The Alignment of Technology and Structure through Roles and Networks

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This paper outlines a role-based approach for conceptualizing and investigating the contention in some previous research that technologies change organizational and occupational structures by transforming patterns of action and interaction. Building on Nadel's theory of social structure, the paper argues that the microsocial dynamics occasioned by new technologies reverberate up levels of analysis in an orderly manner. Specifically, a technology's material attributes are said to have an immediate impact on the nonrelational elements of one or more work roles. These changes, in turn, influence the role's relational elements, which eventually affect the structure of an organization's social networks. Consequently, roles and social networks are held to mediate a technology's structural effects. The theory is illustrated by ethnographic and sociometric data drawn from a comparative field study of the use of traditional and computerized imaging devices in two radiology departments.•

Few organizational scholars would dispute the claim that the structures of organizations and occupations are related to the technologies they employ. Until quite recently, however, organizational theorists have largely ignored the dynamics of technical change, the question of how and why such relations arise. Instead, most have adopted the perspective of contingency theory.

Historically, contingency theory has sought to formulate broad generalizations about the formal structures that are typically associated with or best fit the use of different technologies (Lawrence and Lorsch, 1967; Khandwalla, 1974; Galbraith, 1977). The perspective originated with the work of Woodward (1958), who argued that technologies directly determine differences in such organizational attributes as span of control, centralization of authority, and the formalization of rules and procedures. Later theorists claimed that such differences should stem from variations in the attributes of specific tools, machines, and techniques; for instance, complexity and uncertainty (Perrow, 1967). However, most research programs have typically defined technology more broadly, often equating it with an organization's modal system of production (Hickson, Pugh, and Pheysey, 1969; Mohr, 1971; Blau et al., 1976; Gerwin, 1981; Fry, 1982; Lincoln, Hanada, and McBride, 1986). As a result, much of the tradition's literature speaks to the issue of whether formal structures vary according to whether organizations follow the logic of craft, batch, mass, or continuous-process production.

Contingency theory has been repeatedly refined on both theoretical and methodological grounds (Stanfield, 1976; Comstock and Scott, 1977; Gerwin, 1981; Schoonhoven, 1981; Fry, 1982; Scott, 1990). Nevertheless, for the purpose of explicating how technologies and structures become aligned, the approach remains hampered by two limitations. First, contingency theory's vision is primarily static. Few researchers have sought to do more than correlate attributes of technology with selected characteristics of formal structure. Hence, most studies yield such seemingly universal claims as "the more routine the technology the more formalized the structure." Even when such relations are found to be stable

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across settings and samples, little can be said about how they arise, since contingency studies are rarely designed to address processual questions.

Second, because most contingency theorists postulate direct links between technology and structure, their work propogates a materialistic ontology. Acts, interpretations, and intentions of those who design, purchase, or use technologies play little role in either theory or analysis. Contingency theory, therefore, tends to ignore (if not actually dismiss) human action as a potential cause for observed relations (Child, 1972). Such an oversight may partially explain why contingency theory studies' more consistent findings are relatively weak. More importantly, a strictly materialistic theory has difficulty explaining why similar technologies are often associated with different structures and why identical structures frequently surround widely divergent technologies (Barley, 1986). A more adequate understanding of how technology and organizational structure are related may require attention to social dynamics and human action. Furthermore, any attempt to link structure and action will eventually force organizational researchers to confront the thorny and long-avoided question of how macrosocial and microsocial phenomena are entwined.

ALIGNMENT OF TECHNOLOGY AND STRUCTURE

Two Broad Perspectives

Outside the mainstream of organization theory, students of technology have written of two general processes that may serve to align technology and structure. The first posits a set of overarching macrosocial forces that exert a common influence on organizational structure, individual action, and technological design. The macrosocial view has been most prominent among Marxist scholars, especially those interested in deskilling (Braverman, 1974; Kraft, 1979; Greenbaum, 1979; Glenn and Feldberg, 1979; Wood, 1982; Noble, 1984). Deskilling theorists argue that entrenched interests, established ideologies, and institutional arrangements constrain the design, selection, and implementation of new technologies. Specifically, they claim that capitalist ideologies and institutions place a premium on managerial control and the progressive separation of manual and conceptual work. Therefore, the technologies that are most likely to be commissioned, designed, and deployed are those that are consistent with the larger industrial ethos. Because such technologies are thought to deskill labor and fragment work, they are said to engender a labor process that gradually tightens the association between technology and bureaucracy (Edwards, 1979).

Conservatism is, ironically, deskilling theory's most significant flaw (Jones, 1982; Shaiken, 1984). The macrosocial process envisioned by deskilling theorists leaves little room for significant change. However, macrosocial theories of technology and structure need be neither conservative nor Marxist in orientation. Institutional theory (Meyer and Rowan, 1977; Zucker, 1977; Tolbert and Zucker, 1983; DiMaggio and Powell, 1983), in particular, offers students of technology a less constrained vantage point from which to examine the role of macrosocial forces. Not only can the institutional perspective subsume the conservative dynamics that interest deskilling theorists, but it suggests several paths by which institutional change might lead to shifts in both organizational structure and technical design. For instance, institutionalists have argued that organizations often adopt new structures via mimesis (DiMaggio and Powell, 1983), a process that may reflect top management's desire to signal that a firm is at the cutting edge of its industry (Tolbert and Zucker, 1983). Once in place, these new structures can conceivably shift work roles and work activities, which, in turn, require substantial modifications to the firm's existing technological base.

A second vision of the alignment of technology and structure begins with microsocial processes triggered by new technologies and traces structural changes upward from below. Although microsocial research on technical change has recently enjoyed something of a resurgence (e.g., Kiesler, Siegel, and McGuire, 1984; Zuboff, 1988), the perspective is ultimately rooted in two streams of work prominent during the 1950s and early 1960s: the sociology of automation (Walker and Guest, 1952; Chinoy, 1955; Mann and Hoffman, 1960; Blauner, 1964; Meissner, 1969) and sociotechnical systems theory (Trist and Bamforth, 1951; Rice, 1958; Fensham and Hooper, 1964). Members of both schools argued that new technologies first alter tasks and skills and that these changes create, in turn, opportunities and pressures for modifying organizational structure.

Early work in both traditions consisted of field studies designed to examine the tasks and organizational arrangements spawned by new technologies in specific industries. However, by the late 1960s each line of research had largely abandoned microsocial studies of technical change. After Blauner (1964) postulated a convex, parabolic relationship between automation and alienation, sociologists of automation gradually began to neglect technology's implications for tasks and work relations. Instead, their research gravitated toward proving that craft, mass, and continuous-process manufacturing were associated with alienation in the manner that Blauner had described (Faunce, 1965; Shepard, 1970; Tenne and Mannheim, 1977; Hull, Friedman, and Rogers, 1982). Thus, like the contingency theorists, sociologists of automation began to equate technology with a firm's modal system of production and to pursue the study of technology more or less exclusively at an industrial level of analysis. By the mid-1960s, sociotechnical theorists were also writing about macrosocial systems (Emery and Trist, 1965; Miller and Rice, 1967) as well as the benefits of autonomous work groups (Herbst, 1974). Eventually, sociotechnical systems theory's main agenda became one of advocating experiments in workplace democracy, rather than the study of technology and structure per se. Thus, by the 1970s, research on the microsocial dynamics of technical change largely came to a halt.

Although most researchers work from either a macrosocial or a microsocial perspective, the two are perhaps best understood as complementary processes (Scott, 1990). Existing traditions and ideologies surely influence the way organizations and technologies are designed. But it is also quite likely that all technologies exert unintended as well as intended pressures on the social organization of work. Moreover, while people's actions are undoubtedly constrained by forces beyond their control and outside their immediate present, it is difficult to see how any social structure can be produced or reproduced except through ongoing action and interaction (Collins, 1981; Giddens, 1984). A comprehensive theory of the relation between technology and organizational structure would, therefore, address microsocial and macrosocial forces simultaneously.

However, an empirical integration of the two perspectives may prove to be not only difficult, but premature. The interplay between macrosocial and microsocial forces is often observable only over long stretches of time, in some cases years or even decades. To gather data on both processes would, therefore, require studies of considerable scope and duration. Furthermore, even though theorists may be able to envision the broad contours by which the two dynamics mesh (Giddens, 1984), the fact is that researchers currently lack adequate conceptual and empirical techniques for tracing chains of influence either up or down levels of analysis. Thus, before researchers can hope to conduct comprehensive studies of the dynamics of technology and structure, they will need to devise tools for mapping both flows of influence.

The remainder of this paper seeks to further this intermediate goal by formulating and illustrating one strategy for framing and investigating the microsocial dynamics by which technologies affect the structure of organizations. The approach aims to overcome four shortcomings that characterize much previous research on technology and structure: ambiguous terminology, reliance on distant knowledge, inferential leaps between levels of analysis, and the use of nonsocial concepts.

Potential Pitfalls

Ambiguous terminology. Ambiguous terminology has plagued much of the research literature on technology and structure (Scott, 1990). The first step in articulating a viable microsocial theory of how technologies shape the structure of organizations is to define terms clearly. Ideally, central theoretical notions should be cast as concretely as possible in order to facilitate empirical observation and avoid analytic equivocation. Winner (1977) noted that three uses of the term "technology" have been prevalent in social science. First, technology often refers to apparatus, machines, and other physical devices. Second, technology may mean technique, the behaviors and cognitions that compose an instrumental act. Finally, technology is frequently used in the sense of organization, a specific arrangement of persons, materials, and tasks. The last usage has been particularly common among contingency theorists and latter-day sociologists of automation. However, if one were to ask individuals in organizations what technologies they use, they would undoubtedly mention a machine or describe a technique. In both cases, the technology would have a name and the informant could, at least in principle, point to an instance of its use. Because the criterion of potential tangibility avoids a maze of analytic abstractions, it seems practical to confine the term technology to specific tools, machines, and techniques that admit the possibility of ostensive definition.

Similarly, social scientists have used the term "structure" in numerous ways. By structure different researchers have meant the repetitive features of day-to-day activity, the formal attributes of organizations, and even more global institutional arrangements such as the bureaucratic ideal or professional dominance. These varied usages appear to delineate a hierarchy of increasing abstraction or aggregation. Since the central aim of a microsocial theory of technology and structure is to trace social change up levels of analysis, it seems reasonable to use different terms to refer to social regularities at different levels of aggregation, if only for the sake of clarity. Therefore, following Goffman (1983), I use the term "interaction order" to refer to the concrete, repetitive activities and interactions that characterize the daily routine of a social setting. I use "structure" to denote the abstract relational patterns or social networks inscribed by such actions and interactions. Defining structure in network terms allows one's analysis to remain more closely tied to the concrete actualities of an interaction order without sacrificing the configurational focus associated with the study of formal organizational structure. In fact, most properties of formal structure that have been of interest to organizational theorists (for instance, hierarchy, differentiation, and span of control) can be expressed in terms of network configurations (Krackhardt, 1989). Following Zucker (1977) and Berger and Luckmann (1967), I suggest reserving the term "institution" for sets of overarching principles and practices that have the normative force of taken-for-granted assumptions or cultural blueprints for action. Finally, I propose that "social organization" and "social order" be used as cover terms to denote the general idea of a social pattern or regularity, regardless of level of analysis.

Distant knowledge. With the exception of the early sociotechnical theorists, few researchers of any theoretical persuasion have closely observed the use of specific technologies over extended periods of time. Instead, most have relied either on cross-sectional surveys or on information garnered from historical documents and interviews. Such methods militate against acquiring detailed knowledge of a technology's principles, its mode of operation, and most importantly, the daily activities of those who use the technology. In lieu of such knowledge, analysts have resorted to characterizing both technologies and tasks in terms of such abstractions as analyzability and complexity. Although these global abstractions promise broad nomological scope and facilitate comparative research, they obscure important information, since the actual properties they reference are likely to vary across technologies and tasks. For instance, although nuclear power plants and laser surgery may both be described as complex technologies, the nature of their complexity differs, as do the skills, risks, and forms of social organization associated with their use. In line with the stipulation that terms be defined as concretely as possible, a more promising strategy would be for researchers to examine closely a range of technologies before developing comparative classifications. Categories derived from a working knowledge of machines and techniques might enable researchers to better understand how aspects of specific technical designs occasion particular patterns of use.

Inferential leaps between levels of analysis. To claim that technologies influence structures and institutions by altering forms of action and interaction is to imply that successive levels of analysis are empirically entwined, yet no theory of technical change has ever explicitly articulated the connections that might exist between everyday action and overarching patterns of social organization. Instead, the existence of links between levels of analysis has been relegated to the status of a presumption that allows researchers to work at one level of analysis while blithely making inferences to another. For instance, by employing a doctrine of methodological individualism, sociologists of automation and contingency theorists have relied on statistical aggregation to support the claim that broad classes of technology engender distinctive social orders. The approach assumes that if a sufficient number of a technology's users report similar phenomena, then, by force of large numbers, the technology must have shaped organizational structures and institutions. Deskilling theorists, on the other hand, typically employ the notion of isomorphism to infer connections between industrial institutions and actions on the shopfloor: a link is posited whenever attributes of work are consistent with an overarching zeitgeist or system of domination. Unfortunately, both approaches are logically flawed.

In the first case, even if individuals report similar phenomena with considerable frequency, there is no guarantee that their concurrence indicates a structural or institutional change. As deskilling theorists attest, from the perspective of an institution, it is plausible that technical change and its accompanying effects on the individual amount to no more than a substitution or an obfuscation of means. Yet arguments based on isomorphism between levels of analysis are also suspect because they rest on analogies whose credibility depends on which attributes of an institution and an interaction order one wishes to emphasize. Instead of offering an explicit conceptual lattice for moving between adjacent levels of social organization, both forms of argument simply define away the gaps between levels.

Nonsocial concepts. The lack of such a lattice is at least partially explained by the fact that theorists of technology and structure have often employed concepts that undervalue individual or collective action. This is usually the case, regardless of whether theorists approach technical change from a macrosocial or microsocial perspective or whether they ignore social dynamics altogether. For instance, most contingency theorists and deskilling theorists have meant by structure a set of abstract, formal constraints on daily activity. In Durkheimian fashion, structures and institutions are treated as social facts that have objective existence independent of ongoing social relationships. By approaching structure as an autonomous constraint, researchers can more easily treat technology solely as a material cause, more readily assume that relations between technology and social organization are orderly, and more convincingly propose that such relations hold regardless of context.

A similar problem has hampered researchers who work at a microsocial level of analysis and who emphasize technology's implications for tasks and skill. Sociologists of automation and most sociotechnical researchers argue that as technologies alter tasks and skills, jobs become either more or less interesting, meaningful, and responsible. The difficulty is not that such claims are invalid or that tasks and skill are inappropriate for discussions of technical change. Indeed, technologies do determine job parameters and the abilities that jobs require. Rather, the difficulty stems from the fact that traditional treatments of task and skill are fundamentally nonsocial.

Task and skill point, respectively, to individual acts and attributes that are analytically divorced from a matrix of social relations. Tasks refer to instrumental actions, whereas skills usually refer to abilities. Because most researchers treat skills as attributes, their work reads as if social change proceeds matter-of-factly. Technologies are depicted as implanting or removing skills much as a surgeon would insert a pacemaker or remove a gall bladder. Rarely, however, is the process of technical change so tidy. Events subsequent to the introduction of a technology may show that reputedly obsolete skills retain their importance, that new skills surface to replace those that were made redundant, or that matters of skill remain unresolved. In any case, groups will surely jockey for the right to define their roles to their own advantage. Skill-based theories typically overlook the importance of these interactional and political dynamics. Focusing on skill and task may be adequate if one wishes merely to describe how technologies determine what people actually do for a living, but such a focus is insufficient for linking technology to social organization. If technologies are to influence forms of social order, they must do more than change people's instrumental acts or abilities, they must also affect the relationships on which social orders are ultimately grounded.

To portray adequately how technologies influence structure will therefore require models of social organization that are more intimately tied to actions and social relations. Researchers will also require concepts that, like skill and task, remain close to a technology's point of impact but also allow for orderly movement between levels of analysis. Taken together, negotiated-order theory and role theory provide such leverage.

Negotiated-order theory holds that social orders are more or less stable patterns of action, interaction, and interpretation.[1] Unlike most other approaches, in which structure stands outside of and prior to human endeavor, advocates of the negotiated-order perspective portray social organization as an emergent phenomenon. For example, in their seminal statement on the sedimentation of structure, Berger and Luckmann (1967) argued that social order is largely a social construct whose facticity is generated and maintained by ongoing streams of behavior. Structures and institutions are thus the byproducts of a history of interaction. With time, recurrent behavior leads to the formation of an interaction order and a set of shared typifications that gradually acquire the moral status of taken-for-granted facts. This sense of facticity maintains the behavioral regularities that make up the interaction order, which, in turn, underwrites whatever structural and institutional patterns are observed. From this perspective, people may indeed come to perceive structures and institutions as external constraints. However, the constraints ac-

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The term "negotiated-order theory" was coined by symbolic interactionists concerned with the genesis and maintenance of social structure (e.g., Strauss et al., 1964; Maines, 1977). Their vision is largely consistent with Berger and Luckmann's (1967) notion of sedimented social structures, Silverman's (1971) theory of social action, and Giddens' (1976, 1984) notion of structuration. I use "negotiated-order theory" as a shorthand to refer to any theory that argues that social orders are socially constructed.

quire an aura of facticity, not because they exist beyond action but because actors behave as if structures were somehow divorced from daily life.

Although negotiated-order theory offers students of technology a more "social" conception of social order, it provides few analytical tools for explicating the links between a technology, an interaction order, and an organization's or occupation's structure. Consequently, the general vision of negotiated-order theory must be cast in terms amenable to investigation. Behaviorally based role theories are well suited for such a task. By emphasizing behavioral regularities rather than the role-related typifications from which the regularities spring, one may more easily study the content of an interaction order through observation. Role analysis also has none of the previously discussed shortcomings.

From a behavioral point of view, roles are grounded in interactions that occur in the course of daily life (McCall and Simmons, 1978; Strauss, 1978; Van Maanen, 1979). Hence, a role is intimately bound to a matrix of social relations. But, at the same time, because work roles are partially defined by the tasks that people perform, role analysis also subsumes an individual's use of technology and, hence, his or her skills. Role theory is, therefore, compatible with an analysis of a technology's immediate material implications, but its focus goes beyond such an analysis to examine how a technology's material constraints are transformed into social processes. Finally, a behaviorally based role theory offers the analyst a set of interrelated concepts by which to explicate links between adjacent levels of analysis.

A Role-Based Approach to the Study of Technology and Work

In a much overlooked monograph, Nadel (1957) distinguished between relational and nonrelational roles. According to Nadel, relational roles cannot be played without an alter ego, a specific other who fills a complementary position in the social order. For instance, there can be no son without a mother, no debtor without a creditor, and no subordinate without a superior. In contrast, nonrelational roles require no specific partners. An actor in a nonrelational role need only engage in that bundle of behaviors deemed by members of a culture to be characteristic of the role. Hence, there are no particular alter egos for the butcher, the baker, or the candlestick maker. To perform these roles it is sufficient that the first bakes, the second butchers, and the third makes candles.

Although Nadel's classification targets an important distinction, it would be folly to conclude that roles can be so easily typed. For instance, while the butcher's role clearly depends on how he treats animals for money, without customers, his work would surely earn him another name as well as another place in society. Similarly, mothers not only stand in a unique relation to their sons, they must also perform a minimal set of culturally ordained duties in order to fulfill their role in any but the biological sense of the term. Consequently, rather than separating roles into two types, it may be more appropriate to think of roles as bundles of nonrelational and relational elements that can be separated only analytically. Given this clarification, Nadel's distinction provides a useful framework for conceptualizing how a technology's effects might ramify across levels of analysis.

Nonrelational elements of a work role can be viewed as the set of recurrent activities that fall within the purview of a person who assumes a particular position or job. Included are formal duties as well as other behavioral regularities that accrue as a result of negotiated understandings. Thus, the nonrelational elements of a role involve not only the actual tasks that persons perform, but such incidentals as how to dress, where and when to eat lunch, and on which topics one can knowledgeably converse. In short, nonrelational elements encompass all the behaviors that individuals ordinarily perform as role incumbents, regardless of whether the behaviors are construed as obligations or are explicitly sanctioned. Because nonrelational elements of a role include skills and tasks, it is here that technologies are likely to have their most immediate impact.

Since few tasks are truly independent, however, one's work is likely to influence with whom one interacts as well as how one relates to others. For this reason, technically induced change in the nonrelational aspects of a role are prone to alter the role's relational elements. Altered tasks may narrow or expand the range of one's role set, shift the nature of one's dependencies, or affect the frequency and content of typical interactions. In fact, since nonrelational roles largely comprise solitary actions, one cannot properly speak of technically induced social change until a technology has begun to affect relationships. Therefore, if a technology is to occasion social change, modifications in the nonrelational elements of a role must spill over into the role's relational aspects. With such spillover, one essentially moves from an individual to a dyadic level of analysis. At this point, analysts can begin to determine whether role transformations have confirmed or altered organizational and occupational structures.

If one conceives of structure as a global pattern that emerges from the relationships that exist among all members of a collective, then it is possible to link shifts in role relations directly and empirically to structural change by examining properties of social networks. Network theorists have long argued that social structures can be described as configurations inscribed by the routine interactions that occur among the incumbents of specified roles (Boissevain and Mitchell, 1973; Mayhew, 1980a, 1980b; Burt, 1980, 1982; Hage and Harary, 1983). Some network theorists have even argued that roles are synonymous with a uniquely patterned set of ties (White, Boorman, and Breiger, 1976; Winship, 1989). From this perspective, any modification in a social structure is, by definition, grounded in changes that occur at the level of dyadic interaction. For instance, altered role relations may induce such structural modifications as the reformulation of cliques, the weakening of boundaries between sectors of an organization, or the differentiation of hierarchical statuses. Such changes may occur because technologies reduce or create dependencies, because they require interaction among members of different departments, or because they alter patterns of supervision. Structural change can, therefore, be understood as a transformation that emerges from events at the dyadic level of analysis, rather than as an aggregation of events that affect individuals as individuals.

Taken together, the foregoing notions offer investigators a lens for viewing technically occasioned social change as a series of reverberations that spread across levels of analysis much like ripples on the surface of a pond. When introduced into a work setting, new technologies initially modify tasks, skills, and other nonrelational aspects of roles. These modifications, in turn, shape role relations. Altered role relations either transform or buttress the social networks that constitute occupational and organizational structures. Ultimately, shifting networks should either sustain or modify institutions, since the latter represent blueprints for ongoing action. Using the role-based approach, a researcher would trace a technology's influence, step by step, from what might properly be called an individual level of analysis to a dyadic level of analysis and from the dyadic level to the level of the organization or occupation. Events at the dyadic level are pivotal because they serve as an explicit bridge between individuals and organizational structures. From this perspective, no technology can properly be said to have occasioned social change until it has influenced ongoing relationships.

Those who would adopt a role-based approach to studying technology's implications for organizational structure face a three-part task. First, investigators must show how specific technologies influence tasks, skills, and the other nonrelational aspects of work roles. Second, researchers must indicate how these changes influence relations among incumbents of different roles. Finally, one would need to examine properties of the organization's social network to determine whether shifting role relations have affected the network's configuration.

Data for executing the three components can be compiled by one of two strategies. Because the subject of investigation is ultimately systemic change, all else being equal, researchers should prefer longitudinal studies of specific technologies that employ a before-and-after design. However, diachronic studies are not always possible, either because researchers lack adequate resources or because the technology of interest has already been implemented. Fortunately, the advent of a new technology often creates opportunities to study the microsocial dynamics of technical change indirectly through synchronic analysis, for unlike many other kinds of change, technological change is frequently localized and occurs piecemeal. Consequently, organizations often operate old and new technologies concurrently, at least for some period of time. By comparing the social orders surrounding the older technologies with those surrounding the new, researchers can determine whether the various technologies are associated with differences in relational and nonrelational roles as well as whether the structure of the organization's social network reflects these differences. Thus, even though synchronic designs cannot actually chart the dynamics of change, they can be used to determine whether roles, role relations, and organizational structures entwine, as suggested by a role-based theory of technological change. As part of a larger study on how computerized imaging devices have affected the social organization of radiology departments, I used such a synchronic design to study structural change.

BACKGROUND AND METHODS

The Technical Transformation of Diagnostic Imaging

In perhaps no area of medicine have computers triggered a more thorough metamorphosis than in radiology. Until the late 1960s a radiology department's work consisted almost entirely of radiography and fluoroscopy, technologies that had existed since the turn of the century when x-rays were first used for medical diagnosis. Although both technologies had been modified substantially since the early 1900s, most of the innovations consisted of incremental improvements to existing machines and techniques (Dewing, 1962). As a result, during the first half of the twentieth century, radiology's knowledge had evolved at a pace sufficiently gradual for most radiologists and technologists to remain up to date.

In the mid-1960s, however, the pace of technical change suddenly accelerated. With the invention of the rapid film-changer, radiologists began to perform a series of diagnostic procedures known collectively as "special procedures." Special procedures are invasive examinations during which a rapid series of x-rays are taken to record the movement of iodine dye through the vascular system or the ducts of a specific organ such as the kidney. Because all special procedures entail incisions and catheterization, they led radiologists to engage, for the first time, in forms of minor surgery.

Shortly after the diffusion of special procedures, medical researchers began to create radically new imaging techniques by linking computers to an array of old and new data sources. Ultrasound, the first computerized imaging device, appeared in the early 1970s. During an ultrasound examination, sound waves are projected into a patient's body using a hand-held transducer equipped with a piezo-electric crystal. The crystal not only emits sound waves but converts returning echoes into electrical impulses that are fed into a computer, where they are assembled into patterns and displayed on a video monitor. Because ultrasound was noninvasive and involved no radiation, radiologists could examine organ systems that they could not previously study using radiographic techniques.

The computed tomography (CT) scanner was invented in 1971. Although scanners were quickly regulated by the federal government in an attempt to slow their diffusion, by 1980 a substantial number of community hospitals had purchased one or more of the devices (Office of Technology Assessment, 1978, 1981). CT scanners were the first imaging devices to produce highly detailed, cross-sectional pictures of internal anatomy. Scanners consist of an x-ray tube and a set of detectors, which are housed inside a large gantry and which rotate rapidly around a patient's body. The x-ray tube emits short bursts of electrons that pass through the body to strike the detectors. The detectors feed electrical impulses into a minicomputer, where they are stored as a set of data points. Using a series of simultaneous equations, the computer converts the data into an image and displays it on a video monitor. Because CT scanners triangulate multiple perspectives on a given area of the body, they produce images whose clarity rivals the illustrations of an anatomy textbook.

Since 1980 several other computerized imaging devices have become common in large medical centers. Positron emission tomography (PET) and magnetic resonance imaging (MRI), respectively, use radioisotopes and magnetic fields to create images that enable radiologists to visualize biochemical processes as well as anatomical structures. Computers have also been coupled to traditional radiographic equipment to yield new technologies known as digital radiography and digital subtraction angiography (DSA). Since each new technology, from special procedures onward, has produced images quite different from those associated with radiography and fluoroscopy, radiologists frequently refer to them as "new modalities."

Most authorities readily admit that the new modalities have revolutionized medical diagnosis by enabling physicians to visualize anatomical structures and disease processes previously accessible only during surgery (Banta and McNeil, 1978; Stocking and Morrison, 1978; Wiener, 1979). But, there is also evidence that the modalities may have brought social as well as technical change. Although radiology officially remains an undifferentiated specialty, over the last fifteen years new roles have emerged for radiological technologists. Whereas all technologists previously functioned as "x-ray techs," today radiology departments also employ "specials techs," "sonographers," and "CT techs." Similarly, the territory of the radiology department has become spatially and linguistically differentiated. In the past, the "radiology department" and the "x-ray department" were synonymous. Today, radiology departments encompass the "angiography suite," the "CT department," and the "ultrasound department," as well as the "main department" where radiography and fluoroscopy continue to be used much as they were in the past.

But perhaps the most intriguing suggestion of social change is the fact that an increasing number of radiology departments have changed their name to departments of "medical imaging." As Hughes (1958) once noted, whenever an established occupation chooses to call itself by another name, one should expect to find the social order in flux. It was to determine how new modalities were changing radiological roles, what these changes might portend for the organization of radiology, and whether a role-based approach to the study of technical change was viable that I became a participant observer in the radiology departments of two community hospitals during the year that each began to operate its first body scanner.

Design, Data Collection, and Analytic Strategy

Suburban and Urban were two of four Massachusetts hospitals whose radiology departments received body scanners during the fall of 1982.[2] Both departments employed six radiologists, three administrators, approximately thirty technologists, and a number of secretaries, transcriptionists, and orderlies. Each department performed CT scans, special procedures, and ultrasound exams in addition to a standard array of radiographic and fluoroscopic studies. The radiologists in

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Urban and Suburban were chosen as sites not only because they allowed me to compare synchronically the same set of traditional and computerized imaging devices but also because they allowed me to examine the social implications of CT scanning diachronically. The diachronic study is reported in Barley, 1986.

both hospitals rotated through the various technologies on a daily or weekly basis; however, most technologists were assigned to a single area. X-ray techs worked exclusively in the main department, where they performed "routines," intravenous pyleograms (IVPs), barium enemas, upper GIs, and other less common radiographic and fluoroscopic studies. Sonographers operated the ultrasound machines, CT techs worked the scanners, and special techs staffed the angio suites. Urban differed from Suburban in that it had been operating an EMI head scanner since 1977, whereas the body scanner was Suburban's first experience with CT. Also unlike Urban, Suburban purchased digital subtraction equipment at the time it acquired its scanner.

Observation began in both departments during June 1982, four months before the scanners went online, and continued until the end of May 1983. The study's aim was to compare the social organization of ultrasound, CT scanning, and special procedures to the social organization of radiography and fluoroscopy in order to determine whether and how the new modalities had affected the organizational structure of the two departments. Because the study began before the scanners arrived and before Suburban had acquired its DSA equipment, I was able to chart the scanning operations and Suburban's use of the DSA equipment as they unfolded. However, because ultrasound and special procedures had been in place in both hospitals for at least eight years, a fully diachronic design was untenable. Consequently, I was forced to adopt a synchronic design for comparing the social organization of work in the main department to that of the new modalities. I reasoned that if I could show (1) that the social orders surrounding the new modalities were roughly similar and (2) that these differed consistently from the social organization of radiography and fluoroscopy, then I would have evidence that the new modalities had affected the structure of the two departments.

Because radiologists and technologists are the most important occupations in a radiology department, I focused primarily on examining the nonrelational and relational elements of their roles. Observations centered on the activities and interactions that took place during seven types of diagnostic procedures: routine x-rays, IVPs, barium enemas, upper GIs, ultrasounds, special procedures, and CT scans. The first four were performed in the main department. IVPs and routines were radiographic exams, while barium enemas and upper GIs were the most common fluoroscopic studies. Data were gathered by accompanying targeted radiologists and technologists as they went about their daily routines. Because roles rather than idiosyncratic behaviors were the focus, I coordinated my observations with the departments' duty schedules to ensure that a number of radiologists and technologists were observed performing each type of procedure.

Observations, from six to eight hours in duration, were made at one of the two sites each day throughout the course of the year. Data on the nonrelational and relational elements of the two work roles were assembled by noting all the activities and interactions of radiologists and technologists during the course of a procedure. The content of each activity and the time at which it occurred were recorded in small spiral note-books, creating a behavioral record for each exam observed. Conversations between participants were either taped or written in a shorthand devised for the purpose of documenting setting-specific argots. Observations of actions and interactions were supplemented by data drawn from archival sources such as duty rosters, job descriptions, organizational charts, patient schedules, equipment repair records, order forms, and the radiologists' written reports on the films they had interpreted. I also sought and recorded radiologists' and technologists' interpretations of events at the time they occurred or shortly thereafter. Over the course of the study I observed approximately 400 examinations.

To analyze the relational and nonrelational aspects of radiologists' and technologists' roles, I first sorted the behavioral records by type of technology. The flow of action during each exam was then analyzed to reveal the tasks and activities in which technologists and radiologists typically engaged. Once the typical activities associated with each technology were identified, the nonrelational aspects of a technologist's or radiologist's role were compared across technologies to identify similarities and differences. Specifically, the roles of technologists operating different modalities were compared with regard to the decisions each made during the course of an exam, the actions they took in the face of technical malfunctions, their ability to interpret images, and their status vis-à-vis referring physicians. Radiologists' roles were examined across technologies with regard to frequency of assignment, levels and patterns of consultation, and so forth.

The role relations most relevant to the study were those between radiologists and technologists assigned to different modalities. To analyze these relations, all instances of interaction between a radiologist and technologist were culled from the behavioral records and sorted by technology. Interactions that occurred around the various modalities were then compared with respect to frequency and duration, topics and structure of conversation, the handling of mistakes, and the general tenor of the relationship.

At the end of the study, sociometric questionnaires were distributed to each member of both departments to gather data on the departments' social networks. The questionnaire listed all members of the department and asked the respondent to indicate with whom he or she typically discussed five matters integral to radiological work: (1) the setting of techniques and positioning of patients, (2) the interpretation of films, (3) technical and mechanical problems, (4) problems with patients, and (5) complaints about departmental events.[3] Networks representing the organizationally sanctioned structure were constructed by identifying relationships prescribed by organization charts and job descriptions.

The sociometric data were used to examine collegial relations among the radiologists. They were also used to determine (1) whether the departmental networks were consistent with the observational data on role relations among technologists and radiologists, (2) whether the networks' structures differed from the prescribed ideals, and if so, (3) whether and in what direction the new modalities may have affected the organization of the departments' work. The Quadratic Assignment

3
"Setting techniques" is a phrase used in radiology departments to refer to the act of choosing the milliamperes and kilovolts at which an x-ray tube will operate. The phrase is also used in ultrasound to refer to such acoustic parameters as gain and impedance. "Positioning patients" refers to the act of posing a patient's body in order to produce an image taken from a particular angle.

Procedure (Hubert and Schultz, 1976; Hubert and Golledge, 1981; Baker and Hubert, 1981) was used to determine whether each department's social network differed significantly from the organization's ideal. Directed graphs and blockmodeling techniques were employed to determine whether the differences were consistent with the observational data on interactions and to examine how the modalities had affected each department's structure.

NONRELATIONAL ROLES

Radiologists' Work

According to older informants, during radiology's era of incremental change, practicing radiologists easily remained current with new developments, and interpretive acumen was largely a function of cumulative experience. Younger radiologists reportedly viewed their older colleagues as mentors capable of helping them refine their interpretive skill. Physicians were also said to have preferred consulting with older radiologists because they thought that more experienced radiologists would provide more accurate readings. For these reasons, incremental technical change had apparently supported a social system in which a radiologist's knowledge and status increased with age and tenure.

Special procedures, ultrasound, CT scanning, and other new modalities upset the stability of radiology's knowledge. Not only did these new modalities operate by unfamiliar principles, but each brought to radiology an unfamiliar system of signs. To interpret an ultrasound or CT scan required fluency in an image language whose properties bore no resemblance to an x-ray. While a radiologist could, in theory, remain current with new modalities simply by reading the professional literature or by attending workshops, in practice, such actions proved impractical and ineffective. Most practicing radiologists were unlikely to have either the time or the inclination to learn a modality until their department purchased the equipment. Moreover, because interpretive acumen required concerted practice, a radiologist could not hope to become proficient in a new modality without hands-on experience. Since such opportunities were rare until equipment was actually acquired, most departments, when adopting a new modality hired one or more radiologists who had learned the technology elsewhere. Suburban and Urban were no different in this regard.

Suburban and Urban hired young radiologists fresh from fellowships in CT during the summer before their scanners went on line. Both departments had taken similar steps when adopting special procedures and ultrasound. Because radiologists typically study all the modalities current at the time they attend school, fifteen years of technical change had brought to each department a three-tiered system of expertise in which successively younger cohorts of radiologists had ever broader knowledge. Table 1 groups Suburban's and Urban's radiologists by their relative tenure in radiology (short, medium, and long) and indicates which modalities each could interpret at the time the study began.[4] As the descending step-like patterns indicate, in both departments length of tenure was inversely related to the number of modalities a

4

Tenure and age were highly correlated in the two departments. The short-tenured radiologists were in their late twenties and early thirties, the medium-tenured radiologists were in their late thirties and forties, and the long-tenured radiologists were all over 55. I therefore use age and tenure interchangeably.

Table 1

Distribution of Interpretive Ability among Suburban's and Urban's Short-, Medium-, and Long-Tenured Radiologists*

	Suburban						Urban					
	Tenure						Tenure					
	Short	Medium			Long		Short	Medium				Long
Modality	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
CT scanner	x						x					
Special procedures	x	x	x	x			x	x	x	x	x	
Cardiac ultrasound	x	x	x	x			–	–	–	–	–	
Abdominal ultrasound	x	x	x	x	x	x	x	x	x	x	x	x
Fluoroscopy	x	x	x	x	x	x	x	x	x	x	x	x
Routines/IVPs	x	x	x	x	x	x	x	x	x	x	x	x

* Column entries indicate which modalities each radiologist could interpret. Cardiac ultrasound is treated as a separate modality because it was treated as such by the radiologists. Cardiologists rather than radiologists performed cardiac ultrasounds at Urban.

radiologist could interpret.[5] This distribution of expertise, in turn, influenced the radiologists' work roles.

Although radiologists in both hospitals formally rotated through all duty stations except special procedures, the older radiologists worked most frequently in the main department. Table 2 displays the percentage of working days between October 1982 and May 1983 that each radiologist was assigned to radiography or fluoroscopy, CT or ultrasound, and special procedures. As the first row indicates, the longest-tenured radiologists in both hospitals spent more than 70 percent of their time in radiography and fluoroscopy. In contrast, the shortest-tenured radiologists spent less than 38 percent of their time in the main department, while the medium-tenured radiologists fell in between.

The data suggest that the new modalities may have gradually undermined the homogeneity of radiologists' work. As the departments acquired new modalities, the older radiologists apparently became increasingly tied to the departments' more traditional and now less glamorous work, while the younger radiologists were allowed to monopolize the newer technologies. These differences in ability and formal assignment, in turn, engendered informal distinctions that led to further stratification. Because the older radiologists now spent most of their time in the main department, they had become professionally estranged from their colleagues. Not only did I observe short- and medium-tenured radiologists consulting more frequently among themselves than with their long-tenured colleagues, but the radiologists themselves recognized the pattern's existence.

To document their perception, I asked each radiologist to indicate with whom he routinely "discussed" any of four technical topics: the setting of techniques, the interpretation of films, technical problems, and problems with patients. The matrices in panel A of Figure 1 display for Suburban and Urban the number of topics that each radiologist reported

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The pattern is perfect in neither department. However, the apparent discrepancies are less telling than they appear. In both cases, older radiologists had attempted to learn abdominal ultrasound but were held by sonographers and colleagues alike to be less proficient than either the medium- or short-tenured radiologists. Radiologist R2 at Urban was closely associated with a local medical school and had long been a champion of computer tomography. He therefore attempted to remain current with developments in body CT even before his department purchased its machine. However, his colleagues considered him less knowledgeable than the young radiologist, whose opinions they held in higher regard.

Table 2

Percentage of Working Days that Short-, Medium-, and Long-Tenured Radiologists at Suburban and Urban Were Assigned to Specific Technologies: October 1982 to May 1983*

	Suburban						Urban					
	Tenure						Tenure					
	Short	Medium			Long		Short	Medium				Long
Assignment	R1	R2	R3	R4	R5	R6	R1	R2	R3	R4	R5	R6
X-ray/fluoroscopy	38	50	49	55	87	86	13	28	33	40	52	73
CT/ultrasound	22	21	23	17	13	14	54	57	52	37	30	28
Special procedures	41	29	28	27	0	0	33	15	15	23	18	0

* Due to rounding error, columns may not sum to 100%.

discussing with each colleague. The radiologists are listed in order of ascending tenure and are labeled by the same identifiers used in tables 1 and 2.

Because the radiologists at both hospitals formed a face-to-face work group, all radiologists in a department communicated frequently with each other. However, a strong collegial bond between two radiologists was marked by the tendency to discuss a variety of work-related issues. For this reason, meaningful differences in the relationships among the radiologists are best analyzed by focusing on strong rather than weak ties. To eliminate weak ties, the matrices in panel A were dichotomized by setting each cell equal to 1 if its value was greater than or equal to the second highest number of ties reported by any radiologist in the department; otherwise, the cell was set equal to 0. Thus, cells of Suburban's matrix (a_{ij}) were set equal to 1 if $a_{ij} \geqq 2$, while cells of Urban's matrix were set equal to 1 if $a_{ij} \geqq 3$. The results of this transformation are displayed in panel B of Figure 1.

Furthermore, since discussions are typically symmetric interactions, it seemed reasonable to assume that a strong collegial bond existed between two radiologists whenever either reported having such a relationship. Following this logic, the dichotomized matrices in panel B were made symmetric by union: cells a_{ij} and a_{ji} in the matrices of panel C were both set equal to 1 if either of the corresponding cells in the matrices of panel B were equal to 1. For ease of interpretation, panel D portrays the structure of each symmetric matrix as an undirected graph.

As the graphs in panel D clearly indicate, older radiologists in both departments reported being, and were thought to be, less heavily involved in work-related discussions. Two of the three long-tenured radiologists (Suburban's R5 and Urban's R6) were completely isolated from their colleagues' strong-tie network, while one was included by virtue of a single relationship (Suburban's R6). In effect, the longer-tenured radiologists were not only assigned more frequently to the main department, they were largely excluded from their colleagues' professional network.

Figure 1. Strong work ties among radiologists at Suburban and Urban.*

A. Number of ties between each radiologist

	Suburban							Urban					
	R1	R2	R3	R4	R5	R6		R1	R2	R3	R4	R5	R6
R1	0	2	3	2	1	1	R1	0	4	4	4	4	1
R2	2	0	3	2	1	2	R2	1	0	1	1	1	1
R3	2	0	0	0	0	0	R3	4	3	0	3	3	2
R4	0	2	2	0	0	0	R4	2	2	2	0	2	2
R5	1	0	0	0	0	0	R5	0	0	0	1	0	0
R6	1	1	1	1	1	0	R6	2	1	2	1	2	0

B. Dichotomized at

	$\alpha \geqq 2$							$\alpha \geqq 3$					
	R1	R2	R3	R4	R5	R6		R1	R2	R3	R4	R5	R6
R1	0	1	1	1	0	0	R1	0	1	1	1	1	0
R2	1	0	1	1	0	1	R2	0	0	0	0	0	0
R3	1	0	0	0	0	0	R3	1	1	0	1	1	0
R4	0	1	1	0	0	0	R4	0	0	0	0	0	0
R5	0	0	0	0	0	0	R5	0	0	0	0	0	0
R6	0	0	0	0	0	0	R6	0	0	0	0	0	0

C. Made symmetric by union

	R1	R2	R3	R4	R5	R6		R1	R2	R3	R4	R5	R6
R1	0	1	1	1	0	0	R1	0	1	1	1	1	0
R2	1	0	1	1	0	1	R2	1	0	1	0	0	0
R3	1	1	0	1	0	0	R3	1	1	0	1	1	0
R4	1	1	1	0	0	0	R4	1	0	1	0	0	0
R5	0	0	0	0	0	0	R5	1	0	1	0	0	0
R6	0	1	0	0	0	0	R6	0	0	0	0	0	0

D. Graphs

* Radiologists are labelled and listed in order of increasing tenure, as in tables 1 and 2.

The experience of the newly hired radiologists was precisely the reverse. Because learning CT had suddenly acquired high priority and because the young radiologists were considered experts, their more senior colleagues continually sought their advice. Referring physicians also rapidly realized that the young radiologists were more knowledgeable. They routinely brought CT scans to the young radiologists for second opinions, even when more senior radiologists had already provided a reading based on their own consultation with their younger colleague. Moreover, because the young radiologists were also familiar with the latest developments in ultrasound and special procedures, demand for their assistance extended beyond the interpretation of CT scans. Thus, in a surprisingly short period of time, the young radiologists became increasing critical in the network of diagnostic consultations and often found themselves pulling double duty.[6] Not only were they responsible for their own assignments, but they were

6
On this point the observational data and the sociometric data seem to disagree. After a year of observation it was clear to me that the younger radiologists had become the most central members of the radiologists' consultation network, especially at Suburban. However, panel D of Figure 1 suggests that neither of the short-tenured radiologists was the most central figure in their respective networks, even though no other radiologist was more central than they. The discrepancy may reflect the fact that I asked the radiologists to name discussion partners rather than to indicate whom they consulted. More importantly, because of their unflinching pride, the medium-tenured radiologists were probably unwilling to admit openly that they often abdicated to their younger colleagues' opinions regarding CT and special procedures. Such a stance would be consistent with the day-to-day behavior I observed.

forced to interpret once, twice, and occasionally more often nearly every CT scan the department produced.

As the older radiologists grew more isolated and the younger radiologists more central, the medium-tenured radiologists began to perceive an erosion of their stature.[7] Although the perception was largely revealed by their defensiveness over the mistakes they made in CT (Barley, 1986), their concern also stemmed from other developments. As previously noted, referring physicians demonstrated a lack of confidence in the medium-tenured radiologists by continually asking the younger radiologists for a second opinion. Moreover, the new radiologists' arrival altered the technologists' relative evaluation of the radiologists. Techs in both departments openly claimed that they preferred to work with either the older or the younger radiologists because the former were more compassionate and the latter more competent. With few exceptions, the techs cast the medium-tenured radiologists as overlords and "prima donnas," a term current in both work cultures.

The medium-tenured radiologists' reaction to the perceived threat varied across the two departments. Suburban's medium-tenured radiologists, who had previously formed a tight clique, drifted apart. Two (R2 and R3) aligned themselves with the new radiologist, while the third (R4) withdrew and developed tactics for avoiding loss of face. When assigned to CT duty, the third cloistered himself in his office, avoided CT techs who were more knowledgeable than he, and, rather than admit that he needed to consult before providing a reading, offered referring physicians a variety of excuses for why he had not yet reviewed a study. At Urban, three of the medium-tenured radiologists (R3, R4, and R5) formed an informal coalition against the fourth (R2), who had greater knowledge of CT. The three apparently perceived their younger colleague to be less threatening than their more knowledgeable peer. Thus, in both hospitals the new modalities apparently undermined the homogeneity of the radiologists' work and prompted role distinctions that threatened to invert the radiologists' traditional status system. These forces fragmented collegiality and spawned political rivalries.

Technologists' Work

Differences in roles and status were even more pronounced among the technologists. Not only were CT techs, specials techs, and sonographers paid more than x-ray techs, but they worked in different locations, wore different clothing, and worked different types of shifts.[8] X-ray techs were required to wear color-coordinated uniforms, while all other technologists were allowed to wear lab coats or smocks over their street clothes. CT techs, specials techs, and sonographers worked weekends, rotated shifts, and spent evenings on call. In contrast, x-ray techs worked a fixed, eight-hour shift five days a week. Higher pay, more individualistic forms of dress, and the necessity of being on call signaled that the hospitals valued the newer modalities more highly, a message that was not lost on the x-ray techs, who frequently complained that the other techs received "better treatment." However, these symbolic distinctions paled before the differences that separated the actual work of the two groups.

7
In contrast, the long-tenured radiologists found little threat in the young radiologists' knowledge. At both sites the older radiologists openly admitted their ignorance of CT and sought to learn what they could, while claiming that it was unreasonable to expect to become truly proficient with a new technology so late in their careers.

8
These differences indicate macrosocial processes of technical change. The differences were clearly imposed by the hospitals' management. Because these differences were also evident in three other hospitals where I conducted brief interviews, they probably indicate evidence of institutionalized practices (at least in the metropolitan area where the study was conducted) that spread by mimesis.

Autonomy and discretion. The amount of autonomy and discretion exercised by technologists in the two groups differed greatly. Both departments employed as administrators a chief and two assistant chief technologists, former techs charged with supervising the department's daily activities. On a typical day an assistant chief could be found on the floor of both main departments monitoring the flow of patients and issuing orders or suggestions. The administrators regularly called the x-ray techs' attention to patients who were waiting, exams that were taking too long, and sundry other details relevant to the efficient processing of patients. At Suburban, an assistant chief acted as a quality-control inspector who passed judgment on each film produced in the main department before it was forwarded to a radiologist. In sharp contrast, I observed administrators visit the CT, ultrasound, or specials areas of both hospitals combined on only ten occasions. On nine of these visits, the administrators either sought advice from technologists or delivered personal messages. Since most of the administrators had no knowledge of the new modalities, the technologists checked their own films and received feedback only from radiologists. Hence, even though all technologists formally reported to the administrators, the official line of authority was enacted only in the main departments.

In keeping with the foregoing difference in supervision, CT techs, specials techs, and sonographers set operating procedures for their areas, ordered their own supplies, scheduled their own patients, and kept their own records and inventories. Because they could pace their work by scheduling appointments, techs in the new modalities were able to accommodate unforeseen contingencies, their own needs, and the needs of radiologists and referring physicians. For example, schedules could be arranged to ensure periods of lighter or more varied work as well as to "squeeze in" patients for preferred physicians or to inconvenience physicians who were disliked. In the main department, such tasks were controlled by administrators. Inventories there were maintained by an assistant chief, who was also responsible for ordering supplies and negotiating with vendors. Scheduling and record keeping were done by secretaries and clerks. Each morning the main departments posted a list of patients scheduled for fluoroscopy and IVPs. An administrator allocated the patients to rooms, and any modification in the schedule had to be sanctioned by either a radiologist or an assistant chief. Consequently, the main department's workflow was largely scripted. To be sure, x-ray techs could complain, but aside from their ability to persuade, they had little power to affect the circumstances of their work.

Repairs and technical expertise. Since each hospital operated several rooms of radiographic and fluoroscopic equipment, machine failures in the main department never precluded the completion of an exam. X-ray techs were, therefore, only momentarily inconvenienced by equipment problems. When x-ray equipment malfunctioned, the techs first made sure that the trouble was more than a passing anomaly and then notified an assistant chief. The administrators would sometimes attempt to correct the malfunction, but, more often than not, they would simply summon a repairman. After a machine was deemed officially "down," x-ray techs spread the word among themselves and ceased to be concerned with the situation. Repairmen who visited the main department were rarely hampered by curious techs interested in learning more about the technology.

In sharp contrast, equipment failures could bring a new modality to a complete standstill, inconvenience numerous patients, and create lengthy backlogs. Since these procedures were more costly than a radiographic or fluoroscopic study, their cessation also signaled a substantial loss of revenue. Consequently, specials techs, CT techs, and sonographers remained close to repair efforts and took an active interest in their equipment. In fact, the novelty and complexity of the technology combined with the severity of a malfunction's consequences to make equipment repair a central part of the technologist's role. CT techs, sonographers, and specials techs prided themselves on their technical acumen and delighted in opportunities to enhance their technical reputation. Not only were they prone to give visitors impromptu lectures on their respective devices, but on numerous occasions I observed CT techs and specials techs attempt to diagnose and repair malfunctioning equipment (Barley, 1988).

Because few of the radiologists and administrators had experience with computerized machines, it was assumed that only technologists could describe their technology's operation in sufficient detail to communicate with the manufacturer's "engineers." Techs in the new modalities were, therefore, allowed to deal directly with the manufacturer's representatives and were never asked to justify summoning an engineer before placing a call. The strength of the assumption regarding the technologists' acumen is nicely illustrated by an incident that occurred one afternoon at Suburban when the digital subtraction equipment crashed in the middle of an angiogram. The chief technologist happened to enter the angio suite moments later and insisted on calling the engineers. Because the chief had been a CT tech, she had more experience with computers than any of the specials techs. However, the radiologist performing the angiogram ordered the chief to relinquish the phone so that a specials tech could explain the problem's specifics.

Interpretation of images. Even though technical acumen was rare among x-ray techs, its prevalence among those who operated the new modalities violated no strictures of the technologist's traditional role. All certified x-ray techs had taken courses in the mechanics of radiographic equipment as part of their training. However, the ability to interpret films was an entirely different matter. Radiology had established its diagnostic monopoly, in part, by barring technologists from interpreting films (Brown, 1973; Larkin, 1978). To reinforce the monopoly, technologists were required to graduate from a program accredited by the American College of Radiology. While these programs taught technologists to recognize anatomy, they provided no instruction in pathological signs or the interpretation of films.

However, given that the technologists worked in an environment thick with diagnostic interpretation, it seemed plausible that they might learn to read films while on the job. To determine whether x-ray techs could interpret the films they produced, I made a practice of routinely asking them what their films revealed. I also stationed myself near film processors so that I might overhear what techs said to each other about the films. With the exception of a few older technologists, most x-ray techs could not readily identify pathological signs. Those pathologies that the techs did recognize were either structural or else exceedingly common. For instance, most could identify broken bones in a routine x-ray, kidney stones or blocked ureters in an IVP, and polyps in a barium enema. However, they rarely mentioned the hydronephrotic kidneys, tumors, adelexis, pneumonia, pneumothorax, or a host of other maladies that the radiologists saw in the same films.

In sharp contrast, pathology and interpretation were staples of conversation among technologists who worked outside the main department. When asked to explain an image, sonographers, CT techs, and specials techs often spoke at length not only about the immediate anatomy and pathology visible in the films, but about the disease's etiology and its probable prognosis. Technological requirements partially explained why the sonographers, CT techs, and specials techs had more interpretive knowledge than their brethren in the main department. One can produce an adequate study with an x-ray machine or fluoroscope if one knows how to position a patient correctly and identify anatomical reference points using one's hands as a probe. However, to operate ultrasound equipment, digital subtraction equipment, or a CT scanner skillfully, one must adjust one's actions in response to information contained in the images that are produced. Although all computerized modalities required a cybernetic relationship between technologist and image, the feedback loop was most critical for ultrasound.

Because an ultrasound transducer is a hand-held probe with an extremely narrow field of view, a sonographer cannot automatically rely on the machine to capture evidence of a patient's malady. Instead, to image signs of pathology or to prove that no signs exist, a sonographer must actively search an organ system for confirming or disconfirming evidence while using images on the video monitor as a guide to further exploration. Moreover, because sonograms are more ambiguous than the images produced by other modalities, iatrogenesis is of constant concern. Sonographers must, therefore, not only recognize signs of pathology, they must also distinguish disease from artifact. Finally, since different pathologies often lead to similar structural abnormalities, sonographers must record data on a number of plausible etiologies in order to produce a conclusive study. One of Suburban's sonographers provided the following illustration of the sonographers' modus operandi:

There are two things that can cause a dilated common bile duct. A stone in the duct or a tumor in the head of the pancreas. So if you see a dilated duct, you had better check the whole duct for a stone and look at the head of the pancreas. Actually, there is a third possible cause, but it only occurs about one percent of the time. Anyway, no tumor, then you have to try to see the whole duct. If you can't see the whole duct you can't discount the stone and you have to say that dilation is probably from a stone.

Provision of information to physicians. Each day numerous physicians visited the two radiology departments in search of expert opinion and an opportunity to view their patients' films. By and large, physicians rarely spoke to x-ray techs except to exchange greetings or to inquire of a radiologist's whereabouts. I never witnessed a physician ask an x-ray tech about the results of a study nor an x-ray tech offer a physician information about a patient. In the main department, referring physicians spoke of substantive matters only with radiologists. A technologist's involvement with physicians was qualitatively different in the new modalities. Physicians often consulted sonographers, specials techs, and CT techs regarding the scheduling of patients and the progress of exams. More importantly, when radiologists were unavailable, physicians occasionally asked the technologists for diagnostic information. Usually the techs refrained from providing physicians with detailed information, since it was not only socially proscribed but illegal for technologists to give physicians readings. In most cases, CT techs and specials techs merely provided physicians with a cursory overview, such as "her right side was occluded," "it looked pretty clean," or "she had a lot of disease." For more information, the doctor would need to talk with the radiologist or view the films personally.

Sonographers, however, tended to be more specific. Physicians realized that because of the nature of the technology, sonographers had to be knowledgeable diagnosticians. Since sonographers were easier to locate than radiologists, many physicians habitually contacted the sonographers to discuss a patient's exam. When physicians telephoned for the results of a recent study, sonographers readily offered detailed information, especially if the radiologist's reading had been typed and was included in the patient's folder. Sonographers were more hesitant when physicians arrived in person. Sonographers did occasionally hang films on light boxes and engage physicians in interpretive discussions. However, radiologists at both departments had warned the sonographers that the practice was unacceptable. To circumvent sanction, the sonographers resorted to a rhetoric of anatomy and spatial position to call physicians' attention to specific findings without explicitly referring to pathological entities or disease processes.

It would appear, then, that the work role of the sonographer, the CT tech, and the specials tech was considerably different from that of the x-ray tech. The x-ray tech's role remained well within the bounds of radiology's traditional system of professional dominance: techs were tightly supervised, and the demarcation between production and interpretation of films was routinely enacted. However, techs in the newer modalities performed duties and exhibited types of knowledge that challenged the traditional order. Sonographers, CT techs, and specials techs were allowed greater discretion over the administrative and technical details of their work, they interpreted the images they produced, and they engaged in other behaviors traditionally reserved for radiologists and administrators. These differences were rooted in the fact that the new modalities were cybernetic machines that required knowledgeable operators who could exercise discretion in the face of uncertainty. These nonrelational elements of the technologists' roles and the stratified distribution of expertise among the radiologists shaped role relations among technologists and radiologists, further challenging radiology's institutions.

RELATIONS BETWEEN RADIOLOGISTS AND TECHNOLOGISTS

Frequency of Interaction

The spatial ecologies of the two departments were such that extended interactions between radiologists and technologists occurred primarily during the course of an exam. The offices and reading rooms where the radiologists spent most of their time were separated from the areas where technologists congregated. To be sure, radiologists and technologists frequently encountered each other in hallways, coffee rooms, and other public areas. However, such encounters were brief, and the conversations that ensued consisted primarily of greetings, small talk, and the occasional piece of departmental gossip. Opportunities for interaction among radiologists and technologists were, therefore, largely structured by the dictates of the technologies.

In the main departments, radiologists played a relatively minor role in all procedures. They took no part in routine x-rays and were present during fluoroscopic exams and IVPs only long enough to perform the fluoroscopy or administer an injection of iodine dye, both of which required no more than five minutes to complete. During an IVP or a fluoroscopic exam, techs were at various points required to show a radiologist the films they had taken in order to receive additional instructions. These encounters usually occurred in the radiologist's office and lasted no more than a minute. In contrast, the newer modalities brought radiologists and technologists together for longer periods of time. During special procedures, radiologists and technologists worked side by side in a surgery atmosphere. Radiologists assigned to CT spent considerable time with technologists at the scanner's console. And once sonographers had explored the area of interest, radiologists and sonographers routinely attempted to verify each other's interpretations by examining the images together.

Table 3 displays the mean duration of various procedures and the mean percentage of an examination during which radiologists and technologists were in each other's presence. The data suggest that radiologists and technologists spent considerably less time in each other's company when performing procedures with older technologies. In both hospitals, the smallest average percentage of contact in the new technologies was greater than or equal to the largest average percentage observed in the main departments. The analysis of variance in Table 3 confirms this impression. Irrespective of hospital ($F = 1.73$; d.f. $= 1, 251$; n.s.), the distinction between old and new technologies significantly determined the amount of contact between radiologists and technologists ($F = 68.32$; d.f. $= 1, 251$; $p < .01$). The greater opportunity for interaction, in turn, set the stage for renegotiating the content of traditional role relations.

Interpretive discussions. As discussed above, the cybernetic nature of the newer technologies required sonographers, CT

Table 3

The Average Duration of Various Procedures and the Average Percentage of the Duration during Which Radiologists and Technologists Were in Contact*

Procedure	Suburban		Urban		Combined		
	N	Mean %	*N*	Mean %	*N*	Mean duration	Mean %
Old							
Routine x-ray	5	0	6	0	11	6	0
IVP	19	17	6	14	25	56	16
Barium enema	20	19	19	8	39	43	14
New							
Specials	44	66	8	73	52	90	67
Ultrsound	27	41	17	14	44	16	31
CT scan	42	20	20	48	82	48	34

Analysis of Variance of Percentage Contact

Source	d.f.	Sums of squares	Mean square	*F*
Hospital	1	.119	.119	1.73
New vs. old	1	4.698	4.698	68.32•
Residual	251	17.192	.069	

• $p < .001$.
* Durations are measured in minutes.

techs, and specials techs to possess greater interpretive skill than their counterparts in the main department. However, the technologies' material constraints cannot explain how the technologists obtained their knowledge. To account for the differential ability to interpret, one must examine the opportunities for learning interpretive skills. Since radiologists are the primary source of interpretive acumen in a radiology department and since technologists outside the main department had more contact with radiologists, one might argue that they also had greater access to the radiologists' knowledge.

Table 4 displays, for different procedures, the percentage of examinations during which I observed a radiologist and technologist discuss diagnostic signs. Although there were minor differences across the two departments, as the last column indicates, radiologists were, in general, far less likely to discuss interpretive matters with x-ray techs than with sonographers, specials techs, or CT techs. The analysis of variance in Table 4 confirms that the distinction between old and new modalities significantly influenced the likelihood that interpretive discussions would occur ($F = 52.59$; d.f. = 1, 312; $p < .001$) and that the difference was independent of hospital ($F = 1.72$; d.f. = 1, 312; n.s.).

Although the new modalities increased the frequency of interpretive discussions among radiologists and technologists, more revealing were the stylistic differences that characterized the interactions. Although interpretive discussions between radiologists and technologists evidenced four distinct patterns, only one, which I refer to as "telling," occurred with any frequency in the main departments. In conversations so structured, radiologists told technologists about the pathologies they perceived in a film. If questions were raised, the technologists posed them. If opinions were offered, the radi-

Table 4

Percentage of Examinations in which Radiologists and Technologists Had Interpretive Discussions

Procedure	Suburban *N*	Suburban Percent	Urban *N*	Urban Percent	Combined *N*	Combined Percent
Old						
Routine x-ray	10	0	9	0	19	0
IVP	24	29	7	57	31	35
Upper GI	15	13	20	30	35	23
Barium enema	25	4	28	18	53	11
New						
Specials	27	85	11	27	38	68
CT scan	50	40	42	64	92	51
Ultrasound	31	77	16	100	47	85

Analysis of Variance of Interpretive Discussions

Source	d.f.	Sum of squares	Mean square	*F*
Hospital	1	.338	.338	1.72
New vs. old	1	10.339	10.339	52.59•
Interaction	1	.074	.074	.377
Residuals	312	61.340	.197	

• $p < .001$.

ologist stated them. The following excerpt from a transcript of an IVP at Urban illustrates such a conversation:

Tech: (*Enters the radiologist's office and hangs a film on a light box in front of the radiologist.*) That OK?

Rad: (*Looking at the table top in front of him*) Sure.

Tech: You didn't even look!

Rad: (*Laughs*) I didn't even look. (*Examines the film.*) Oooop! There's a rock! [Gallstone.]

Tech: Oh yeah, where?

Rad: (*Points to a white speck along the side of the spine at the upper pole of the left kidney.*)

The radiologist's interpretive comment was made in passing, without elaboration. When telling, radiologists made no attempt to engage the technologist's attention or to ensure that the tech retained the information. Although radiologists casually noted findings for CT techs, specials techs, and sonographers, they also actively strove to teach the techs to recognize pathology.

When "teaching," as opposed to telling, radiologists went beyond simply naming and noting, to explain diagnostic signs and their implications. Moreover, when teaching, radiologists made explicit their intention that the technologist learn. For instance, during the first several weeks of Urban's body-scanner operation, the experienced radiologists repeatedly told the CT techs that they would have to learn to recognize anatomy and pathology in the scans. Similarly, on several occasions I observed Suburban's young radiologist drawing anatomical diagrams to teach inexperienced CT techs to recognize the landmarks of cross-sectional anatomy. Teaching was also common in specials and ultrasound. As an example, consider the following transcript of a radiologist at Suburban teaching a new sonographer to perform a gall bladder study:

Rad: (*Standing beside the sonographer and pointing to the screen*) Ok, that's just fluid. Have to go transverse to get the long axis . . . it isn't very well centered. [*The sonographer moves the transducer.*] . . . Ok, that's bladder. Now we come down to . . . Look at this portal vessel. . . .

Tech: (*To patient*) Breathe. Now, take in another deep breath and hold it please. . . .

Rad: Try to get to the long axis here (*points*). What we like to do on the gall bladder . . . you have to come all the way through and make sure that you get back to where you've done [e.g., you rotate the probe]. Now you have to do the liver, plus the kidney. Ok, you want to make sure that this area here is the same. Run straight over and view a stretch of the diaphragm and then you walk around the surface going the other way. Then you start getting your duct down here again. . . . You're just sliding toward the midline.

(*To patient*) Ok, breathe when you have to.

(*To sonographer*) Your liver texture. Make sure that you go over it. This is a tricky area. This is a big fooler. You get this fallout down here. Ok, you've got to be very careful that you're dealing with just fallout and not a lesion. But you can practice. Whenever you see it, make sure when you get that fallout, that it is fallout. . . . Make sure that you can see the echoes are there [because if not, the image would suggest a lesion].

The radiologist's talk tacks back and forth between how to move the transducer and the meaning of the images on the video monitor. At the very end he speaks specifically of signs and how to discriminate pathology ("lesions") from artifact ("fallout"). Interactions such as this were unthinkable in the main department, where it was not important if techs understood what they saw.

When technologists were already familiar with the modality's images, a third form of interaction could occur, the mutual discussion of an image. Mutual discussions were spontaneous and unself-conscious conversations that took place either when technologists showed films to radiologists or when both watched images for the first time on a video monitor. In mutual discussions, radiologists and technologists were equally likely to ask questions and offer opinions. Thus, the structure of a mutual discussion was similar to what might occur between radiologists. The tacit presumption of such an interchange was roughly situational parity, a presumption that never guided interactions in the main department. The structure and tenor of a mutual discussion is illustrated by the following excerpt from a conversation between a radiologist and two specials techs at Suburban who were reviewing runs from a carotid digital subtraction:

Rad: Fred, can you run one of those to see if there's any vertebral arteries? Ah, I thought she did have vertebral arteries.

Tech1: Yeah, she had the left. It overlaps the . . . ahhh . . .

Rad: The left. And how about the right? I see the left.

Tech1: The right, I didn't see it. Let me see if I can see it on this first run. (*He now has the computer bring images from the first run to the video monitor.*)

Rad: Right vertebral. (*The images begin to appear.*) Shit, I don't believe it. She has all kinds of problems.

Tech1: She had peripheral disease too.

Rad: That's the first run?

Tech1: Yeah. I don't think she has a vertebral on that side, does she?

Rad: No.

Tech1: What's this?

Rad: No, that's a . . . I'd say a pocket. Keep going there.

Regardless of whether interpretive conversations between radiologists and technologists occurred as instances of telling, teaching, or mutual discussion, the flow of the interaction was such that the radiologist's expertise was never in doubt. For instance, in the previous interchange the radiologist showed no lack of understanding. Thus, even mutual discussions posed no direct challenge to the radiologist's status, they merely indicated how far the technologist's role had expanded. However, in some situations, role inversions occurred. In these cases, radiologists evidenced less knowledge of the images than did the technologist. Such interactions, which never involved the youngest radiologists and which took place most frequently in ultrasound or CT, may be labeled instances of "reverse teaching," since their unfolding inverted the usual roles of a teaching conversation. In reverse teaching, interpretive questions came from the radiologist and opinions or statements from the technologist. The following excerpts illustrate instances of reverse teaching. The first occurred in Suburban's CT scanner area, the second in Suburban's ultrasound department:

Rad: Now is that the posterior fossa? It's too noisy isn't it?

Tech: A little.

Rad: This was a bleed without trauma, wasn't it? This was a ruptured aneurism?

Tech: Yes.

Rad: How old?

Tech: Twenty-four hours.

Rad: Now is that blood in the temporal lobe?

Tech: Yes I think so. (*Tech measures the density of the area.*)

Rad: Fresh blood is about what?

Tech: About 35–40 [*Hounsfield numbers*].

Rad: This is the pituitary?

Tech: Yes.

****

Sono: (*Referring to the uterus on the monitor*) It's 4 cm in the longitudinal and 3 cm in transverse.

Rad: This is transverse, where you've got her?

Sono: Yes, sir.

Rad: I don't see any ovaries, do you?

Sono: I don't either.

Rad: The ovaries probably atrophied.

Sono: Probably, I haven't seen anything.

Rad: Uterus is normal size, isn't it?

Sono: Yes, for her age. There's the uterus there. Now, moving to the right.

Rad: So, nothing to explain the asymmetry?

Sono: Right.

Rad: Ok.

Reverse teaching could occur only when a radiologist thought a technologist knew as much, or more, than he. Because it blatantly challenged the core of radiology's professional dominance, reverse teaching was a delicate matter. CT techs at Suburban claimed that they felt uncomfortable "doing the radiologist's job," that they were not trained to give diagnostic information, and that they ought not be put in such a position. Sonographers, who had more experience with the phenomenon, had developed a philosophy and a set of tactics for handling the touchy encounters. They were largely managed by the sonographer's assuming a deferential manner that was guided by the credo "We recognize pathology, we don't diagnose it."

Opportunities to see mistakes. X-ray techs had few opportunities to observe radiologists make mistakes because of the routine nature of their work, the brevity of their encounters with radiologists, and the hierarchical distribution of expertise. To be sure, x-ray techs frequently faulted radiologists on moral grounds when, for instance, they refused to cancel a barium enema on a senile patient or failed to introduce themselves to a patient. However, it was rare for an x-ray tech to catch a radiologist in a technical or interpretive blunder. Not only did the techs have insufficient knowledge for determining when a radiologist had made a faulty interpretation, but the radiologists were well versed in the use of radiographic and fluoroscopic equipment.

CT techs, specials techs, and sonographers were better positioned to observe a radiologist's failings because they had greater knowledge of the technology and because they were also more familiar with diagnostic signs. For instance, during the first several months of scanner operations at Suburban, inexperienced radiologists occasionally ordered contrast injections for patients whose suspected malady would have been obscured by the iodine. In these instances, the more experienced technologists explained why the course of action would be ill-advised and suggested an alternate protocol. But even the more inexperienced CT techs were better situated than their brethren in the main department to observe radiologists making technical and diagnostic errors. When CT-inexperienced radiologists first began to work the body scanners, they were frequently accompanied by a more experienced colleague. While standing behind the technologists at the console, the radiologists openly debated anatomy and pathology. During these conversations, an inexperienced radiologist often named structures and maladies with great excitement only to be corrected by his colleague. A novice's order to a technologist about how to proceed with a scan was similarly open to review and countermand. Thus, within a few months, CT techs at both hospitals developed articulate notions about which radiologists did and did not "know what they were doing."

Yet of all the technologists in a radiology department, it was the specials techs who were privy to the radiologists' most serious blunders. While CT techs and sonographers could observe radiologists miscalculating the technology or misinterpreting films, only specials techs regularly observed mishaps that endangered patients. If a radiologist suffered a lapse of skill while positioning a catheter or biopsy needle, he could trigger a stroke, a pneumothorax, or, worse, a patient's death. Even the most skilled physician or surgeon can make an occasional mistake and, as might be expected, the radiologists at Suburban and Urban were no different.

Opportunities to observe radiologists in trouble significantly shaped relationships between radiologists and technologists who operated the new modalities. The technologists' support was necessary if the radiologists were to define mishaps successfully as events that could happen to anyone. Should the techs choose to offer another account, they could seriously damage a radiologist's reputation. So adept were the techs at providing obligatory support that they were often the first to suggest a cause for a mistake. For instance, while watching special procedures, I once observed a radiologist transfix a patient's stomach, which he had mistakenly identified as a kidney. The radiologist immediately became visibly depressed and claimed several times that there was no excuse for his mistake. Within the space of five minutes, the specials techs had discovered four distinct rationales for why the mistake was excusable. Under such circumstances, it also became much easier for radiologists to discount a technologist's mistakes.

General tenor of relations. The tenor of relationships among radiologists and technologists also differed by technology. Because the distribution of technical and interpretive knowledge in the main department was stratified, encounters between radiologists and technologists fostered situations in which radiologists issued orders and offered critiques but rarely sought opinions. While most x-ray techs readily admitted that radiologists were knowledgeable individuals, they also claimed that the radiologists "thought they were God."

X-ray techs held that it was useless to try to "tell a radiologist anything." Consequently, x-ray techs felt that they had little choice but to do what the radiologists said and refrain from giving advice, even when they were certain a radiologist was wrong. Sentiments of powerlessness and passivity at times reached absurd proportions, particularly at Urban, where x-ray techs submitted to radiologists far more readily than at Suburban. For example, during one morning's fluoroscopy at Urban, a radiologist had difficulty deciphering the following comment written on a patient's requisition: "No B.M. in 20 days." After noting that he couldn't make sense of the sentence, the radiologist went to his office to call the referring physician. In the radiologist's absence, I asked the tech if she didn't think the note meant that the patient had had no bowel movement in three weeks. The tech replied, "Of course that's what it says, but who am I to say." Such was the technologist's version of "working to rule."

By failing to speak their minds and by obeying the radiologists' dictates without question, the x-ray techs reaffirmed their own lack of importance. When events seemed to vindicate the techs' better judgment, they took the incident as further proof that "you couldn't tell a radiologist anything." At the same time, by failing to take independent action and by not intervening when they thought intervention was necessary, the x-ray techs created the impression among radiologists that as a group they were less skilled and responsible than they should be. The perception, in turn, reinforced the radiologists' willingness to issue orders and their obliviousness to the x-ray techs' concerns. Thus, the main departments' interaction orders fed on themselves.

The tenor of relations in the new modalities was different. While the techs occasionally felt anger toward radiologists, the interaction order was not structured to perpetuate hostility. The novelty and excitement that surrounded the new technologies, the more equal distribution of technical and interpretive expertise, and the potential for technologists to observe radiologists making mistakes reduced status distinctions. Not only did radiologists ask technologists for opinions, but CT techs, specials techs, and sonographers all felt that they could affect the circumstances of their work.

At both hospitals, technologists sensed the difference. CT techs, specials techs, and sonographers at Urban routinely noted that whereas the x-ray techs were treated like "employees," they, themselves, were treated as members of a "team." Even the radiologists were aware of the different atmospheres. On the way to lunch one day, two of Urban's radiologists were speaking of the differences between x-ray techs and the CT techs. One radiologist said to the other, "I see what you mean by the joys of industrial peace." The radiologists concluded that they did not feel nearly as embattled when they were assigned to the newer modalities.

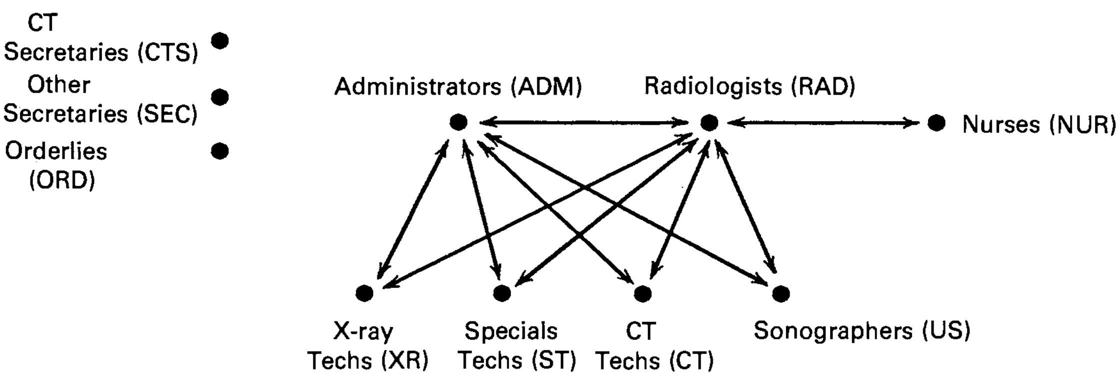
IMPLICATIONS FOR ORGANIZATIONAL STRUCTURE

The foregoing pattern of role relations among radiologists and technologists suggests a technologically induced split in the social organization of the two departments. Older radiologists claimed that twenty years ago both departments had been unified organizations in which all members of an occupational group played equivalent roles. The older technologists made similar claims. Over time, however, the new technologies had apparently generated a set of distinctions that divided the departments into two social worlds. On one hand, there were the main departments, increasingly staffed by older radiologists, populated by technologists with comparatively less discretion and knowledge, and characterized by bureaucratic practices conducive to conflict and tense work relations. On the other hand, there were the new modalities where younger radiologists dominated, where technologists had greater knowledge and discretion, and where relations between radiologists and technologists were more collegial and cooperative. If these changes had, in turn, transformed the structure of the two departments, then one would expect their social networks to differ from the institutionally prescribed ideal.

Figure 2 displays how both networks should have appeared had members responded to the sociometric questionnaire in light of each department's official job descriptions. Note that x-ray techs, specials techs, CT techs, and sonographers are portrayed as having identically patterned ties: each group communicates with administrators and radiologists who reciprocate the communication. In the language of network analysis, all technologists are "structurally equivalent" (Lorrain and White, 1971), that is, each group is tied in an identical manner to the same actors. Note that, ideally, administrators and radiologists should also communicate with each other, while nurses are bound only to the radiologists, since their sole charge was to assist radiologists in special procedures and medical emergencies. Orderlies and secretaries are

Figure 2. The institutionally legitimate (ideal) network of role relations in a radiology department.

A. Graphic Representation



B. Matrix Representation

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	0	1	1	1	1	1	1	0	0	0
ST	1	0	0	0	0	1	0	0	0	0
CT	1	0	0	0	0	1	0	0	0	0
US	1	0	0	0	0	1	0	0	0	0
XR	1	0	0	0	0	1	0	0	0	0
ADM	1	1	1	1	1	0	0	0	0	0
NUR	1	0	0	0	0	0	0	0	0	0
CTS	0	0	0	0	0	0	0	0	0	0
SEC	0	0	0	0	0	0	0	0	0	0
ORD	0	0	0	0	0	0	0	0	0	0

shown as isolates because their work gave them little reason to be involved in the discussions on which the sociometric study focused. In short, the general configuration of the ideal network inscribes the dual hierarchical structure characteristic of most health care institutions.

To determine if and how the actual structure of the two departments departed from the institutional ideal, each department's sociometric data were analyzed separately. Five adjacency matrices were constructed from members' responses to each of the five relations covered by the questionnaire: discussions regarding (1) the setting of techniques and the positioning of patients, (2) machine problems, (3) problems with patients, (4) the meaning of films, and (5) departmental complaints. An adjacency matrix is an N by N matrix in which N equals the number of persons in the network, where the Nth row and Nth column identify the same individual, and where the cells, a_{ij}, record whether person i reported discussing the topic with person j.

The rows and columns of the five adjacency matrices were then permuted so that individuals filling the same occupational role were arrayed contiguously: the raw adjacency matrices were blocked by occupational roles rather than by clustering algorithms, such as CONCOR (Breiger, Boorman, and Arabie, 1975) or STRUCTURE (Burt, 1986). Although previous researchers have rarely blocked raw adjacency matrices using a priori groupings, such an approach seems particularly well suited for answering questions regarding relations among the social groups into which members of a culture classify each other.

Next, each permuted adjacency matrix was transformed into a D by D density matrix where D denotes the number of occupational groups in the radiology department. The cells of these density matrices, d_{ij}, recorded for each relation the proportion of possible ties between the members of occupational groups I and J that were actually reported to exist.[9] Any cell in a density matrix could, therefore, range in value from 0 to 1. The five density matrices that were constructed from each hospital's data are contained in the Appendix.

The density matrices for each department were then averaged to yield a mean density matrix whose cells record the average density of relations between the members of two occupational groups. Figure 3 reports the mean density matrix for each hospital. Cell values range from 0 to 1, and the greater the value, the stronger the relationship between the members of two groups. Since stronger ties indicate more salient relations and since salient relations are the object of scrutiny, a tie was deemed to exist when, on average, the members of an occupation reported that more than a fifth of its possible ties with another group actually occurred. For example, a tie between group I and group J was counted only when the value of a cell (d_{ij}) in the mean density matrix was greater than .20. Given the relatively small value of most of the cells in the mean density matrices, this cutoff was preferred over the mean value as a more conservative estimate of a strong tie's existence. The image matrices in Figure 3 were constructed by setting each cell of the corresponding mean density matrix to 1 whenever $d_{ij} \geqq .20$. Otherwise the cell was set to 0. To aid interpretation, Figure 3 also depicts the structure of each image matrix as a directed graph. Circles in the graphs represent occupational groups, and arrows run from group I to group J if, and only if, the corresponding cell of the image matrix (i_{ij}) is equal to 1.

The Quadratic Assignment Procedure was used to determine whether the observed networks differed significantly from the institutional ideal depicted in Figure 2.[10] QAP is a statistical technique for assessing whether two matrices have the same structure (Hubert and Schultz, 1976; Hubert and Golledge, 1981; Baker and Hubert, 1981). The technique entails calculating the distribution of a measure of association, in this case, the Pearson product moment correlation coefficient. The distribution is generated by repeatedly holding the structure of one matrix constant, randomly permuting the rows and columns of the second, and then calculating the correlation between the fixed and the permuted matrix. The magnitude of the correlation between the two original matrices is then compared to the reference distribution to determine whether the observed correlation is greater than one would expect by chance. Hubert and Schultz (1976) demonstrated an analytic solution that closely approximates the reference distribution and showed that the statistical significance of the correlation can be assessed using Mantel's Z. The analytic

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The density of relations between two groups, I and J, can be expressed as: $d_{ij} = N/(n_1 \times n_2)$, where N is the number of reported ties, n_1 is the number of members in group I, and n_2 is the number of members in group J. Intragroup densities, d_{ii}, are found on the main diagonal of a density matrix and are calculated by the formula $d_{ii} = N/n_1(n_1 - 1)$.

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The QAP and CONCOR procedures I used can be found in Version 3 of the software package UCINET. UCINET can be obtained by writing Professor Linton Freeman, Group in Mathematical Sociology, School of Social Sciences, University of California, Irvine, Irvine, CA 92717.

Figure 3. Reported networks of work relations at Suburban and Urban.

A. Mean Density

Suburban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD	Group *N*
RAD	.30	.26	.14	.32	.04	.23	.03	0	.02	0	6
ST	.14	.93	0	.15	.01	.06	0	0	0	.02	3
CT	.22	0	.71	0	.01	.07	0	.26	.01	0	5
US	.30	.26	.01	.80	.13	.10	0	0	0	.01	3
XR	.10	.19	.07	.15	.26	.23	.01	.01	.06	.03	16
ADM	.22	.10	.08	.05	.09	.40	.03	.03	.09	.01	4
NUR	.18	.50	0	0	0	.08	.05	0	0	0	2
CTS	.20	0	.42	0	0	.02	0	.50	.04	0	2
SEC	.01	.03	0	.01	0	.11	0	0	.10	.01	8
ORD	.04	.19	.03	.05	.02	.15	0	0	.01	.18	5
											54

Urban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD	Group *N*
RAD	.50	.43	.35	.28	.08	.22	.34	.03	.01	0	6
ST	.61	1	.80	.33	.05	.33	.63	.03	.01	.04	4
CT	.45	.75	.86	.16	.01	.12	.46	.08	.01	.01	5
US	.57	.07	.08	.90	.07	.07	.15	0	0	0	2
XR	.06	.04	0	.05	.20	.31	.14	0	.01	0	14
ADM	.08	.07	0	0	.07	.22	.03	0	.02	0	3
NUR	.63	.53	.34	.15	.07	.07	.30	0	.01	.01	2
CTS	.07	.13	.02	0	0	0	.05	.50	.02	0	2
SEC	.03	0	0	0	.01	.08	.04	.02	.03	0	19
ORD	0	.03	.03	.03	.01	.04	.04	0	.02	.09	7
											64

B. Image Matrices

Suburban:

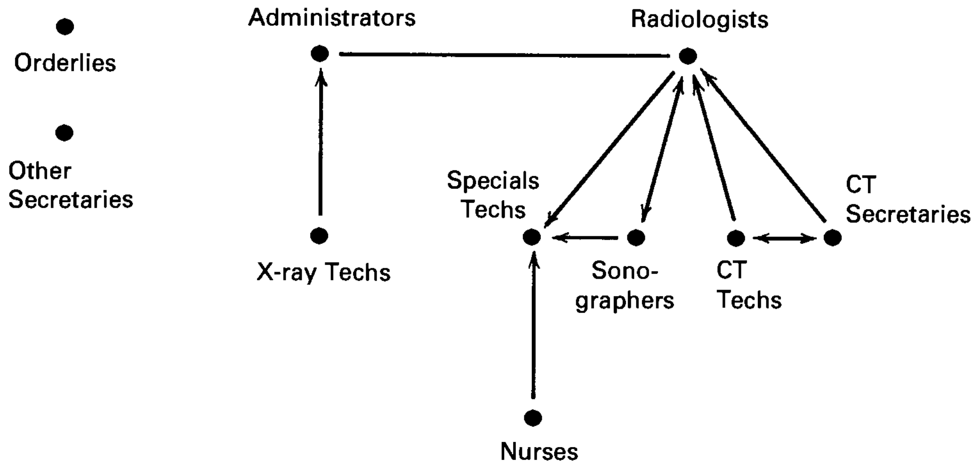
	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	1	1	0	1	0	1	0	0	0	0
ST	0	1	0	0	0	0	0	0	0	0
CT	1	0	1	0	0	0	0	1	0	0
US	1	1	0	1	0	0	0	0	0	0
XR	0	0	0	0	1	1	0	0	0	0
ADM	1	0	0	0	0	1	0	0	0	0
NUR	0	1	0	0	0	0	0	0	0	0
CTS	1	0	1	0	0	0	0	1	0	0
SEC	0	0	0	0	0	0	0	0	0	0
ORD	0	0	0	0	0	0	0	0	0	0

Urban:

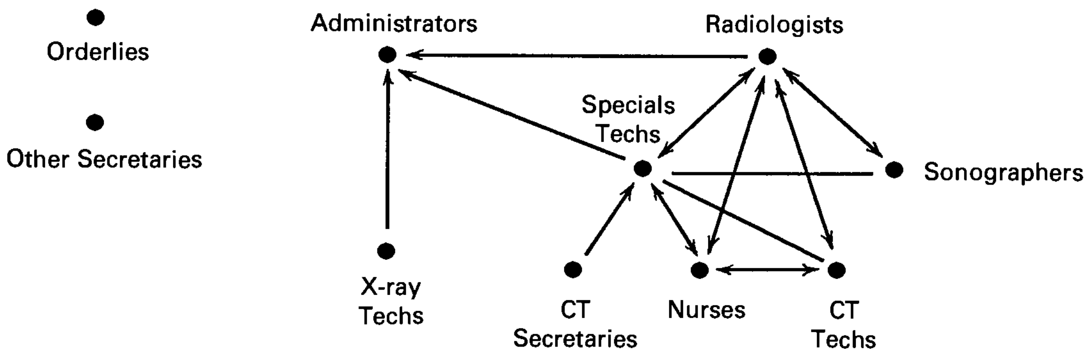
	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	1	1	1	1	0	1	1	0	0	0
ST	1	1	1	1	0	1	1	0	0	0
CT	1	1	1	0	0	0	1	0	0	0
US	1	0	0	1	0	0	0	0	0	0
XR	0	0	0	0	1	1	0	0	0	0
ADM	0	0	0	0	0	1	0	0	0	0
NUR	1	1	1	0	0	0	1	0	0	0
CTS	0	0	0	0	0	0	0	1	0	0
SEC	0	0	0	0	0	0	0	0	0	0
ORD	0	0	0	0	0	0	0	0	0	0

C. Digraphs:

Suburban



Urban



solution was used to determine whether the structure of the two observed networks differed significantly from the institutional ideal.

To execute the QAP analysis, rows and columns for secretaries and orderlies were deleted from the image matrices for both hospitals as well as from the image matrix for the institutional ideal. Secretaries and orderlies were deleted because the research did not focus on their roles and because the sociometric questions were irrelevant for their jobs. After deleting the rows and columns for secretaries and orderlies, each of the image matrices in Figure 3 were QAPed against the matrix in Figure 2. The results indicated that the correlations between Suburban's (r = .36; z = 1.23; p = .22) and Urban's (r = .31; z = .31; p = .75) networks and the institutional ideal were not significant. Thus, with regard to role relations among radiologists, technologists, and administrators, the observed structures of both departments apparently departed from the institutional ideal. To understand the nature of the departure one needs to examine the network structure directly.

A visual comparison of the graphs in Figure 3 and Figure 2 indicates that the structures of both departments were considerably different from the ideal network. At Suburban, specials techs, sonographers, and CT techs were linked directly to radiologists but not to administrators. The pattern was reversed for the x-ray techs. As expected, the radiologists were tied to administrators. Also as expected, the orderlies and the main department's secretaries formed isolated groups. The CT secretaries, however, had a pattern of ties identical to that of the CT techs.

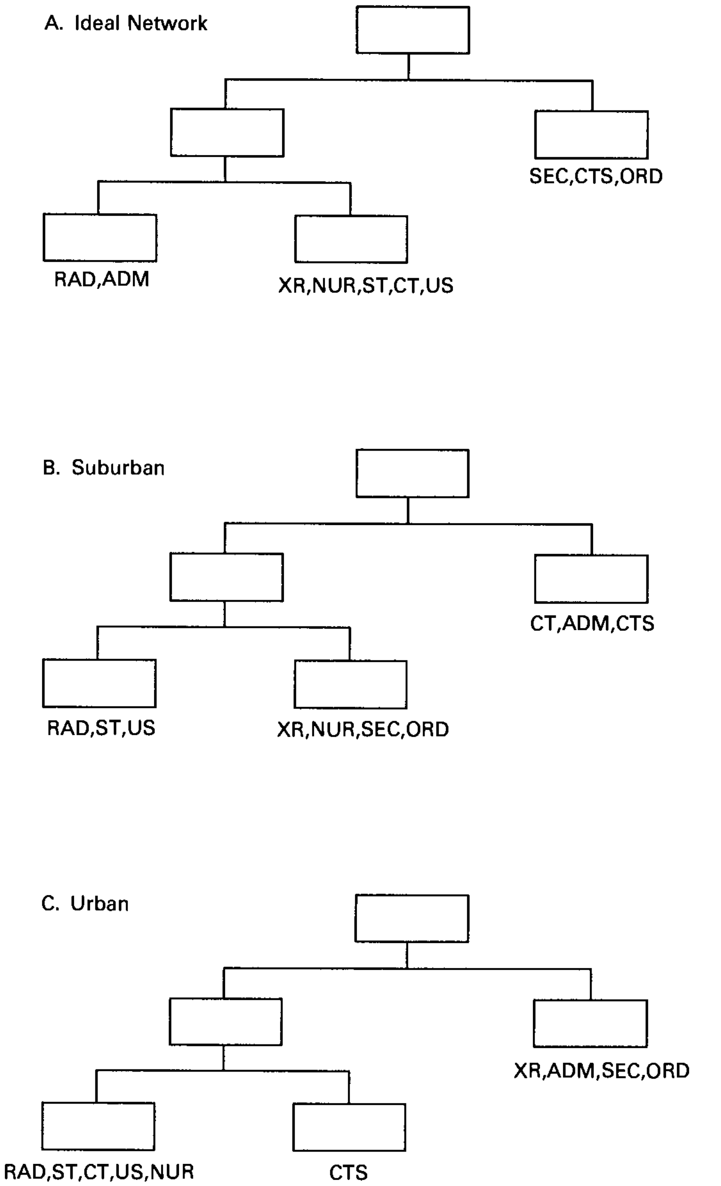
A similar but slightly more complex structure characterized Urban's department. As at Suburban, the x-ray techs were linked only to the administrators. Moreover, all techs who worked with the new modalities were linked directly to radiologists and, with the exception of the specials techs, none were tied to administrators. However, unlike Suburban's personnel, the groups who operated Urban's new modalities had established stronger intergroup relations. Were it not for the absence of four ties, Urban's radiologists, specials techs, nurses, CT techs, and sonographers would have formed a completely connected subgraph, the classic definition of a sociometric clique (Harary, Norman, and Cartwright, 1965).

The graphs in Figure 3 strongly suggest that the role relations surrounding the different technologies induced a structural bifurcation of the two departments. In comparison to the balanced institutional ideal portrayed in Figure 2, the networks in Figure 3 show the existence of two distinct substructures, one associated with the main department, the other with the new modalities. In fact, were it not for the relationships between the radiologists and the administrators (and, at Urban, the relation between administrators and specials techs), both departments would have consisted of two separate social systems (or subgraphs), one under the direction of the administration and the other under the aegis of the radiologists. While such a structure is consistent with the differences in roles and role relations previously discussed, it clearly violates radiology's institutionalized system of authority and the traditional dual hierarchy of a radiology department.

The nature of the violation is made more explicit when the five relations are blockmodeled. The five density matrices for each hospital, shown in the Appendix, were submitted to CONCOR, an algorithm designed to cluster the nodes of a network into structurally equivalent groups (Breiger, Boorman, and Arabie, 1975; White, Boorman, and Breiger, 1976). CONCOR begins by correlating a set of stacked adjacency matrices. The resulting correlation matrix is then submitted to an iterative correlation analysis until the entire set of actors is reduced to two groups. Members of each group have a pattern of ties that is maximally similar to each other and maximally different from members of the other group. By then subjecting the original data for members of each subgroup to the same analysis, CONCOR splits off increasingly smaller subsets of actors, whose ties become increasingly homogeneous. Hence, CONCOR forms a hierarchy of increasingly similar clusters via a divisive rather than an agglomerative technique. The image matrix for the ideal network in Figure 2 was also submitted to CONCOR.

The dendograms in Figure 4 display the results of successive CONCOR blockings of the ideal network, Suburban's data, and Urban's data. By reading down each tree, one can determine how, in each case, CONCOR split the set of occupations into increasingly more structurally equivalent groups. The three-block partitioning of the ideal network in Figure 4 implies the existence of three structurally equivalent sets: (1)

Figure 4. Dendograms of CONCOR blockings of the ideal network and the density matrices of five work relations at Suburban and Urban.



Key: RAD = Radiologists
ST = Specials technologists
CT = CT technologists
US = Sonographers
XR = X-ray technologists
ADM = Administrators
NUR = Nurses
CTS = CT secretaries
SEC = Other secretaries and clerks
ORD = Orderlies

radiologists and administrators, (2) nurses and all technologists, and (3) orderlies, secretaries, and CT secretaries. The analysis of the data from the two hospitals departed dramatically from the ideal partitioning. The three-block partitioning of Suburban's data (Figure 4, B) indicates that radiologists, specials techs, and sonographers should be considered structurally equivalent. CT techs, administrators, and CT secretaries formed a second block. Finally, the x-ray techs were grouped with the nurses as well as with the department's traditionally lower-status occupations, orderlies and secretaries. The three-block partition for Urban's data (Figure 4, C) was even more telling. CT techs, sonographers, and specials techs were shown to be structurally equivalent to each other, to radiologists, and to nurses. The CT secretaries formed their own block, while x-ray techs and administrators were grouped with orderlies and the main department's secretaries.

In general, both blockmodels show that the technologists who operated the new modalities were not only structurally equivalent to each other but that their position in the departments was more similar to that of a radiologist than to that of an x-ray tech. In turn, the x-ray techs were structurally more akin to orderlies and secretaries than to their counterparts in the new modalities. These patterns were stronger at Urban, where the new modalities were physically distant from the main department but in close proximity to each other. At Suburban, the CT personnel's similarity to the administrators can be explained by two facts: (1) the CT area was physically removed from all other areas of the department, and (2) one of the administrators was a former CT tech, which led the CT techs to deal more closely with that administrator. Nevertheless, the data from both hospitals indicate that the two departments were not only split into two tenuously connected social systems along technological lines but that membership in the social systems surrounding the newer technologies carried higher status and prestige.

CONCLUSIONS

At minimum, the foregoing analysis of events in two radiology departments shows that it is possible for sociologists of technology and work to link technical change more tightly to modifications in organizational structure by adopting a role-based approach. Like earlier traditions, such an analysis grounds technically occasioned social change in the nonrelational aspects of work roles. However, unlike previous traditions, the role-based approach explicitly articulates how skills, tasks, and activities influence role relations and how role relations, in turn, affect an organization's and occupation's structure.

Aside from allowing analysts to explicate linkages between action and structure, a role-based approach to the study of technology and work may also bring other benefits. Specifically, role-based studies may help clarify the long-standing debate over the relative importance of material and social forces in the technological transformation of work. Sociologists of automation and contingency theorists have generally treated technology as a material cause, while deskilling theorists and sociotechnical systems theorists have tended to view technical change as socially determined. The two ontologies have led to accusations and counteraccusations but to little substantive advance (Adler and Borys, 1988). A role-based approach represents a hybrid perspective that may be more veridical.

As in the case of new imaging modalities, technically driven social change is likely to be rooted in a technology's material constraints. However, if any technology is to have significant implications for patterns of social organization, its material constraints must be transformed into social forces. From the perspective of role theory, such a transformation occurs at precisely the point at which materially induced changes in the nonrelational aspects of roles spill over into the corresponding system of role relations. Furthermore, since the parameters of role relations are negotiated and renegotiated in the course of ongoing interaction, it is plausible that the same material conditions could give rise to different social systems. The ramifications of any specific instance of technical change are, therefore, likely to be the joint product of material and social forces whose interaction must become an explicit focus of study.

Finally, theorists must begin to wrestle with the difference between the short- and long-run implications of technical change. Although the new imaging devices discussed in this paper challenged radiology's traditional division of labor and its system of professional dominance, the challenge occurred largely at the level of ongoing interaction. It is critical to realize that the devices did not overthrow the radiologists' professional dominance, nor did they completely level distinctions between technologists and radiologists. One might argue that, with time, radiology's roles and structures will reassert themselves. Whether or not they will can only be answered at a much later date. At the time the study took place, however, ultrasound and special procedures had existed in both hospitals for nearly a decade, hence, the changes described in this paper seemed relatively well codified. A more adequate argument might be to claim that radiology's institutions remain but that their contours have been substantially modified in the process of absorbing potential challenges. Perhaps this is precisely what Hughes (1936) had in mind when he claimed, rather mysteriously, that institutions evidence a permanence of a relative sort.

REFERENCES

Adler, Paul S., and Bryan Borys
1988 "Bringing technology back in: Theoretical and empirical issues in the relationship between technology and work in the machining case." Unpublished manuscript, Department of Industrial Engineering and Engineering Management, Stanford University.

Baker, Frank B., and Lawrence J. Hubert
1981 "The analysis of social interaction data." Sociological Methods and Research, 9: 339–361.

Banta, David J., and Barbara J. McNeil
1978 "Evaluation of the CAT scanner and other diagnostic technologies." Health Care Management Review, 3: 7–19.

Barley, Stephen R.
1986 "Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments." Administrative Science Quarterly, 31: 78–108.
1988 "The social construction of a machine: Ritual, superstition, magical thinking and other pragmatic responses to running a CT scanner." In M. Lock and D. Gordon (eds.), Knowledge and Practice in Medicine: Social, Cultural, and Historical Approaches: 497–540. Boston: Kluwer Academic Publishers.

Berger, Peter L., and Thomas Luckmann
1967 The Social Construction of Reality. New York: Doubleday.

Blau, Peter M., Cecilia McHugh Falbe, William McKinley, and Phelps K. Tracy
1976 "Technology and organization in manufacturing." Administrative Science Quarterly, 21: 20–40.

Blauner, Robert
1964 Alienation and Freedom. Chicago: University of Chicago Press.

Boissevain, J., and J. C. Mitchell
1973 Network Analysis: Studies in Human Interaction. The Hague: Mouton.

Braverman, Harry
1974 Labor and Monopoly Capitalism: The Degradation of Work in the Twentieth Century. New York: Monthly Review Press.

Breiger, Ronald L., Scott A. Boorman, and Phipps Arabie
1975 "An algorithm for clustering relational data with applications to social network analysis and comparison with multidimensional scaling." Journal of Mathematical Psychology, 12: 328–383.

Brown, Carol A.
1973 "The division of laborers: Allied health professions." International Journal of Health Services, 3: 434–444.

Burt, Ron
1980 "Models of network structure." Annual Review of Sociology, 6: 79–141.
1982 Toward a Structural Theory of Action: Network Models of Stratification, Perception and Action. New York: Academic Press.
1986 "Structure, Version 3.0." Technical Report #TR2, Research Program in Structural Analysis, Center for the Social Sciences, Columbia University.

Child, John
1972 "Organizational structure, environment, and performance: The role of strategic choice." Sociology, 6: 1–22.

Chinoy, Eli
1955 Automobile Workers and the American Dream. New York: Doubleday.

Collins, Randall
1981 "On the micro-foundations of macro-sociology." American Journal of Sociology, 86: 984–1014.

Comstock, Donald E., and W. Richard Scott
1977 "Technology and the structure of subunits: Distinguishing individual and workgroup effects." Administrative Science Quarterly, 22: 177–202.

Dewing, Stephen B.
1962 Modern Radiology in Historical Perspective. Springfield, IL: Charles C Thomas.

DiMaggio, Paul J., and Walter W. Powell
1983 "The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields." American Sociological Review, 48: 147–160.

Edwards, Richard C.
1979 Contested Terrain: The Transformation of the Workplace in the Twentieth Century. New York: Basic Books.

Emery, F. E., and Eric L. Trist
1965 "The causal texture of organizational environments." Human Relations, 18: 21–31.

Faunce, William A.
1965 "Automation and the division of labor." Social Problems, 13: 149–160.

Fensham, Peter J., and Douglas Hooper
1964 The Dynamics of a Changing Factory. London: Tavistock.

Fry, Louis W.
1982 "Technology-structure research: Three critical issues." Academy of Management Journal, 25: 532–552.

Galbraith, Jay R.
1977 Organization Design. Reading, MA: Addison-Wesley.

Gerwin, Donald
1981 "Relationships between structure and technology." In Paul Nystrom and William Starbuck (eds.), Handbook of Organization Design, 2: 3–38. Cambridge: Cambridge University Press.

Giddens, Anthony
1976 New Rules of Sociological Method. London: Hutchinson.
1984 The Constitution of Society. Berkeley, CA: University of California Press.

Glenn, Evelyn Nakano, and Roslyn L. Feldberg
1979 "Proletarianizing clerical work: Technology and organizational control in the office." In Andrew Zimbalist (ed.), Case Studies in the Labor Process: 51–72. New York: Monthly Review Press.

Goffman, Erving
1983 "The interaction order." American Sociological Review, 48: 1–17.

Greenbaum, Joan M.
1979 In the Name of Efficiency. Philadelphia: Temple University Press.

Hage, Per, and Frank Harary
1983 Structural Models in Anthropology. Cambridge: Cambridge University Press.

Harary, Frank, Robert Z. Norman, and Dorwin Cartwright
1965 Structural Models: An Introduction to the Theory of Directed Graphs. New York: Wiley.

Herbst, P. G.
1974 Socio-technical Design. London: Tavistock.

Hickson, David J., D. S. Pugh, and Diana C. Pheysey
1969 "Operations technology and organizational structure: An empirical reappraisal." Administrative Science Quarterly, 14: 378–397.

Hubert, Lawrence J., and Reginald G. Golledge
1981 "A heuristic method for the comparison of related structures." Journal of Mathematical Psychology, 23: 214–226.

Hubert, Lawrence J., and James Schultz
1976 "Quadratic Assignment as a general data analysis strategy." British Journal of Mathematical and Statistical Psychology, 29: 190–241.

Hughes, Everett C.
1936 "The ecological aspects of institutions." American Sociological Review, 1: 180–189.
1958 Men and Their Work. Glencoe: Free Press.

Hull, Frank M., Nathalie S. Friedman, and Theresa R. Rogers
1982 "The effect of technology on alienation from work." Work and Occupations, 9: 31–58.

Jones, Bryn
1982 "Destruction and redistribution of engineering skills: The case of numerical control." In Stephen Wood (ed.), The Degradation of Work: Skill, Deskilling and the Labour Process: 179–200. London: Hutchinson.

Kiesler, Sara, Jane Siegel, and Timothy W. McGuire
1984 "Social psychological aspects of computer-mediated communication." American Psychologist, 39: 1123–1134.

Khandwalla, Pradip N.
1974 "Mass output orientation of operations technology and organizational structure." Administrative Science Quarterly, 19: 74–97.

Krackhardt, David
1989 "Graph theoretical dimensions of the informal organization." Paper presented at the Sunbelt Conference on Network Analysis, Tampa, FL, February 1989.

Kraft, Philip
1979 "The industrialization of computer programming: From programming to software production." In Andrew Zimbalist (ed.), Case Studies in the Labor Process: 1–17. New York: Monthly Review Press.

Larkin, Gerald
1978 "Medical dominance and control: Radiographers in the division of labor." Sociological Review, 26: 843–858.

Lawrence, Paul R., and Jay W. Lorsch
1967 Organization and Environment: Managing Differentiation and Integration. Boston: Harvard University Press.

Lincoln, James R., Mitsuyo Hanada, and Kerry McBride
1986 "Organizational structures in Japanese and U.S. manufacturing." Administrative Science Quarterly, 31: 338–364.

Lorrain, F. P., and W. C. White
1971 "Structural equivalence of individuals in social networks." Journal of Mathematical Sociology, 1: 49–80.

Maines, David R.
1977 "Social organization and social structure in symbolic interactionist thought." Annual Review of Sociology, 3: 235–259.

Mann, Floyd C., and Richard L. Hoffman
1960 Automation and the Worker. New York: Henry Holt.

Mayhew, Bruce
1980a "Structuralism and individualism, part I: Shadowboxing in the dark." Social Forces, 59: 335–375.
1980b "Structuralism and individualism, part II: Ideological and other obfuscation." Social Forces, 59: 627–648.

McCall, George J., and J. L. Simmons
1978 Identities and Interactions: An Examination of Human Association in Everyday Life. New York: Free Press.

Meissner, Martin
1969 Technology and the Worker: Technical Demands and Social Processes in Industry. San Francisco: Chandler.

Meyer, John W., and Brian Rowan
1977 "Institutional organizations: Formal structure as myth and ceremony." American Journal of Sociology, 83: 340–363.

Miller, Eric J., and A. K. Rice
1967 Systems of Organization. London: Tavistock.

Mohr, Lawrence B.
1971 "Organizational technology and organizational structure." Administrative Science Quarterly, 16: 444–459.

Nadel, Siegfried F.
1957 A Theory of Social Structure. London: Cohen and West.

Noble, David F.
1984 Forces of Production: A Social History of Industrial Automation. New York: Knopf.

Office of Technology Assessment
1978 Policy Implications of the Computed Tomography (CT) Scanner. Washington, DC: Congress of the United States.
1981 Policy Implications of the Computed Tomography Scanner: An Update. Washington, DC: Congress of the United States.

Perrow, Charles
1967 "A framework for the comparative analysis of organizations." American Sociological Review, 32: 194–208.

Rice, A. K.
1958 Productivity and Social Organization: The Ahmedabad Experiment. London: Tavistock.

Schoonhoven, Claudia B.
1981 "Problems with contingency theory: Testing assumptions hidden within the language of contingency theory." Administrative Science Quarterly, 26: 349–377.

Scott, W. Richard
1990 "Technology and structure: An organizational level perspective." In P. S. Goodman and L. S. Sproull (eds.), Technology and Organizations. San Francisco: Jossey-Bass.

Shaiken, Harley
1984 Work Transformed: Automation and Labor in the Computer Age. New York: Holt, Rinehart, and Winston.

Shepard, Jon M.
1970 Automation and Alienation. Cambridge, MA: MIT Press.

Silverman, David
1971 The Theory of Organizations. New York: Basic Books.

Stanfield, Gary G.
1976 "Technology and organization structure as theoretical categories." Administrative Science Quarterly, 21: 489–493.

Stocking, Barbara, and Stuart L. Morrison
1978 The Image and the Reality. London: Oxford University Press.

Strauss, Anselm
1978 Negotiations. San Francisco: Jossey-Bass.

Strauss, Anselm, Leonard Schatzman, Rue Bucher, Danuta Ehrlich, and Melvin Sabshin
1964 Psychiatric Ideologies and Institutions. Glencoe, IL: Free Press.

Tenne, Ruth, and Bilha Mannheim
1977 "The effect of the level of production technology on workers' orientations and responses to the work situation." In Marie R. Haug and Jacques Dofney (eds.), Work and Technology: 61–79. Beverly Hills, CA: Sage.

Tolbert, Pamela S., and Lynne G. Zucker
1983 "Institutional sources of change in the formal structure of organizations: The diffusion of civil service reforms, 1880–1935." Administrative Science Quarterly, 23: 22–39.

Trist, Eric L., and K. W. Bamforth
1951 "Some social psychological consequences of the longwall method of coal getting." Human Relations, 4: 3–38.

Van Maanen, John
1979 "The self, the situation, and rules of interpersonal relations." In Warren Bennis et al. (eds.), Essays in Interpersonal Dynamics: 43–101. Homewood, IL: Dorsey.

Walker, Charles R., and Robert H. Guest
1952 The Man on the Assembly Line. Cambridge, MA: Harvard University Press.

White, Harrison C., Scott A. Boorman, and Ronald L. Breiger
1976 "Social structure from multiple networks, I: Blockmodels of roles and positions." American Journal of Sociology, 81: 730–779.

Wiener, H.
1979 Findings in CT: A Clinical and Economic Analysis of Computed Tomography. New York: Pfizer.

Winner, Langdon
1977 Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought. Cambridge, MA: MIT Press.

Winship, Christopher
1989 "Thoughts about roles and relations: An old document revisited." Social Networks, 10: 209–232.

Wood, Stephen
1982 The Degradation of Work: Skill, Deskilling, and the Labour Process. London: Hutchinson.

Woodward, Joan
1958 Management and Technology. London: HSMO.

Zuboff, Shoshanna
1988 In the Age of the Smart Machine: The Future of Work and Power. New York: Basic Books.

Zucker, Lynne G.
1977 "The role of institutionalization in cultural persistence." American Sociological Review, 42: 726–743.

APPENDIX: Density Matrices for Five Work Relations at Urban and Suburban

Key: RAD = Radiologists
ST = Specials technologists
CT = CT technologists
US = Sonographers
XR = X-ray technologists
ADM = Administrators
NUR = Nurses
CTS = CT secretaries
SEC = Other secretaries and clerks
ORD = Orderlies

A: With whom do you usually discuss setting a technique or positioning a patient?

Suburban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.03	.44	.27	.67	.16	.21	0	0	0	.03
ST	0	1	0	.11	0	0	0	0	0	0
CT	.27	0	.75	0	0	0	0	0	0	0
US	.44	.22	0	.67	.15	0	0	0	0	0
XR	.08	.21	.03	.15	.30	.19	0	0	.01	0
ADM	.04	0	0	0	.05	.17	0	0	0	0
NUR	0	.50	0	0	0	0	0	0	0	0
CTS	0	0	0	0	0	0	0	0	0	0
SEC	0	0	0	0	0	0	0	0	0	0
ORD	.03	.20	0	0	.04	.15	0	0	.03	.10

Urban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.33	.67	.67	.58	.30	.17	.42	0	.04	0
ST	.61	1	.87	.17	0	.22	.33	0	0	0
CT	.70	.67	.85	.10	.03	.07	.30	0	0	0
US	.67	0	0	1	0	0	0	0	0	0
XR	.07	.04	0	0	.20	.21	.07	0	.01	0
ADM	0	0	0	0	.10	0	0	0	0	0
NUR	.50	.50	.40	0	0	0	.50	0	0	.07
CTS	0	0	0	0	0	0	0	0	0	0
SEC	.04	0	0	0	0	.05	.05	0	0	0
ORD	0	.14	.11	0	.05	.10	.14	0	.05	.12

B: With whom do you usually discuss problems with a machine?

Suburban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.07	.22	.10	.22	0	.42	0	0	0	0
ST	0	1	0	.11	0	.17	0	0	0	0
CT	.17	0	.60	0	0	0	0	.10	0	0
US	.33	.22	0	.67	.02	.25	0	0	0	0
XR	.00	.17	.01	.06	.17	.34	0	0	0	.05
ADM	.08	.25	.25	0	.05	.42	0	.13	.03	0
NUR	0	0	0	0	0	.25	0	0	0	0
CTS	.17	0	.70	0	0	.12	0	1	.06	0
SEC	0	0	0	0	0	.16	0	0	.07	0
ORD	0	.08	0	0	0	.30	0	0	0	.30

Urban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.23	.44	.27	.17	0	.44	0	.08	0	0
ST	.78	1	.80	.33	.02	.55	.50	0	0	0
CT	.50	.87	1	0	0	.20	.20	.20	0	0
US	.25	0	0	1	0	.17	0	0	0	0
XR	0	.07	0	0	.14	.50	0	0	0	0
ADM	.11	.11	0	0	.02	.33	0	0	.02	0
NUR	.83	.83	.50	.25	.18	.33	0	0	0	0
CTS	0	0	0	0	0	0	0	.50	.03	0
SEC	.02	0	0	0	0	.11	0	0	0	0
ORD	0	0	0	0	0	.05	0	0	0	.12

C: With whom do you usually discuss the meaning of films or images?

Suburban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.60	.28	.17	.39	.04	.04	0	0	.02	0
ST	.44	.67	0	.11	.02	0	0	0	0	0
CT	.30	0	.65	0	0	.05	0	.20	0	0
US	.33	.11	0	1	.13	0	0	0	0	0
XR	.30	.29	.10	.19	.25	.20	0	0	.01	0
ADM	.42	.25	.15	.25	.28	.33	.13	0	.22	.05
NUR	.50	1	0	0	0	0	0	0	0	0
CTS	.42	0	.72	0	0	0	0	0	0	0
SEC	0	0	0	0	0	0	0	0	0	0
ORD	0	.20	.13	.07	.01	0	0	0	0	.05

Urban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.83	.72	.53	.58	.10	.11	.58	0	0	0
ST	.78	1	1	.50	.02	0	.67	0	0	0
CT	.53	.73	.80	.20	.01	.07	.60	0	0	0
US	.92	.17	.10	1	.04	0	0	0	0	0
XR	.14	.07	0	0	.18	.17	.07	0	0	0
ADM	.17	0	0	0	.21	.11	0	0	.02	0
NUR	.50	.17	.50	.25	0	0	0	0	0	0
CTS	.25	0	0	0	0	0	0	0	0	0
SEC	.05	0	0	0	.01	.07	.08	0	.01	0
ORD	0	0	0	0	0	0	0	0	0	0

D. With whom do you usually discuss problems with patients?

Suburban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.33	.17	.10	.17	0	.17	.17	0	.02	0
ST	.11	1	0	.11	0	0	0	0	0	0
CT	.23	0	.60	0	0	.05	0	.30	0	0
US	.33	.22	0	.67	.17	.25	0	0	0	0
XR	.05	.13	.01	.15	.23	.20	0	0	.04	.03
ADM	0	0	0	0	.06	.17	0	0	0	0
NUR	.33	.50	0	0	0	0	0	0	0	0
CTS	.25	0	.10	0	0	0	0	1	.06	0
SEC	0	0	0	0	0	0	0	0	0	0
ORD	0	.20	0	.07	.03	.10	0	0	.03	.20

Urban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.53	.22	.27	.08	0	.17	.60	.08	0	0
ST	.61	1	.67	.33	.07	.44	.83	0	0	.05
CT	.47	.73	.80	.20	0	.07	.60	.20	.01	.06
US	.92	0	.10	1	.14	0	.25	0	0	0
XR	.10	0	.01	.04	.27	.26	.25	0	.01	.01
ADM	.06	.11	0	0	0	.33	.17	0	.02	0
NUR	.92	.67	0	0	.07	0	.50	0	0	0
CTS	0	.33	0	0	0	0	0	1	0	0
SEC	.01	0	0	0	0	.07	0	.03	.04	.02
ORD	0	0	0	.07	.01	.05	0	0	.01	.12

E. With whom do you usually share your complaints about things that happen in the radiology department?

Suburban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.47	.17	.07	.17	.01	.29	0	0	.06	0
ST	.17	1	0	.33	.04	.11	0	0	0	.08
CT	.13	0	.95	0	.03	.25	0	.70	.03	0
US	.06	.55	.07	1	.17	0	0	0	0	.07
XR	.08	.15	.20	.21	.35	.22	.03	.03	.23	.09
ADM	.54	0	0	0	0	.92	0	0	.19	0
NUR	.08	.50	0	0	0	.13	.25	0	0	0
CTS	.17	0	.60	0	0	0	0	.50	.06	0
SEC	.06	.13	0	.04	.02	.37	0	0	.43	.03
ORD	.17	.27	0	.13	.03	.20	0	0	0	.25

Urban:

	RAD	ST	CT	US	XR	ADM	NUR	CTS	SEC	ORD
RAD	.60	.11	.03	0	0	.22	.08	0	0	0
ST	.28	1	.67	.33	.12	.44	.83	.17	.04	.14
CT	.07	.73	.85	.30	0	.20	.60	0	.03	0
US	.08	.17	.20	.50	.18	.17	.50	0	0	0
XR	0	0	.01	.18	.23	.40	.29	0	.02	0
ADM	.06	.11	0	0	0	.33	0	0	.02	0
NUR	.42	.50	.30	.25	.11	0	.50	0	.05	0
CTS	.08	.33	.10	0	0	0	.25	1	.05	0
SEC	.02	.02	.01	0	.02	.12	.05	.05	.11	0
ORD	0	0	.03	.07	.01	0	.07	0	.02	.10