Computers, Systems Theory, and the Making of a Wired Hospital: A History of Technicon Medical Information System, 1964–1987

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This paper investigates the controversy surrounding the systems approach in medicine, contributing to the body of literature on systems and information technology in civilian contexts. Specifically, the paper follows the design and implementation of a hospital information system at El Camino Hospital in Mountain View, California, in the 1960s and 1970s. The case study suggests that while many considered "people problems" like healthcare too complex for the systems approach, in fact it could have positive results if system engineers could translate social concerns about medicine into business and organizational strategies. This paper identifies the ways systems designers approached an organization characterized by autonomy rather than collaboration, craft rather than science, and charity rather than business, and helped to redefine that organization as one that emphasized rationality, efficiency, and the coexistence of man and machine.

Introduction

Following World War II, military and aerospace organizations set their sights on civilian problems, arguing that the approaches that put a man on the moon or launched a decisive wartime attack could solve the complex, human-oriented problems that plagued society ranging from water pollution to juvenile delinquency. Among these problems, the faltering state of healthcare in the United States stood out. By 1969, President Nixon had declared that medicine faced a "massive crisis."[1] Rising costs, debates over patient rights, concern about government involvement, and increasing physician error dominated the discourse.[2] Systems theory appeared poised to make an intervention, but selling the approach would not be easy, as many considered new technologies and automated processes anathema to the human-focused healthcare industry. Historians have demonstrated how corporations, factories, government entities, and many other organizations utilized systems theory to tackle the challenges faced by their respective industries.[3] Yet by and large, scholars tell stories of failure or unrealized potential. Although professionals applied many ideas from systems theory to business problems, this way of thinking failed to penetrate organizations focused on "people problems" or to effect noticeable institutional change.[4] By contrast, this paper interjects a new narrative into the historiography of systems theory, proposing a successful application of systems thinking to the civilian healthcare industry. Although aerospace engineers and system designers did not revolutionize the whole of medicine, their approach positively impacted one hospital's operations and served as a model for others to follow.[5]

Specifically, this paper follows the design and implementation of a hospital information system known as the Technicon Medical Information System (TMIS) at El Camino Hospital in Mountain View, California, in the 1960s and 1970s.[6] The case study suggests that while many considered civilian problems like healthcare too complex for the systems approach, in fact the strategy could succeed if system engineers emphasized and built toward the human element of a technological system. Rather than allow machines to dominate or replace users, as often happened in other applications of systems theory to civilian projects, TMIS designers envisioned a harmonious system in which man and machine could coexist. This paper identifies the ways that system designers approached an organization characterized by autonomy rather than collaboration, craft rather than science, and charity rather than business, and helped to redefine that organization as one that emphasized rationality, efficiency, and the coexistence of humans and technology.[7] Recognized by early players in medical informatics—including physicians and system engineers—as one of the most successful systems with input from aerospace, industry, and government

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sectors, the story of TMIS provides a new dimension to the history of systems.[8]

Diagnosing the Healthcare Problem: A Systems Approach

> "The systems approach, if it is used wisely, is, at the least, a cure for chaos. Either we take the systems-approach route and perform well, or we accept absolute and utter confusion and chaos."—Dr. Simon Ramo, 1969.[9]

In an enthusiastic endorsement of the systems approach for civilian problems, Vice President Hubert Humphrey commented in 1968, "The techniques that are going to put a man on the Moon are going to be exactly the techniques that we are going to need to clean up our cities. . .the systems analysis that we have used in our space and aeronautics program—this is the approach that the modern city of America is going to need if it's going to become a livable social institution." He concluded emphatically, "So maybe we've been pioneering in space only to save ourselves on Earth."[10] Industry players adept at building systems invested in this hopeful rhetoric, marshaling resources for diverse projects ranging from oceanography and water pollution to crime and urban renewal. Medicine quickly rose to the fore as an industry that could benefit from the technologies and philosophies of systems previously utilized in other sectors.[11]

For proponents of the systems approach, a core strategy focused on interpreting healthcare's failure as an "information problem," suggesting that the industry needed better organization, greater efficiency, and technological interventions to manage the data that circulated in a hospital. In a treatise on the value of medical information systems (MIS), Melville Hodge, an early player in the development of TMIS, wrote, "Many hospitals have undoubtedly reached, and some probably have even passed, the limits of information processing with traditional methods. All are dangerously close to a breakdown in information handling."[12] Hodge paints a picture of hospitals on the brink of collapse due to information overload, and "traditional methods" as unfit to handle the crisis. In a similar vein, physician F. Raymond Keating, Jr. commented in a 1967 *Los Angeles Times* article that the computer revolution could not come soon enough, as healthcare was "choking to death" on medical information.[13] An article entitled "Computers Called Only Way Out for Hospitals" from the preceding year echoed Keating Jr.'s sentiment, when deputy county superintendent of charities L.A. Witherill suggested ominously, "There's no question that we have to go to computers. It's a matter of survival."[14] By interpreting healthcare's problems as a failure to house or transmit information in each of these cases, interventionists in favor of systems and new technologies redefined the debate as a technical and strategic one, and information as a tangible good, a commodity.[15] Beyond the borders of the healthcare sector, too, an "information crisis"—focused on interpreting the concept of information in new and controversial ways—pervaded numerous industries from insurance agencies to libraries.[16] While professionals across fields struggled to redefine their roles within this context, government fears about obtaining intelligence and maintaining security in the Cold War era also gained ground.[17] In this climate, where computers and other new technologies possessed almost mythical status, management officials across disciplines regarded information as a vital asset. To wield this information required innovative technological solutions, and business professionals seized computers as a key component of the information movement. Although they were not the first to employ systems theory and new technologies to information problems, aerospace organizations quickly recognized an opportunity for growth and advancement in this industry. By harnessing the rhetoric of systems theory, these organizations claimed they possessed expert insight into applying technological applications to any situation, whether in space or on Earth.

For Hodge and others at Lockheed Missiles & Space Company—the originator of TMIS—the solution to healthcare's problems lay in the creation of a total hospital information system: a series of linked computer terminals situated throughout the hospital that would control, communicate, and reproduce information about every area of operations from doctor–patient interactions, billing and laboratory services, to the scheduling of flowers and mail delivered to patient rooms. The information system would not only bring together patient data and tasks, but the people of the hospital, connecting "man" and "machine" to provide a new, systematic standard of care in sync with the modern world. This concept of the "total system" certainly did not only preoccupy the healthcare industry, nor did it originate solely from the realm of aerospace or military organizations. In the late 1950s and early 1960s, many sectors of corporate America seized the concept of the "totally integrated management information system" and promoted it enthusiastically, often equating advanced systems with their institutions' survival.[18] Even when executives disagreed about the basic definition of systems theory or how to employ it, the appeal of an approach that would combine humans and machines to manage large and complex tasks could not be denied.[19]

Before Technicon, There Was Aerospace

> "We must bring systems analysis to health services just as it has successfully been focused on military and industrial problems. The need, the supply, and the delivery of health services must be viewed broadly as a total system, not as series of unrelated bits and pieces. . . . Medicine cannot solve today's medical problems with yesterday's medical structure and organization." —Dr. Cesar A. Caceres, Department of Health, Education and Welfare, Medical Systems Development Laboratory, 1968.[20]

In 1964, Lockheed Missiles & Space Company took steps to establish itself as a major developer of healthcare technologies, even while participating heavily in the conflict in Vietnam. Citing a need to diversify and in recognition of "important human needs in [healthcare] that might be satisfied in large measure by the systematic application of

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modern technology," Lockheed created an Information Systems Division staffed by managers, engineers, and analysts who knew a great deal about aerospace but very little about medicine.[21] Lockheed appointed Kenneth Larkin, Director of Special Systems to head the project. Larkin's diversity of experience included work on the Polaris missile system and Air Force satellite systems for Lockheed, as well as holding positions outside of the company at Raytheon Manufacturing Corporation and as a scientist for the Naval Research Laboratories. Yet Larkin's biography included no experience with medical technologies, and thus Lockheed also received outside counsel from a number of experts who recommended the development of MIS, including Dr. Raymond White, Director of Socio-economic Affairs for the American Medical Association, Dr. Howard Aiken, founder and director of the Computation Laboratory at Harvard University, and Dr. Clarence Lovell, Director of Switching Systems at Bell Laboratories.[22]

Lockheed's transition into the healthcare space indicated a larger trend: many aerospace companies, recognizing the fragile ties between war and business, set their sights on civilian problems they believed they could address using the commonplace tools, systems, and theories of scientific management at work during the war.[23] A 1967 *Los Angeles Times* reporter speculated that in order for California's industries to survive after disarmament in Vietnam, aerospace companies must inevitably turn their sights to civilian applications, or risk "tumbling into economic depression."[24] This perilous financial climate made the entry into civilian sectors such as healthcare both appealing and necessary in the eyes of companies such as Lockheed. Much of the rhetoric espoused by aerospace organizations about conducting healthcare projects involved minimizing the differences between the aerospace infrastructure and the hospital and emphasizing healthcare's problems as organizational ones. In a 1966 issue of the *Los Angeles Times*, Philip Horwith of TRW Systems commented, "You can build new hospitals and plan hospital logistics just like a missile system. Look at the subsystems: Cafeteria, laundry, pathology, operating rooms. . . . Hospitals are usually all little subsystems, with actually very little planned co-ordination. There hasn't been a breakthrough in hospital planning for 50 years."[25] By equating a hospital with a "missile system," Horwith not only claimed territory for the aerospace industry in healthcare, but also stripped the hospital of its unique features, actors, and context-specific processes, thus naturalizing the notion of "hospital as missile system."[26] This approach not only made the hospital appear antiquated, but also desperately in need of physical reorganization.

Aerospace officials frequently used language to universalize the systems approach, as evinced by comments from Frank Lehan of Space-General in a 1965 issue of *The Wall Street Journal*: "Our talent lies in the systems approach — being able to organize a vast, complex problem by its components. Whether we understand the relationships or not and without necessarily understanding any of the whys of those relationships, we can then expose that problem to the technical devices and methods we use, for instance, in devising a grand plan to land a man on the moon."[27] By dismissing the hospital as a unique instance, Lehan argued that systems theory could adequately attend to any problem without understanding the specifics of that problem.[28] Comments like Lehan's and Horwith's reflect the aerospace industry's general failure to treat civilian problems as unique cases apart from what the organizations had encountered in space and war. Yet in the early stages of designing its MIS, Lockheed took a contrasting approach that emphasized context-specific knowledge focused on system users, a strategy that would continue throughout the development and implementation of TMIS. Although Lockheed did not explicitly identify healthcare's structure as a unique instance, it recognized the importance of understanding ground-level operations within a hospital setting.[29] In an effort to gain this kind of information, Lockheed's Information Systems Division sent 12 engineers to Mayo Clinic in Rochester, Minnesota, in November 1966 to expose the inner workings of the hospital system, conducting the first-ever systems analysis of hospital operations.[30] Housing a clinic and two affiliated hospitals, Mayo Clinic offered a diverse environment for understanding the organizational complexities of healthcare.

Lockheed's engineers and specialists spent 2 years working with Mayo Clinic physicians, learning how to automate workflow processes and observing daily interactions among various actors in the hospital network. In a 1967 proposal to the U.S. Public Health Service for further funding of its initial prototype, Lockheed suggested three features unique to the proposed MIS: First, the system would utilize a "total systems approach" that would manage all information circulated in the hospital beginning with the physician's order of tests and medications. Whereas engineers designed other systems to dissect individual hospital functions into "silos" or independent entities, the Lockheed MIS team envisioned the hospital as a centralized, integrated system. To this end, Lockheed also proposed the creation of a central information processing facility off-site where the aerospace company would house all data. By taking the burden off of the hospital to maintain its physical information, Lockheed's system created a helpful division between the tasks of administering patient care and running a data-driven business. Second, Lockheed imagined a system that would require direct use by physicians and nurses in their day-to-day operations, rather than placing the computer in the sole hands of secretaries or technical specialists. Lockheed engineers conjectured that only by putting control of technology in the possession of primary users would the system succeed, a progressive notion at the time that furthered the cybernetic concept of "man" and "machine" working harmoniously together. Third, the system emphasized this integration between humans and nonhumans by promoting technology that used "human reasoning" rather than special skills, an idea that Technicon would further develop when it took over development of the system in the 1970s. Each of these features balanced the need to make system-wide organizational changes and implement new technologies with sensitivity to maintaining the hospital's functioning on a daily

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basis. Additionally, by focusing its innovations on streamlined processes and human-oriented tasks, the engineers imagined a system with people—rather than machines—at its center.

After nearly 2 years of research, Lockheed's 12 "no longer naïve" engineers returned to Sunnyvale, California, ready to begin building and testing the MIS.[31] During the development process, Lockheed had identified El Camino Hospital as one of its first desired sites for MIS implementation. Less than 5 miles down the road from Lockheed's headquarters, El Camino Hospital in Mountain View offered not only a convenient geographic location, but also represented a modern, community hospital offering high quality of care.[32] The initial study at Mayo Clinic not only affirmed to Lockheed the need for a medical MIS, but also that its prototype held much promise, and thus Herschel Brown, Executive Vice President, and Larkin decided to move forward with commercial development. Yet by 1971, although the MIS prototype had come a long way, Lockheed reached an impasse. A series of financial setbacks related to Lockheed's commercial airplane development and its military and aerospace program pushed the company into deep financial trouble; as a result, the fledgling aerospace company quickly cut the MIS project and other new business programs.[33] Nevertheless, determined to see its vision realized, Lockheed began negotiating with Technicon Corporation to jointly produce the MIS. Technicon, under the leadership of philanthropist and entrepreneur Edwin C. Whitehead, already possessed a reputation for creating and distributing technologies used to automate clinical laboratory processes, and thus seemed a natural fit. In light of Lockheed's financial difficulties, however, Technicon resolved to purchase the Information Systems Division and MIS prototype outright, transforming its organization into Technicon Medical Information Systems Corporation on May 28, 1971. On this same day, El Camino Hospital formalized its partnership with Technicon to produce the first "fully operational total medical information system installed in a private practice, community hospital setting, which interfaces directly with professional personnel in a real-time interactive fashion."[34] While Lockheed could not see its MIS through implementation, the company left an indelible mark on the product. In particular, Lockheed recognized the value of a systems approach and helped to translate the hospital's needs into a technological solution that leveraged human skills.

TMIS Developed

> "In Mountain View, Calif., at the El Camino Hospital, a doctor wonders how his patient on the first floor is doing. The thought of walking through several wings of the hospital and hunting up the attending nurse to find out crosses his mind. Instead, he stops at a console at the nearest nursing station and punches a few buttons on the keyboard. Almost instantly a screen flashes with a complete log of his patient's temperature, medication, blood pressure and latest test results. On the same keyboard, the physician types in a note to adjust the medication slightly, then proceeds on his way." —Roger Field, Reporter, *The New York Times*, 1971.[35]

In June 1971, The National Center for Health Services Research (NCHSR) chose El Camino Hospital as an evaluation and demonstration site for a 4-year, $1.2 million study of its medical information system in conjunction with Battelle Laboratories.[36] Throughout the course of the study, Technicon engineers and El Camino personnel would wrestle with the challenges of implementing a system that could both lower costs and better serve the hospital's patients. At the outset, Technicon faced a great challenge given that Lockheed's engineering team largely built its prototype outside of the hospital environment, a fact that would become a stumbling block to both the corporation and its test site.[37] Luckily, both organizations benefited from the experience of Melville Hodge, an industry player who shepherded TMIS from Lockheed to Technicon. Hodge joined Lockheed Missiles and Space Company in 1955 as manager of Lockheed's Engineering Development Laboratories, where he oversaw testing of missile and space vehicle structural testing. Lockheed promoted Hodge to assistant director of the MIS project in 1965 and he remained with the company until 1971, when the project changed hands. He went on to serve as Technicon's president and chief executive officer from 1973–1977. Hodge steadfastly supported the system's development and recognized that any system would have a significant effect on the human dynamics of a hospital. Looking back on the system in 1987, Hodge had clearly learned the importance of designing a system made for its users: "It is imperative. . .to never forget that introduction of MIS into a new hospital profoundly impacts a *human* organization to perhaps an unparalleled degree. . .the business of doctors is *not* to make computer systems successful; success has been repeatedly demonstrated to be the consequence of each doctor, one at a time, coming to see how his performance is enhanced and his hospital practice facilitated by investing his always scarce time in learning how to use MIS efficiently."[38] While Hodge managed Technicon's development of MIS, a number of leaders at El Camino Hospital also supported the difficult process. Chief among them, hospital administrator R. Edwin Hawkins and physician Ralph J. Watson, chair of the MIS Physician Committee (which included physicians Bryan Shieman and Joseph Ignatius), led physicians, nurses, and other staff through many iterations of TMIS. Both individuals supported TMIS to their cohorts and in the popular press. "The system *can* do the job we want it to do," Watson claimed in a 1973 article entitled, "Some Claim System a 'Nightmare'" in *Computer World*, a sign of the physician's continuing support of the system despite setbacks.[39] Commitment to MIS by both Technicon and hospital staff helped to create a climate in which the technology could take hold.

At the same time, all involved parties recognized the importance of implementing technology that worked for its users. To create its system, Technicon began by distributing 60 computer terminals known as video matrix terminals (VMTs) across departments. Each terminal consisted of a

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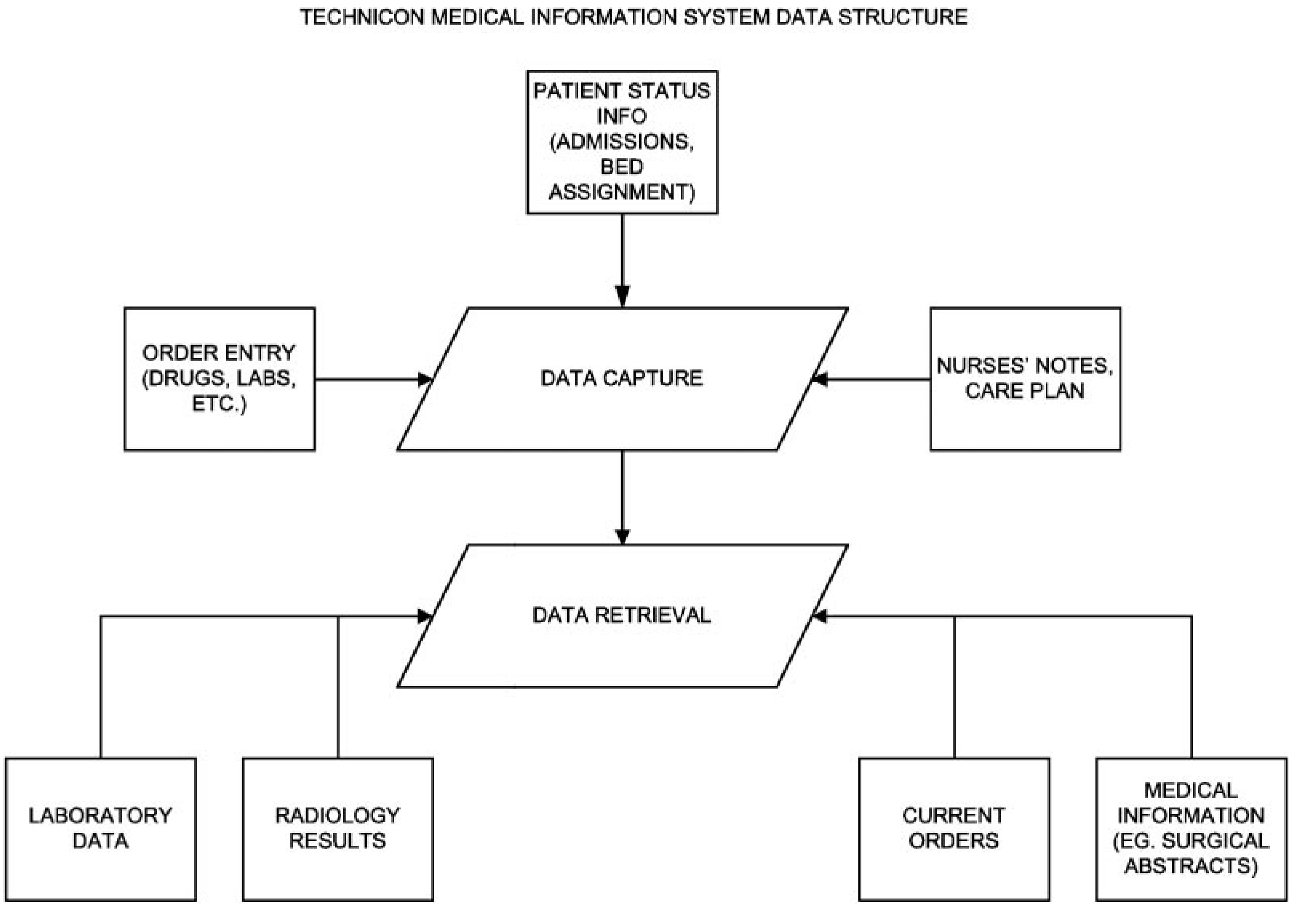

FIG. 1. Technicon Medical Information System data structure.

television screen, "lightpen," keyboard, and a high-speed printer for producing reports. Engineers designed the system so users would primarily operate the technology by aiming a lightpen at CRT screens to make selections rather than utilizing a typical computer keyboard, although users could choose either method.[40] Technicon designers reasoned that the lightpen would particularly appeal to physicians, who typically associated keyboards and typing with clerical work rather than medical work. Watson described the lightpen as integral to the system in a written reflection on the technology in 1977: "To select items on the TV screen display, a user merely points the lightpen at the desired word or phrase and presses a button on the electronic lightpen. By making a series of selections, a physician can rapidly and accurately compose medical orders, review patient data or test results, or consult a wide variety of medical reference information from a library of antibiotic sensitivity surveys, lab results, interpretation aids, current surgical abstracts, antibiotic ordering information, hematology programs, etc."[41] Notably, the Technicon system made possible the first commercial use of CRT and lightpen in combination.

TMIS operated on large-scale IBM computers (370 series) and Technicon housed data at its off-site location in Mountain View. Four 29-megabyte discs housed the system's patient database, and system programs were called from another 29-megabyte disc.[42] By maintaining data off-site, Technicon reduced El Camino Hospital's burden and emphasized usability over maintenance. Watson noted in his review of the system that the hospital had never lost its database and that users prized reliability as a feature of the technology. On average, TMIS remained operational 99.3–99.6% of the time (excluding 20–30-minute update periods once a month), and that this amount of downtime did not noticeably disrupt hospital procedures.[43] Technicon designed TMIS to use real-time computer processes to facilitate the patient's hospital experience from the time they entered to the moment of discharge. In large part, this meant managing physicians' orders, ranging from laboratory and medication requests to x-rays and other tests, as well as nurses' care plans for food delivery, administration of medication and family visits (Figure 1). Unlike other MIS products created during this time, early versions of TMIS maintained an electronic patient record for only 48 hours, stressing acute care and the management of workflow processes rather than maintenance of long-term records.[44] Linked up with every hospital department, TMIS would not only integrate services and people, but also manage billing and insurance by connecting to a business office services system (BOS).

Once the next phase of the project gained footing, Technicon personnel and El Camino Hospital administrators

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determined two primary goals for TMIS: (1) to provide measurable economic benefits (i.e., reduce costs) to the hospital, and (2) to improve patient care (as measured by a reduction in errors).[45] Both of these goals reflected a desire for better organization, more streamlined services, and attention to business management. To these ends, Technicon entered into a unique—and controversial—financial agreement with El Camino Hospital. Rather than charge the hospital for its services at the outset, Technicon assumed full financial burden for its product, receiving only the hospital's actual cost savings. It was not until 1974 that Technicon and El Camino staff renegotiated the contract so Technicon would receive its full fee. This unorthodox approach gave hospital users time to learn about the hardware and software and to evaluate its benefits before incurring significant costs. This structure also taught Technicon personnel that "hospital managers, not computer systems, save money," according to Hodge, a lesson that would further highlight the importance of putting users first and technology second.[46]

In an effort to appeal to the system's chief users, nurses and physicians, Technicon developed and refined a number of the features identified by Lockheed. Importantly, the system supported standard medical terminology rather than "computerese," i.e., machine lingo. Dating back to Lockheed's involvement in the system, engineers recognized that physician acceptance would dictate the success or failure of the MIS, and thus they designed a system that would respond to physicians' strengths and weaknesses.[47] Technicon engineers also quickly learned that the system must process information rapidly. Engineers endeavored to have the system respond in "thinking time" so as to correspond with physicians' natural habits.[48] Notably, when Technicon assumed responsibility for development of the system the corporation shied away from deeming its information system a "total" system, as Lockheed had envisioned it. Although it linked multiple hospital departments and personnel, TMIS primarily facilitated physician order entry and did not attempt to provide a solution that would wholly eliminate paper charts. Indeed, Watson suggested in a reflection on the system that a "total" approach almost always inevitably failed due to its ambitiousness.[49] By building a system around the physician's order and the nurse's care plan, TMIS emphasized patient care as the foundation of all hospital operations, but it did not claim to fully automate the hospital.

Importantly, this picture of TMIS did not emerge coherently in Technicon's initial conception of the product, nor did the system garner widespread appeal in its early versions. Extensive user feedback in the form of surveys, hospital committee participation, and outside review from Battelle Laboratories all contributed to the development of the system. A core team of three industrial engineers, four to five vendor system engineers, a nurse, and a part-time physician worked together testing different areas of the system's design over the course of its lifespan.[50] These engineers constantly produced new iterations of TMIS, performing 2,000–3,000 changes in the first year of implementation.[51] Participants in the project at El Camino Hospital describe the early system's use as a "battle," with many users rejecting the technology outright.[52] In fact, in mid-1972 ≈66% of users opposed TMIS.[53] While ultimately personnel came to accept and incorporate the system into their work, Technicon encountered significant obstacles against user uptake.

Technicon Faces Computer–Physician Conflict

> "Today our world is different. It is automated, but let us not automate medicine. In medicine, our scientific advancements have led to the practice of fragmented medicine and the sick person as a whole is relegated to being a case history in parts. This signifies a shocking indifference to the dignity of the individual, to the dignity of human values, and it is a sad disregard of the importance and the inviolability of the individual spirit. Let us not make our patients dots and dashes on a punch card to be fed into a machine." —Casper Epsteen, MD, 1963.[54]

In his impassioned speech at an annual Chicago Medical Society dinner, Epsteen called for humanized medicine, for a kind of medicine that stands opposed to the "automation" that characterizes the rest of the modern world. His words echoed a common sentiment among many physicians during this period and in the years to come: that machines, computers in particular, and automated systems more generally, represented a fundamental threat to the practice of medicine. While the fervor of systems caught on in many segments of society, medical practitioners on the whole remained wary, if not belligerently against, the idea of automated healthcare.[55] Physicians and other segments of society interpreted technological systems as a direct threat to "people problems." This climate of wariness and fear similarly dominated the discourse surrounding the introduction of TMIS into the hospital community. In a retrospective look at TMIS, Hodge detailed the local and national press headlines that followed the El Camino Hospital TMIS story in its early years, indicating the overwhelmingly negative response to the system (Table 1).[56] Early backlash against TMIS fell primarily into one of three categories: (1) technological flaws; (2) change in work processes; and (3) social/cultural factors. While the first two problems signified difficulties in the areas of functional and organizational change, the third points to uneasiness about

TABLE 1. News media response to TMIS 1972–1973.

Date	Publication	Headline
July, 1972	San Jose News	Doctors Look with Ill Favor at New Computers
July, 1972	San Jose Mercury	Physicians Deeply Split Over 'Dream Computer'
Summer, 1973	San Jose News	'Work Saving' Computer Enslaves Hospital Staff, Doctors Claim
June, 1973	Computer World	Some Claim System a 'Nightmare'
June, 1973	San Jose News	Independent El Camino Hospital Study Discloses: 'Computer Doesn't Help Doctors or Patients'
Summer, 1973	San Jose News	Among Most Doctors: Hospital Computer Unimpressive

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whether TMIS called for a higher-order change by personnel that involved deeply entrenched social and cultural factors. By parsing through these problems, it becomes clear that system engineers faced a great challenge in making the systems approach work.

Technological Flaws

As typically occurs with any new system, initial TMIS users expressed great frustration about technological problems. W. Ed Hammond, a medical informatics pioneer, notes that system-wide flaws characterized most early MIS: "Hardware failures were the norm rather than the exception. Software crashes were commonplace. Perhaps life with these early systems was best described as 'working with a machine you can't touch; working with a machine that didn't work; working with a machine that you couldn't afford; and working with systems that were not useful.'"[57] Clearly the first TMIS users experienced significant setbacks as they learned alongside Technicon engineers, contributing to their frustration with the entire concept of a hospital information system. Physicians also expressed distrust of the "black box" and whether it would handle orders accurately.[58] Used to relying on their own handwritten notes, physicians shied away from the mystery and uncertainty a computer system provided. Importantly, a number of the first TMIS users note that once physicians experienced trouble with the system, they no longer expressed interest in using it again.

Change in Work Processes

A second source of resistance to TMIS came from users' negative attitudes toward behavior change, particularly in the case of physicians. Two competing philosophies dominated the discourse around the use of TMIS. On one hand, system engineers promoted the idea of a "natural" and organic system that should attempt to mirror the physicians' thinking processes, language choice, and skill. By emphasizing quick response-time, the use of common medical terms rather than computer jargon, and the implementation of lightpens rather than keyboards, TMIS attempted to mimic physicians' behaviors as they existed before the introduction of new technologies. Yet the implementation of TMIS necessarily required that personnel adapt their skills, thinking, and ways of practicing medicine to the system. According to a study of MIS conducted by the U.S. Office of Technology Assessment in 1977, "Medical information systems require providers to change their patterns of behavior. They must, for example, learn an entirely new set of procedures for keeping records. Breaking with established, habitual routine is difficult and sometimes frustrating. Providers were alienated at first."[59] Physicians echoed this sentiment during their initial use of TMIS, noting that, among other changes, the doctor must necessarily "reorganize his thinking processes along the lines of the computer display sequence."[60] Finally, Battelle's evaluation of TMIS concluded that: "the system *is* workable for physicians, but it requires willingness on the part of the physicians to change their methods" (emphasis in original).[61] Each of these comments suggests the difficulty of trying to adapt the machine to the human and the human to the machine in order to encourage a truly useful and efficient system. Many observers of the TMIS implementation noted that without physician uptake, the system would fail. Indeed, if users' "frames" or expectations of a technology do not agree with the system they intend to use, the technology will not gain footing: "Frames can create 'psychic prisons' when people 'cannot look at old problems in a new light and attack old challenges with different and more powerful tools — they cannot reframe.'"[62] An inability to align one's technological frames with the expectations of the creators commonly occurs in organizations and can have catastrophic effects on the uptake of a system. Observers of the TMIS implementation commented that engineers completed much of the system's initial development outside of the hospital rather than in joint collaboration with physicians, thus creating incongruence between the engineers' expectations and those of the users in early phases.[63] This misalignment prevented TMIS from taking hold in the hospital.

Social/Cultural Factors

The introduction of MIS into El Camino Hospital fundamentally destabilized professional roles within the institution.[64] In particular, TMIS relocated responsibility for producing legible, systematized records from nurses to physicians. Margo Cook, a nurse and early user of TMIS at El Camino Hospital noted that: "The system. . .shifts the responsibility where it belongs. . . . Physicians are responsible for accurate, clear orders. . . . The transfer of responsibility caused a change in the traditional relationship between nurse and doctor, for the responsibility to see that orders were carried out now fell on the doctor as he wrote them in the system."[65] Far from neutral objects, medical records "materially constitute power differences," mediating the ways that personnel conduct medical work in a hospital.[66] As social objects that "trigger social dynamics," technologies like TMIS draw into question previously held assumptions and clearly defined roles.[67] For physicians, whose power and legitimacy has continually been challenged since the inception of the modern hospital, MIS represented a significant threat to professional status and autonomy.[68] Confronted by a new way of operating in the hospital, physicians found "the role reversal [between nurses and physicians] distasteful."[69] Thus, in order to convince physicians to adopt MIS despite the threatening nature of the technology, proponents of the systems approach had to prove to users that system benefits outweighed those of remaining outside of it.[70] TMIS engineers and hospital administrators emphasized the functional benefits of the technology—from reduced paperwork and decreased errors to global access throughout the hospital. Yet until "alignment" could take place between users, developers, and the system itself, physicians would continue to reject TMIS.[71]

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TMIS Succeeds

> "Early systems were designed partly by the scientist, partly from the business world, and very little by the practicing physician.... Often we fail to realize that the computer is no substitute for intelligence. It is not a magic box which can make gold from straw."—W. Ed Hammond, PhD, 1987.[72]

Battelle Laboratories' 4-year study of the partnership between Technicon and El Camino Hospital not only provided a historical record of the TMIS implementation, but also investigated whether the total hospital information system could deliver on its promises to improve patient care while cutting costs. By 1975, Battelle concluded that the hospital's utilization of TMIS resulted in "more efficient operations, higher productivity, higher employee morale, and better patient care."[73] Specifically, Battelle found that TMIS had decreased operating costs and length of patient stay, spurred more accurate and complete medical records, and fostered communication both within and across departments. In addition to these notable improvements, ≈94% of nurses, a majority of the 300 physicians on staff, and nearly all administrative personnel had voted to keep the system in place by casting secret ballots in the summer of 1974.[74] The impressive turnaround of TMIS at El Camino Hospital reveals the success of Technicon and hospital personnel in developing a product that balanced the need for greater efficiency and streamlined work processes with user friendliness and context-specific features. Yet the product's success also reflects each constituency's willingness to rethink, revise, and remain committed to the system despite setbacks.

Many reasons account for users' ultimate acceptance of TMIS, including improved technology, ease of use, and attention to human factors. Notably, nurses' overwhelming acceptance of the system promoted its continued use and high approval. Nurses, who participate in every stage of care and most frequently interact with patients, represented an important user base. Cook, reflecting upon TMIS in 1974 noted: "Ask any nurse at El Camino Hospital what she thinks of our recently implemented medical information system and you are certain to receive a positive response."[75] Cook emphasized that nurse acceptance certainly took time, but ultimately TMIS condensed numerous processes and enabled nurses to spend more time with their patients. Accustomed to dealing with day-to-day organizational processes (filling out paperwork, filing charts, implementing orders, etc.), nurses could recognize the value of a systems approach that not only created standardized protocols, but also redefined their roles within the institution. Hodge suggests that nurses in fact goaded physicians into using the system once it gained widespread acceptance among their cohort, a kind of peer pressure.[76] Nurses translated the organizational benefits of the systems approach into their work, much as other personnel of similar rank and responsibility had done in corporations and military environments.[77]

In the case of physician acceptance, key requirements for uptake included recognizing the benefits of the system and integrating it into one's professional identity. Others who have studied TMIS note that physician acceptance depended on cost–benefit analysis, proposing that if physicians recognized the benefits of MIS, they would use it. While cost–benefit certainly played a role in physician acceptance, most individuals needed to make a higher-level commitment by recognizing themselves as part of the system, both aligning themselves with the technology and as part of a larger technological network of care providers, systems, and machines. One El Camino Hospital physician's comment reflects this notion of "becoming one" with the system; Hodge recalled an internist approaching him, saying of TMIS, "It's just like breathing, I couldn't get along without it."[78] By associating use of the system with a biological function such as breathing, the internist imagines being fully in sync with the machine, fulfilling the very goal of the systems approach. More than a simple recognition of benefit, then, physician acceptance hinged upon reconciling and integrating one's professional identity into the technological system.

In subsequent years, Technicon implemented its product in numerous hospital and clinical environments. Most notably among them, Technicon developed an MIS for the National Institutes of Health (NIH) Clinical Center in 1975. Engineers designed the NIH system to collect, transmit, and store information about patients for physicians and nurses conducting clinical studies and research protocols. Still functional after more than 25 years, the NIH system currently supports over 110,000 patient records.[79] In 1980, Revlon Corporation purchased Technicon so Technicon's founder, Edwin Whitehead, could focus his efforts and funds on a biomedical technology foundation.[80] The TMIS product stagnated in subsequent years until Technicon repurchased the company in 1986, this time under the direction of Whitehead's son. By 1987, 85 locations across the country including NYU, Temple University, Loyola University of Chicago, and University of California-Irvine housed the Technicon product. El Camino Hospital, whose system continues to evolve and embrace new technologies, received the title of one of the U.S.'s "most wired" hospitals in 2003, with nearly 97% of physicians using computerized physician order entry.[81]

The Landscape of MIS

While this paper focuses on TMIS, the system played but one small part in the broader landscape of MIS implementations in the 1960s and 1970s. Early systems were characterized by great diversity in their purposes and affordances, varying degrees of user adoption, and a wide range of measures for success. Some organizations focused on innovations related to decision support systems, helping doctors diagnose patients and model disease processes, others developed computerized medical records and patient care plans, and a rare few envisioned systems that would combine all of these functions. Yet despite pioneers' best efforts, the "daunting complexity" of early systems across the board led to a "lack of major achievements...in the first four decades of medical informatics."[82] Nevertheless, technologies implemented at sites such as the University of Vermont (PROMIS),

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Massachusetts General Hospital System (MGH), and Kaiser Permanente (KP) made significant contributions to the field of medical computing.[83] While these systems certainly do not encompass all of the innovations and ideas at work during this time period, they provide a glimpse into the promise and challenges of MIS.

At the University of Vermont Medical Center, Lawrence L. Weed and his associates created the computerized problem-oriented medical record in 1968 to provide physicians with a new model to diagnose and treat patients. Despite its creative approach to the structure of medical records, an analysis of the system in later years noted that "PROMIS users perceived. . .that they were working for the system rather than vice versa," and physicians especially shied from using the technology.[84] At MGH, a teaching hospital of Harvard Medical School, G. Octo Barnett helmed a revolutionary computing project in MGH's Laboratory of Computer Science. Among its many developments, the MGH team implemented a computer terminal system that interacted directly with patients, and it pioneered the development of COSTAR (Computer Stored Ambulatory Record), which managed the primary medical records of over 30,000 hospital patients by 1973.[85] Despite its significant contribution to the field, MGH's system, like PROMIS, did not get taken up by physicians; rather, clerical employees entered information into the computer. Barnett surmised that the interface "did not favorably compare with the ease of use, availability, and reliability of the classical method of recording information or orders through written communication."[86]

With the help of Morris F. Collen, KP made perhaps the greatest strides of any organization to develop a "physically integrated, continuing, computer-stored patient record."[87] By the early 1970s KP's MIS could manage thousands of patient records collected daily in its physicians' offices. Yet the pilot MIS did not survive beyond 1973, when necessary funding fell through. The MIS fell victim to "unique and unfortunate circumstances," according to Donald Lindberg, one of the lead developers of a medical terminology and "fact bank" system at the University of Missouri, Columbia.[88] In each of the above cases a complex negotiation of technological, economic, and social/cultural factors affected the uptake of a given system. For the University of Vermont's PROMIS and MGH, a lack of support from physicians prevented the systems from reaching their full potential, while in the case of KP a dearth of financial backing ended the product's development prematurely. For other systems, available technologies simply could not match users' needs and desires. In 1968, Lindberg wrote that MIS would most likely succeed when it satisfied four criteria: (1) when a medical institution "enthusiastically endorsed" a system; (2) when a computing group reported to high-level authorities within a hospital but had no ultimate authority within the hospital; (3) when a system received the necessary financial support; and (4) when users and their tasks were aligned.[89] Given the great difficulty of satisfying these criteria, it is unsurprising that most systems failed or never realized their full potential. Yet the stops and starts, hurdles overcome, and lessons learned in the early days of medical computing made possible any and all successes in the field's present moment.

Conclusion

> "From time immemorial, this has been the goal of man: to control systems. For almost all men in the past, and for uncounted millions today, life has been a constant bitter struggle against chaos, against uncontrolled events. . . . And man wants to have control of his society; peace instead of war, prosperity in place of depression, domestic tranquility rather than civil disorder."—Irving S. Bengelsdorf, Reporter, *Los Angeles Times*, 1968.[90]

In a 2005 Web editorial, nurse Ann Farrell—a former employee of El Camino Hospital during the TMIS implementation—reflected on the system's success, noting that Technicon "got it really right on the really big things: usability, response time, reliability and flexibility. . . . [TMIS'] inherent flexibility gave the system a long shelf life by addressing each organization's unique requirements and supporting the ever-changing healthcare environment." She adds that Technicon "invented technology where it didn't exist, based on clinician requirements, not the other way around."[91] Farrell's positive assessment of TMIS more than 30 years later suggests the narrative's importance to the historiography of systems. Where current literature describes the post–World War II systems approach faltering in most civilian contexts, the successful case of TMIS depicts the diversity of outcomes during this time period and provides insight into the conditions necessary for meaningful technological interventions. TMIS showcases the importance of designing systems made for people, as well as the necessity of taking into account social and cultural factors in any organization that influence the uptake of new technology. Rather than laud successes, historians traditionally identify flawed systems, characterizing strategists' efforts as lacking complexity and attention to human factors. While indeed many large-scale civilian projects never reached fruition, a number of smaller, unique examples like that of TMIS re-imagine the systems approach as malleable and useful under the right conditions. By studying technological interventions at a micro-level—at the level of one organization and one system—it becomes possible to understand the nuances of systems theory and its application at distinct historical moments.

Discourses of the mid-twentieth century routinely debated man versus machine, questioning the role of automated systems in every sector of life—from the Apollo space mission to the hospital emergency room.[92] With the advent of computers came an undeniable tension between automation and control, forcing humans to redefine their relationship to work and to reconcile their professional identities in the context of machines. The case of TMIS reminds historians of technology that the grand battle of man versus machine often existed in the mundane avenues of the workplace, in the routine filing of paperwork, and the casual conversations between coworkers. In addition to examining highly visible organizations in government and industry, scholars should set their sights on

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those workplaces that fall outside of the radar—those organizations whose systems appear small but have the potential to affect civilian problems on a much larger scale.[93] In these places struggles for identity and autonomy rise to the surface, prompting questions about what it means to participate in a society where humans and technology must peacefully coexist.

Endnotes

[1]Schmeck, H.M. (1969). President Warns of 'Massive Crisis' in Health Care. The New York Times, p. 1.

[2]Among these problems, perhaps the greatest was the issue of health insurance. For an excellent article discussing the rise of computers in medicine in relationship to government policy (particularly related to insurance), see Kaplan, B. (1995). The computer prescription: medical computing, public policy, and views of history. Science, Technology, & Human Values, 20 (1), 5–38. For a broader overview of the history of computers in medicine, see November, J.A. (2006). Digitizing life: the introduction of computers to biology and medicine. Princeton, NJ: Princeton University.

[3]For case studies of the systems approach and cybernetics, see Hughes, A.C., & Hughes, T.P. (2000). Systems, experts, and computers: the systems approach in management and engineering, World War II and after. Cambridge, MA: MIT Press. For historical examinations of systems theory and cybernetics, see Beniger, J.R. (1986). The control revolution: technological and economic origins of the information society. Cambridge, MA: Harvard University Press. While cybernetic theory and the use of computers in systems is a newer phenomenon, Beniger notes that society has strived for control through technology since the 19th century, which he describes as increasing "systemness" in society. Also see Mindell, D.A. (2002). Between human and machine: feedback, control, and computing before cybernetics. Baltimore: Johns Hopkins University Press. Mindell, like Beniger, challenges the notion that cybernetic and systems theory did not begin until Norbert Wiener coined the term in 1948, and finds roots of these theories as early as the 19th century.

[4]Hughes and Hughes note that most practitioners of the systems approach failed to "cope with complex urban problems involving political and social factors." Similarly, Light notes that military applications to urban problems "rarely served as sources of solutions." See Light, J.S. (2003). From warfare to welfare: defense intellectuals and urban problems in Cold War America. Baltimore: Johns Hopkins University Press.

[5]Pioneers in medical informatics created many other information systems and artificial intelligence products for healthcare during the same time as TMIS. These include INTERNIST-I (University of Pittsburgh), DENDRAL (Stanford), HELP (University of Utah), PROMIS (University of Vermont), and COSTAR (Massachusetts General Hospital). Each possessed specific advantages but did not receive the all-around attention or praise of TMIS by individuals in the field of medical informatics.

[6]El Camino Hospital is a 464-bed community hospital serving the suburban communities of Mountain View, Sunnyvale, Los Altos, Los Altos Hills, and Cupertino. Its proximate position to Silicon Valley has enabled many new technologies to penetrate its system.

[7]The hospital is characterized under the rubric of "civilian problems" rather than discussing it as a typical corporation, given that during this time period physicians and hospitals more closely associated themselves with charitable contributions and human welfare rather than bottom lines or business.

[8]Pioneers in medical informatics gathered at a 1987 ACM conference on the history of medical informatics to examine the field's roots; participants routinely identified TMIS as one of the most successful early systems.

[9]See Ramo, S. (1969). Cure for chaos; fresh solutions to social problems through the systems approach. New York: D. McKay. Ramo, a physicist, engineer, and businessman was known for inventing the intercontinental ballistic missile (ICBM), as well as founding two Fortune 500 companies in the 1970s: Ramo-Woolridge (later TRW Systems) and Bunker-Ramo (now part of Honeywell).

[10]Day, M.S. (1968). Space technology for non-aerospace applications. Wescon Technical Papers, Vol. 12, pp. 5–16.

[11]Following World War II, medicine's credibility surged and physicians and researchers made many discoveries, some stemming from wartime such as advances in prosthetics and rehabilitation medicine. Problems on all fronts of the healthcare industry came to the fore beginning in the 1960s. For a history of medicine, see Starr, P. (1982). The social transformation of American medicine. New York: Basic Books. While this article focuses on the role of the total hospital information system in healthcare, another key part of the history between systems theory and medicine addresses artificial intelligence and clinical decision-making tools in medicine. See Berg, M. (1997). Rationalizing medical work: Decision-support techniques and medical practices. Cambridge, MA: MIT Press.

[12]Hodge, M.H. (1977). Medical information systems: A resource for hospitals. Germantown, MD: Aspen Systems. Hodge joined Lockheed in 1955 as manager of Lockheed's Engineering Development Laboratories. He became an instrumental member of the team working on MIS and eventually followed the system to Technicon in 1971. He served as president and chief executive of Technicon Corporation from 1973–1977.

[13]Getze, G. (1967). TV and Computer May Be Doctors' Aides of Future. The Los Angeles Times, p. A1.

[14]Goff, T. (1966). Computers Called Only Way Out for Hospitals. The Los Angeles Times, p. 18.

[15]See Kline, R. (2006). Cybernetics, management science, and technology policy: the emergence of "information technology" as a keyword, 1948–1985. Technology & Culture, 47 (3), 513–535. Kline notes that the concepts of "information" and "technology" underwent significant changes as key terms based on which group was using them. Similarly, in his landmark paper, Michael Buckland notes that "information" occupies multiple categories and is situation-specific. He importantly suggests that with the rise of database and information management systems a new category of information as a concrete entity (which he calls "information-as-thing") comes to exist. See Buckland, M. (1991). Information as thing. Journal of the American Society for Information Science, 42 (5), 351. For a history of "information," see Schement, J.R., & Curtis, T. (1997). Tendencies and tensions of the information age: The production and distribution of information in the United States. Edison: Transaction Publishers.

[16]For a discussion of how two different professional groups fought over the concept of "information," see Bowles, M.D. (1998, October). The information wars: Two cultures and the conflict in information retrieval, 1945–1999. Paper presented at the History and Heritage of Science Information Systems, Pittsburgh, PA. Also see Haigh, T. (2001). Inventing information systems: The systems men and the computer, 1950–1968. Business History Review, 75, 15–61, for a useful analysis of the ways in which one professional group tried to redefine itself around the systems approach.

[17]Hayes, R.M. (1998, October). History review: The development of information science in the United States. Paper presented at the History and Heritage of Science Information Systems, Pittsburgh, PA.

[18]Haigh, T. (2001). Inventing information systems: the systems men and the computer, 1950-1968. Business History Review, 75, 15–61. Haigh and others note that systems theory grew out of a number of theoretical and professional traditions and was seized by different actors for their specific purposes. One key thinker in North America was biologist Ludwig von Bertalanffy, who defined "general systems theory" (GST). See Bertalanffy, L. v. (1968). General system theory; foundations, development, applications. New York: Braziller.

[19]See Meacham, A.D., & Thompson, V.B. (1965). Total systems. Detroit: American Data Processing. The diverse volume follows the idea of the "total system" from a number of industry leaders in business and aerospace and reveals the complex meaning of the term at the time, as well as the varied outcomes of employing such an approach.

[20]Lyon, R.D. (1968). Money in Health Is Attracting Many Nonmedical Companies. The New York Times, p. F1. Lyon identifies a number of corporations entering the healthcare industry including Westinghouse, United Aircraft, International Business Machines (IBM), TRW Systems, and Gillette Company, among others.

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[21]Lockheed Missiles & Space Company. (1965). Hospital information system: Multihospital operational demonstration: A proposal to the United States Public Health Service. Lockheed first met with the U.S. Public Health Service (USPHS) (then a part of the Department of Health, Education and Welfare) in May 1965 to discuss funding for MIS. This proposal represents a revised version based on feedback from USPHS.

[22]Hodge, M.H. (1987). History of the TDS medical information system. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 143–152). New York: ACM Press.

[23]For information about Lockheed's involvement in civilian projects as well as that of other aerospace organizations, see Light, J.S. From warfare to welfare: defense intellectuals and urban problems in Cold War America. Baltimore: Johns Hopkins University Press.

[24]Seidenbaum, A. (1967). If Peace Breaks Out, Can California Survive? The Los Angeles Times, p. A12.

[25]Sederberg, A. (1966). Aerospace 'Think Tanks' Getting Earthly Look. The Los Angeles Times, p. K1. For a discussion of aerospace techniques applied to civilian problems, see Webb, J.E. (1969). Space age management: The large-scale approach. New York: McGraw-Hill.

[26]By naturalizing the idea of "hospital as missile system," Horwith and Lehan invoke the notion of cybernetics as a "universal truth" and "cutting edge science" that could be applied to all societal spheres.

[27]Gordon, M. (1965). Down to Earth. The Wall Street Journal, p. 1.

[28]Proponents of the systems approach imagined systems as a "universal science" that could apply to nearly any situation. See Bowker, G. (1993). How to be universal: some cybernetic strategies, 1943-70. Social Studies of Science, 23 (1), 107–127.

[29]In initial MIS documentation created by Lockheed, there is no mention of what makes medicine unique or different in the case of systems. Engineers simply note that physician acceptance is a key component of success. Over time, the importance of context-specific systems became increasingly understood when the system did not gain acceptance or uptake.

[30]Wilford, J.N. (Dec. 5, 1966). Aerospace Men Turning to Problems of Earthlings. The New York Times, p. 38.

[31]Hodge, M.H. (1987). History of the TDS medical information system. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 143–152). New York: ACM Press.

[32]Lockheed Missiles & Space Company. Hospital information system: Multihospital operational demonstration: A proposal to the United States Public Health Service.

[33]For one description of Lockheed's financial difficulties, see The Lockheed Bailout Battle. (1971). Time.

[34]Norwood, D. (1974). Introduction of a user-oriented THIS into a community hospital setting — introduction and system. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 295–298). Amsterdam: Elsevier.

[35]Field, R. (1971). Computers Enter Medicine. The New York Times.

[36]Watson, R.J. (1977). A large-scale professionally oriented medical information system — five years later. Journal of Medical Systems, 1 (1). The National Center for Health Services Research is now known as the Agency for Healthcare Research Quality (AHRQ) in the Department of Health and Human Services. For a history of AHRQ funding for research in medical computing, see Fitzmaurice, J.M., Adams, K., & Eisenberg, J.M. (2002). Three decades of research on computer applications in health care: medical informatics support at the agency for healthcare research and quality. Journal of the American Medical Informatics Association, 9 (2), 144–160.

[37]Hawkins, R.E. (1974). Introduction of a user-oriented THIS into a community hospital setting—introductory agents and their roles. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 75–77). Amsterdam: Elsevier.

[38]Hodge, M.H. (1987). History of the TDS medical information system. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 143–152). New York: ACM Press.

[39]Some Claim System a "Nightmare": MDs at Odds over Hospital MIS. (June 6, 1973). Computer World.

[40]Hodge, M.H. (1987). History of the TDS medical information system. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 143–152). New York: ACM Press.

[41]Watson, R.J. (1977). A large-scale professionally oriented medical information system—five years later. Journal of Medical Systems, 1(1).

[42]There is a long history of database management systems of which TMIS could be included. For an overview of this history, see Haigh, T. (2006). "A veritable bucket of facts": Origins of the data base management system. SIGMOD Record, 35 (2), 33–49. For a case study of SDC's (a Cold War systems vendor) entry into this area, see Baum, C. (1981). The system builders: The story of SDC. Santa Monica, CA: System Development.

[43]Watson, R.J. (1977). A large-scale professionally oriented medical information system—five years later. Journal of Medical Systems, 1 (1).

[44]It was not long before Technicon redesigned TMIS to maintain records for a longer period of time, as the short-term model prevented adequate feedback—a key component of systems theory—from being available to a patient's physicians and other caretakers.

[45]Barrett, J.P., Caswell, R.J., & Hersch, P.L. (1975). Evaluation of the impact of the implementation of the Technicon Medical Information System at El Camino Hospital. Part II: Economic trend analysis. Columbus, OH: Battelle Memorial Institute.

[46]Hodge, M.H. (1987). History of the TDS medical information system. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 143–152). New York: ACM Press.

[47]See Lockheed Missiles & Space Company. Hospital information system: Multihospital operational demonstration: A proposal to the United States Public Health Service. The proposal noted that: "...it is expected that the most critical aspect of system evaluation will be that of physician acceptance."

[48]"Thinking time" was calculated to be a response time less than three seconds. See Watson, R.J. (1974). Medical staff response to a medical information system with direct physician-computer interface. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 299–302). Amsterdam: Elsevier. Watson chaired the El Camino Hospital MIS committee and was responsible for encouraging use among all hospital constituencies.

[49]Watson, R.J. (1977). A large-scale professionally oriented medical information system—five years later. Journal of Medical Systems, 1 (1).

[50]Watson, R.J. (1977). A large-scale professionally oriented medical information system—five years later. Journal of Medical Systems, 1 (1).

[51]See Watson, R.J. Medical staff response to a medical information system with direct physician-computer interface. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 299–302). Amsterdam: Elsevier. One notable change was the introduction of an automatic "log out" function. Physicians often forgot to log out of their sessions, causing concerns about privacy and misuse of the system.

[52]Gall, J.E. (1974). Introduction of a user-oriented THIS into a community hospital setting—tactical management revelations. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 121–126). Amsterdam: Elsevier.

[53]Hammond, W. (Ed.) (1987). Patient management systems: The early years. In B.I. Blum (Ed.), Proccedings of the ACM Conference on the History of Medical Informatics (pp. 153–164). New York: ACM Press.

[54]Gibbons, R. (1963). Doctors Told: Automation Is Bad Medicine. The Chicago Tribune, S16.

[55]In addition to a cold reception of computers in medicine, many other sectors of society and business expressed hostility toward the technology's introduction. For a discussion of the conflicts between utopianism and hostility over computers, see Turner, F. (2006). From counterculture to cyberculture: Stewart Brand, the Whole Earth Network, and the rise of digital utopianism. Chicago: University of Chicago Press.

[56]Hodge, M.H. (1990). Direct use by physicians of the TDS Medical Information System. In B.I. Blum & K. A. Duncan (Eds.), A history of medical informatics. New York: ACM Press.

[57]Hammond, W.E. (1987). Patient management systems: The early years. In B.I. Blum (Ed.), Proccedings of the ACM Conference on the History of Medical Informatics (pp. 153–164). New York: ACM Press. Hammond, an academic and medical doctor, was an early pioneer of electronic medical records at Duke University. He received the Morris F. Collen lifetime achievement award in medical informatics in 2003.

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[58]Watson, R.J. Medical staff response to a medical information system with direct physician-computer interface. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 299–302). Amsterdam: Elsevier.

[59]Office of Technology Assessment. (1977). Policy Implications of Medical Information Systems. OTA's report examines the current state of medical information systems and discusses their strengths and limitations. The report uses three case studies, including TMIS.

[60]Watson, R. J. Medical staff response to a medical information system with direct physician-computer interface. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 299–302). Amsterdam: Elsevier.

[61]Gall, J.E. (1977). Demonstration and evaluation of a total hospital information system. Hyattsville, MD: El Camino Hospital. Battelle Laboratories promoted the systems approach in its own work, perhaps making its review of the system more favorable.

[62]Quoting Bolman, L., & Deal, T.E. (1991). In Orlikowski, W.J., & Gash, D.C. (1994). Technological frames: making sense of information technology in organizations. ACM Transactions on Information Systems, 12 (2), 174–207. Orlikowski and Gash define "technological frames" as the "assumptions, expectations and knowledge" used to understand technology in organizations.

[63]Hawkins, R.E. (1974). Introduction of a user-oriented THIS into a community hospital setting — introductory agents and their roles. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 75–77). Amsterdam: Elsevier.

[64]Duncker, E. (2000). How LINCs were made: alignment and exclusion in American medical informatics. Information Society, 16 (3), 187–199.

[65]Cook, M. (1974). Introduction of a user-oriented THIS into a community hospital setting — nursing. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 303–304). Amsterdam: Elsevier.

[66]Berg, M. (1996). Practices of reading and writing: The constitutive role of the patient record in medical work. Sociology of Health & Illness, 18 (4), 499–524.

[67]Barley, S.R. (1986). Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments. Administrative Science Quarterly, 31 (1), 78–108.

[68]Rosenberg, C.E. (1987). The care of strangers: The rise of America's hospital system. New York: Basic Books.

[69]Watson, R.J. (1977). A large-scale professionally oriented medical information system — five years later. Journal of Medical Systems, 1 (1).

[70]Gall, J.E. Introduction of a user-oriented THIS into a community hospital setting — tactical management revelations. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 121–126). Amsterdam: Elsevier. Gall notes that those users who complained most about the system were those who received least direct benefit from it.

[71]Duncker, E. (2000). How LINCs were made: Alignment and exclusion in American medical informatics. Information Society, 16 (3), 187–199.

[72]Hammond, W.E. (1987). Patient management systems: The early years. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 153–164). New York: ACM Press.

[73]Barrett, J.P., Caswell, R.J., & Hersch, P.L. Evaluation of the impact of the implementation of the Technicon Medical Information System at El Camino Hospital. Part II: Economic trend analysis. "Better patient care" was defined as a reduction in errors, rather than a qualitative assessment of patients' or the community's satisfaction. This reflects a continuing emphasis on improving organizational and business processes.

[74]Watson, R.J. (1977). A large-scale professionally oriented medical information system — five years later. Journal of Medical Systems, 1 (1).

[75]Cook, M. Introduction of a user-oriented THIS into a community hospital setting — nursing. In J. Anderson & J.M. Forsythe (Eds.), Proceedings of the First World Conference on Medical Informatics (MEDINFO '74) (pp. 303–304). Amsterdam: Elsevier. While this paper only addresses the involvement of nurses in TMIS to a limited degree, nurses were considered not only early adopters, but also key proponents of the system.

[76]Hodge, M.H. (1987). History of the TDS medical information system. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 143–152). New York: ACM Press.

[77]Personnel in subordinate positions in many industries took to the systems approach as a way of legitimizing their work and reinventing their status in their organization, with varying degrees of success. See Haigh, T. (2001). Inventing information systems: The systems men and the computer, 1950–1968. Business History Review, 75, 15–61.

[78]Hodge, M.H. Direct use by physicians of the TDS Medical Information System. In B.I. Blum & K. A. Duncan (Eds.), A history of medical informatics. New York: ACM Press. As physicians came to accept TMIS, and Battelle returned a favorable review of its abilities, the media came to support the system as well. Hodge identifies newspaper headlines becoming more positive in 1973, including "Medical Computer Draws a Worldwide Audience," "'Automated Hospital' Backed" and "Doctors Favor Computerized System."

[79]For a brief history of the NIH Clinical Center system, see the Center's July 2001 newsletter at: http://www.cc.nih.gov/about/news/newsletter/2001/jul01/index.html

[80]Reporter, The Wall Street Journal. (December 21, 1979). Revlon and Technicon Sign a Merger Accord With Revised Terms. Whitehead used the profits from the sale of Technicon to build the Whitehead Institute for Biomedical Research at Massachusetts Institute of Technology (MIT) in the 1980s, where it still exists today.

[81]Most wired winners 2003. (2003). Hospitals & Health Networks Magazine. Retrieved March 1, 2009, from http://www.hhnmostwired.com/hhnmostwired/html/winners2003.html

[82]Collen, M.F. (1995). A history of medical informatics in the United States, 1950–1990. Indianapolis, IN: American Medical Informatics Association.

[83]Other influential hospital systems include: LDS Hospital System (HELP); Johns Hopkins Hospital System; and Texas Institute for Research and Rehabilitation Information System.

[84]Collen, M.F. (1995). A history of medical informatics in the United States, 1950–1990. Indianapolis, IN: American Medical Informatics Association.

[85]Collen, M.F. (1995). A history of medical informatics in the United States, 1950–1990. Indianapolis, IN: American Medical Informatics Association. Also see: Barnett, G.O. (1987). History of the development of medical information systems at the laboratory of computer science at Massachusetts General Hospital. In B.I. Blum (Ed.), Proceedings of the ACM Conference on the History of Medical Informatics (pp. 43–49). New York: ACM Press.

[86]Barnett, G.O. (1974). Massachusetts General Hospital computer system. In M.F. Collen (Ed.), Hospital computer systems (pp. 517–545). New York: John Wiley & Sons.

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[90]Bengelsdorf, I.S. (1968). Systems Analysis Opening New Horizons for Mankind. The Los Angeles Times, p. B6.

[91]Farrell, A. (2005). What We Can Learn from TDS Even Today [Electronic Version]. HISTalk. Retrieved February 20, 2010, from http://histalk.blog-city.com/guest_article__what_we_can_learn_from_tds_even_today.htm Farrell is also a former Product Director at Technicon, giving her unique perspective as medical personnel and designer.

[92]See Mindell, D.A. (2008). Digital Apollo: Human and machine in spaceflight. Cambridge, MA: MIT Press. Mindell discusses the theme of man and machine in the context of space.

[93]Good case studies in this vein include: Yates, J. (1989). Control through communication: the rise of system in american management. Baltimore: Johns Hopkins University Press and Zuboff, S. (1988). In the age of the smart machine: The future of work and power. New York: Basic Books.

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