and W. R. Nord, Eds., Sage, Thousand Oaks, CA, pp. 409–423.

Rogers, E. (1995), *Diffusion of Innovations,* 4th Ed., Free Press, New York.

Sarter, N., and Woods, D. D. (1997), "Team Play with a Powerful and Independent Agent: Operational Experiences and Automation Surprises on the Airbus A-320," *Human Factors,* Vol. 39, No. 4, pp. 553–569.

Schein, E. H. (1985), *Organizational Culture and Leadership,* Jossey-Bass, San Francisco.

Schlie, T. W. (1996), "The Contribution of Technology to Competitive Advantage," in *Handbook of Technology Management,* G. H. Gaynor, Ed., McGraw-Hill, New York.

Schlie, T. W., and Goldhar, J. D. (1995), "Advanced Manufacturing and New Direction for Competitive Strategy," *Journal of Business Research,* Vol. 33, No. 2, pp. 13–114.

Sherman, J. D., and Sounder, W. E. (1996), "Factors Influencing Effective Integration in Technical Organizations," in *Handbook of Technology Management,* G. H. Gaynor, Ed., McGraw-Hill, New York.

Sweat, J. (1999), "New Products Help Companies Link Apps Across and Beyond Their Organization," *Information Week,* June 14, http://www.informationweek.com/738/integrate.htm.

Taylor, J. C., and Felten, D. F. (1993), *Performance by Design,* Prentice Hall, Englewood Cliffs, NJ.

Twiss, B. (1980), *Managing Technological Innovation,* Longman Group, Harlow, Essex.

Tyre, M. J., and Orlikowski, W. J. (1994), ‘‘Windows of Opportunity—Temporal Patterns of Technological Adaptation in Organizations,’’ *Organization Science,* Vol. 5, No. 1, pp. 98–118.

Unterweger, P. (1988), ‘‘The Human Factor in the Factory of the Future,’’ in *Success Factors for Implementing Change: A Manufacturing Viewpoint,* K. Balache, Ed., Society of Manufacturing Engineers, Dearborn, MI.

Wall Street Journal (1998a), ‘‘At Oxford Health Financial ‘Controls’ Were out of Control,’’ April 29, p. 1.

Wall Street Journal, The (1998b), ‘‘Some Firms, Let Down by Costly Computers, Opt to ‘De-engineer,’ ’’ April 30, p. 1.

Wall Street Journal (1999), ‘‘Europe’s SAP Scrambles to Stem Big Glitches,’’ November, p. A26.

Weick, K. E. (1990), ‘‘Technology as Equivoque: Sensemaking in New Technologies,’’ in *Technology and Organizations,* P. S. Goodman and L. Sproull, Eds., Jossey-Bass, San Francisco.

Weick, K. E., and Roberts, H. K. (1993), ‘‘Collective Mind in Organizations: Heedful Interrelating on Flight Decks,’’ *Administrative Science Quarterly,* Vol. 38, pp. 357–381.

Whiston, T. G. (1996), ‘‘The Need for Interdisciplinary Endeavor and Improved Interfunctional Relationships,’’ in *Handbook of Technology Management,* G. H. Gaynor, Ed., McGraw-Hill, New York.

Wiener, E. (1994), ‘‘Integrating Practices and Procedures into Organizational Policies and Philosophies,’’ Invited presentation at the International Civil Aviation Organization (ICAO) Flight Safety and Human Factors Seminar (Amsterdam, May 18).

Works, M. (1987), ‘‘Cost Justification and New Technology Addressing Management’s No. 1 to the Funding of CIM,’’ in *A Program Guide for CIM Implementation,* 2nd Ed., L. Bertain and L. Hales, Eds., SME, Dearborn, MI.