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Studying The Increased Use of Software Applications: Insights from the Case of the American Petroleum Industry, 1950-2000

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Abstract: Software applications represents a new field of study within the history of computers. The author discusses how to do research on the history of applications, using the example of the petroleum industry to illustrate the approach. It involves discussing interactions among technologies, software, business issues, and industries, and argues that without such a holistic approach it becomes difficult to appreciate the historical importance of computers and their effects on society.

Keywords: software applications, petroleum industry, Texas Instruments, IBM, historiography

When historians launch a major phase in their study of a general subfield, for example the history of software, they must engage in a dialogue concerning the definition and scope of such studies. So far, and at the risk of a large generalization, software is generally thought of as programming languages, systems that make computers operate, or code for sale (such as an application or game). Taxonomies exist and, no doubt, new ones will be developed in response to the historian's impulse to organize and rationalize the study of important topics.[1] The majority of the research done on the history of software has focused on ephemera, such as programs ("lines of code"), how they were written, and the history of their integration and relative performance one versus the other. So far, the majority of the work has centered on programming languages and systems software.[2] Yet even with these two topics, there still exists a paucity of material, which becomes evident whenever an historian looks about for the prior historical literature to offer direction and scope. The study of software's history by professional historians is sufficiently new that the subject has a startup feel about it. However, a body of responsible research is slowly accumulating around the business of software, that is to say, histories and economic analyses of the "Software Industry."[3]

Those defending the particularist historiography of software might argue that the history of an industry is not the same as the study of software's past, claiming instead, that the study of the history of software involves discussions about the science and technology involved and, in time, the circumstances under which these evolved. Over time, one might expect such arguments to suggest a hint of the future historiography that is more social, perhaps economic in tone. But that all lies in the future; today the hunt is largely focused on the history of specific types of software and the techniques for their creation and use.

We have an equally large problem that involves the one category of software that provided the rationale for using computers in the first place, applications. Corporations, government agencies, schools and universities rarely acquired programming languages or systems software just for their own sake; rather, these were put into service to create and operate machines running application software. The latter provided services to an end user; put another way, "answers" from a computer. Examples include word processors, spreadsheets, inventory control systems, software to operate ATMs, POS terminals, factory production planning systems, online blueprint design tools, and so forth. The list is endless.[4]

But how are we to study such a vast eclectic accumulation of trillions of lines of applications software?[5] It would seem a more comfortable proposition to write histories of programming languages, a few famous software packages, perhaps boldly move toward a history of a specific use (e.g., email, word processing), and, of course, all the various methods for the design, writing, testing, and installation of software. But I would like to propose that the study of software applications can have some discipline to it that makes it possible to take the other kinds of studies of software (e.g., of specific programming languages) and place them nicely, and simultaneously, into the rich context of their use. Only if we do that does the history of software ultimately become historically important in a broad sense, especially to audiences beyond historians of information technology (IT). A rationale approach to the study of applications also serves the important requirement of the historian to provide a taxonomy with which to organize the work of millions of programmers and users of computers over the past half-century, whose total output of effort led the economies of the world to spend one to four percent of their Gross Domestic Products over the past quarter century; in short, trillions of dollars.

A possibly useful, early approach is to examine the role of applications, software packages, and end user communities within the context of specific industries. What little we know about the use of computers at an industry level suggests that what applications were adopted by specific companies was largely influenced by what other firms in the same industry did; in fact, adoption often took the form of an industry-wide initiative coordinated by a trade organization (as occurred with bar codes in retail, and check design in banking). To test that assumption, looking at what uses to which companies deployed computers can serve as an early step in the right direction. It holds out several possibilities. First, we can learn what applications were used, when, and by how many. That inventory can then lead secondly to a series of discussions about providers of such software, such as data processing departments within firms, vendors of hardware and software, their interactions, and so forth. Third, we then can move to discussions about the effects of computing on specific industries, and ultimately to individual types of applications, programming languages, and other software tools across multiple industries or a national economy.

Historians have learned that the study of specific artifacts must proceed hand-in-hand with non-technical issues such as biographies of inventors and users and analyses of societal impacts. The study of the automobile, the clock, computers, flight, weapons, just to mention a few, are familiar examples. But the same also applies to application software. To write a history of an inventory control package written in COBOL, operating on an IBM System 360 computer, using OS in the mid-1960s, ignores the central issues of why someone wanted the software in the first place, how it influenced the affairs of a company, an industry, or an economy. To conduct the research effectively, we are quickly forced to recognize what historians of clocks, cars, and computer chips have known for some time, that context and other issues must be drawn into the discussion.[6] Looking at software through industry eyes can help launch a fuller discussion of software's history and role.

It is the nature of application software that it is not so unique *per se* to one company or organization. A team of programmers might write an inventory control application in COBOL for an aerospace company that, line for line reads differently than an inventory control system used at the same time by an automotive manufacturer, written in Assembler. But they both perform essentially the same functions: tracking and forecasting the "ins" and "outs" of inventory movement in a company. Furthermore, it is also a characteristic of users of applications to borrow notions of how best to incorporate them, and for what reasons, from other enterprises and industries. Nobody, it seems, operated in isolation. They read each other's trade magazines, IT industry publications, and attended industry and technical conferences where people shared their experiences about software applications.[7] By the early 1960s, computer user groups were in evidence, such as the important IBM user's group, SHARE.[8]

My own research suggests that the greatest influence on which applications were written (or bought) came from the experiences others had within an industry.[9] That is not to say that vendors were not important, or other programming experiences within a particular IT organization or company, but ultimately, enterprises learned from others in their own industries. In commercial operations, the hunt for competitive advantage and productivity meant that business and technical managers made their decisions about what application software to acquire almost always within the context of their competitive circumstance. Put another way, it is difficult to imagine that one could study the history of software applications without coming to the topic from a business or user-centric perspective. There may be other ways to study application software, but approaching it through the lens of business history is a useful way to start since we know little about the history of this topic.[10] Furthermore, it appears practical to begin the historiographical exercise by looking at the subject from a user perspective, since industries influenced the types of applications enterprises installed, the experience an organization had with this class of software, and the rate of its deployment.

This approach offers certain advantages for the historian. First, every major industry long had associations and trade publications that documented the issues of the day, including the role of computers and applications. Most of these transcend the entire period during which computers existed and in some cases, date back to the early years of the twentieth century, which provides the added benefit of being able to study pre-computer histories of other uses of business machine applications. In the case of the United States, there are almost no exceptions to this generalization about the availability of materials for the entire period of the computer. There exists a large body of contemporary material conveniently available on such issues as what applications were used, their features, why, when, by whom, to what extent, and with what consequences.

Second, there are a substantial number of contemporary "how to" technical IT publications that describe how to write and implement software. These often include case studies. Related materials include thousands of application briefs published by hardware and software vendors, describing specific examples of implementation, all done to support the sale of their products. This ephemera, nonetheless, cites specific users by name, dates the installation and use of applications, describes rationale for these and the consequences of deployment, and provides many other specific details, all grist for the historian. Third, archival evidence exists, primarily of hardware and software vendors, along with old consultants' reports on the scope of deployment of applications; the collections of these kinds of resources at the Charles Babbage Institute (CBI) and at the IBM Archives, for example, are substantial and understudied. Very few historians have examined these materials. Finally, we know that some individual companies and government agencies have buried in their respective archives documentation on their use of applications. These collections have barely been tapped, although we have some stunning examples of the potential of this documentary evidence in the studies done on military applications, airline reservation systems, and ERMA (an early banking application).[11] Not all of these various sources need be used in every study of an industry's use of applications, but eventually one would expect all to be examined.

So how would one go about examining applications from an industry-centric perspective? How would technical issues and business concerns integrate to provide both insights into the use of computing technology (especially software) while contributing to the history of an industry? These are new questions to ask of the history of software applications. In part the answers will be a reflection of what the historical evidence begins to suggest, while over time, other concerns will surface suggesting new lines of research. But taking an institutional, non-technical view of applications suggests a useful approach to the initial study of software applications.

The best way to illustrate this approach is to try it. It quickly becomes very clear that software, hardware, business, and economic issues mixed together from the beginning of commercial uses of computers. It is virtually impossible to isolate them and still preserve a sense of the true importance of application software from the context of its use. The case study below is intended to suggest what a study of an application might look like from an industry perspective. Given the fact that in any advanced economy there are literally hundreds of industries that one could study, the opportunity for both historians of technology and business to come together, to learn from each other, and to be informed in new ways is significant.

I focus entirely on the perspective of the user, leaving out the real possibility that the software or hardware industries had a role to play in injecting software into an industry. To discuss that side of the economic equation—the supply side of the story—would have more than doubled the size of this essay. But it will need to be done elsewhere to provide a full picture of other industries, such as those that supplied the technology and software. For example, Texas Instruments, in the decades before the arrival of the computer had sold a variety of seismographic tools to companies in the petroleum industry which were logical candidates for computerization in the 1950s and 1960s, leading to the evolution of this firm into a major participant in the IT industry.[12] Yet to be answered, and beyond the scope of this essay, are such obvious questions as who provided software and how. Did users write all their own software, or if not, who did? Were conditions placed on the use of software tools by vendors? These are all questions that would increase our understanding of the role of software in general, and more specifically, the interactions between the petroleum industry and other computer-related industries and firms, such as software vendors beginning in the 1970s.

The U.S. petroleum industry suggests how the history of software applications can be studied. It is an industry profoundly influenced by the use of software. That influence extends to the daily work in all corners of the trade, and ultimately affects the organization of its enterprises and the configuration of the industry as a whole. It is an industry that has a long history of working with all kinds of technologies, so that by the time the computer came along, its managers were sufficiently versed in complex instrumentation and earlier information technologies to effectively leverage computers and software. This is also an industry that embraced the use of computers early on, pushing some of the technical boundaries of both hardware and especially software, particularly in the formative years of the technology (1950s-60s), for which we have a useful body of historical records with which to trace their adoption and evolution. The companies making up the industry were large, hence could afford to install many computers, build complex IT systems, and write a great deal of software. It also employed many thousands of IT professionals, spending a great deal on computing over the past half-century. While other industries might well have been chosen, such as those in manufacturing or even other process industries (like the chemical trade), the petroleum industry did just a little more than others over the entire continuum of the half-century.

The high level of concentration of activities in this industry in the hands of a few companies is one of its most distinguishing features. For the historian, it is an example of the arguments put forth by Alfred D. Chandler, Jr., about the propensity of industries to look for efficiency, and to use a term from the late 1990s, the reduction of "friction" in the economy of its internal operations. It is an industry that also spent a great deal of its time and resources selling and working within itself, unlike so many manufacturing industries that needed to interact with firms in other industries or in retail, which has to work with manufacturers and transportation industries. Its insularity made it possible for the petroleum industry to develop its own distinctive cultural traits. While a discussion of that culture is outside the scope of this essay, one feature that at least should be acknowledged is a propensity to rely on and be comfortable with technologies of all types, especially those that deal with continuous processing. It is within that context that the industry embraced various forms of information technology and its management software as a valued asset, much like an invention or a trade secret, even from the earliest days of computing.

Software applications in the U.S. petroleum industry

This is one industry of the post-World War II period which became the subject of so much attention around the world because it was the source of a series of oil supply and pricing crises. It remained tied up in various Middle Eastern wars, including most recently the Gulf War of 1991, and involved questions of national security as American dependence on Arab oil remained high through the second half of the twentieth century. However interesting and important all these issues are in understanding the international economics of the recent past, we can safely bypass most of that history because, regardless of political considerations, day in and day out this industry still drilled for oil, refined it, and shipped it to customers. Its products fueled the American economy.[13]

This is an industry which has long suffered from an image of being stodgy, even old fashioned; however, nothing could be further from the truth in so far as it concerns the use of technologies of many types. Of all the long-established manufacturing industries, the petroleum trade has consistently been one of the most high-tech, extensive users of computing technologies. It has been high-tech all over the world, from the oil fields in the Arab Emirates to its retail gas stations across America. The breadth of its inventory of software applications is impressive by any measure.

But to understand the nature and value of these applications, first we need to understand the industry's structure because firms within each part of the industry are the ones that embraced information technology, and installed applications. This industry essentially comprised four parts over the half-century. The first was production, which located and extracted natural gas and crude oil from the earth. The second consisted of refineries, which manufactured such finished products as gasoline, jet fuel, kerosene, and other liquid petroleum-based goods. This second cluster often has been called the petrochemical industry. A third piece of the industry consisted of those firms or divisions of companies that marketed and sold products, both wholesale and retail. Gas stations fit into this segment of the industry. The fourth component comprised transportation which, in this industry in the U.S., normally consisted of all the pipelines that moved oil from well heads to refineries (but also ships if coming from outside the country), and by truck and pipe to retail outlets. Over the past century, the largest firms in the industry have generally attempted to play an active role in each of these four segments. There also existed smaller firms active in one or some of this industry's sectors.

In the decade following World War II, seven vertically integrated firms dominated the industry and were called the majors or "seven sisters." Five were based in the U.S., the others in Europe. The American firms were Exxon (Esso initially), Texaco, Gulf, Chevron, and Mobile. British Petroleum and Royal Dutch/Shell are the two major European firms, although sometimes experts on the industry like to add an eighth, the French Compagnie Francaise des Petroles (CFP). In 1950 these eight companies controlled one hundred percent of the production of crude oil outside of North America and the Communist bloc. In 1970, they still controlled eighty percent. This control always involved an extensive array of alliances, supported by national governments. In short, it was an oligopolistic arrangement, operating on a global basis for much of the twentieth century. In addition to these firms, in the 1950s a series of smaller companies emerged called "the Independents." These companies found, extracted, and sold oil on the "spot" market. They caused national governments in producing nations to play an extensive role in determining prices, availability, and other terms and conditions as the century marched on.[14]

In 1950 the U.S. produced the majority of the oil it needed; by the early 1970s it was importing over a third of its requirements. On a worldwide basis in 1974, the U.S. produced 15.6 percent of the world supply, 10.6 percent in 1998. The Middle East in 1974 produced 38.9 percent and in 1998, 34.8 percent. Newly emerging economies in the intervening years added to the total supply of oil, such as the North Sea fields in the Atlantic Ocean off northern Europe, and Latin America. Beginning in the late 1990s new sources emerged in Asia and in what used to be the Soviet Union.[15]

At the end of the twentieth century, oil companies went through another round of mergers and acquisitions to reduce overall operating costs, and to enhance what economists liked to call “forward integration,” which meant firms participating in more sectors of the four parts of the industry.[16] National governments permitted this after several decades of attempting to control industry dynamics. In August 1998 British Petroleum (BP) and Amoco merged; then in December Exxon and Mobil. Other mergers occurred around the world as well. Members of OPEC (Organization of Petroleum Exporting Countries, established in September 1960) expanded their ownership of assets in the American economy, most notably Saudi Arabia, which had acquired half-ownership of Texaco’s American refining and distribution network in November 1988. The newly merged majors accounted for about four percent of the world’s crude oil production. One of the reasons such mergers could occur was due to application software, which made it possible to integrate various operating units. This held out the promise of efficiencies of scale while extending market share, or what economists called “scope.”

IT deployment

Because of the widely differing activities of each of the four parts of this industry, a brief survey of computing by sector gives us a better sense of what happened within petroleum firms. Production is the first area to look at. There are essentially two basic activities involved: determining where to drill for oil and gas, a geological exercise, and second, drilling holes and extracting the crude oil and natural gas. The earliest software applications in production were used to accumulate and present data on various processing conditions, beginning in the 1950s. Linking existing instruments to computers allowed firms to begin presenting information useful to operators in the field. During the 1960s and 1970s, software increasingly directed instruments to change their activities in real-time, thereby bringing a profound level of automation to field production work. The same trend appeared in refinery operations.[17] In the 1950s and 1960s, the majors all experimented with centralized computing and data collection from field operations.

With the availability of smaller computer systems (e.g., IBM’s 1400s) in the 1960s, and minicomputers in the 1970s, local data processing operations were established in the field, but normally linked to some centralized control function, particularly as software increasingly took over functions performed by field personnel. By the late 1960s, one could speak about a computer production and control system that monitored status of remotely located wells, collected production information, and generated a raft of management reports. Automating these functions proved essential since many wells were small and isolated, and there were tens of thousands of them scattered all over the United States. Typical software applications written by these companies included monitoring and scheduling production, conducting automated well testing, controlling secondary recovery, operating alarms for problems with flow and leaks and machine failures, performing data reduction and reporting, executing engineering computations, and managing optimized gas plant controls. These firms were increasing overall production and yields per site, determining from an economic perspective when it was best to abandon a field, reduce production downtime, lower operating costs, utilize field engineers more effectively, and inform management. In the 1950s much of this was batch processing, but by the end of the 1960s, a great deal was real-time and online computing.[18] By the early 1970s, drilling operations were coming under computer control for the purposes of monitoring drilling activities (such as drill penetration rates), reporting results in offshore drilling, optimizing drill-bit life, and reducing various testing operations. Many locations often would have a staff of one to three DP professionals to do this work. However, extensive deployment of computing in drilling operations did not occur until the end of the 1970s.[19]

Determining where to drill for oil has long been a critical activity, requiring extensive knowledge of geology and calling for good judgment because drilling has always been an expensive operation. "Dry holes" normally cost millions of dollars in unproductive expenses. In the 1950s, computers held out the hope of being used to model geological conditions and perform analysis to help firms determine where to drill. Not until the amount of computing increased sufficiently in the 1960s did this become possible. At that point the first geological and geophysical mapping software applications were written, a collection companies continuously have enhanced to the present. These applications included the study of shock wave reflection patterns, and analysis of data from test well drilling. By the end of the 1960s many firms had developed software applications that helped in well drilling control, using mathematical models to determine in advance where best to put wells, relying on financial models to figure out what to pay for acquiring mineral rights to drill, others for online testing, and then pipeline management systems. By the end of the 1970s these tools were in wide use, reducing the amount of guesswork by highly experienced personnel, their work and decisions now controlled more by software.[20]

When initial experimentation with computer-based models started at the beginning of the 1960s, it was not clear to management in general, and even to DP professionals, exactly how useful computing could be in the area of simulation. That is largely why one commentator from the period could argue casually that simulation made it possible "to allow management to 'play around' with supply and distribution schedules, or the design of complex process facilities, without disrupting present operations." But they quickly found out that software could handle even better than humans the "interpretation of tremendous volumes of seismic and geologic data." One of the earliest databases of such information, known at the time as the Permian Basin Well Data system, evolved into "a huge electronic library of information relating to one particular oil producing area."[21] Today no drilling occurs without extensive computer-based modeling of options. At the same time, all drill sites are overwhelmingly automated, extensively controlled from remote locations.[22]

Refining is as close to pure manufacturing as one gets in this industry, with the critical task being the conversion of raw crude into a variety of products that can either be shipped in bulk to other firms, e.g., gas stations, or are converted into consumer products, such as cans of oil sold in a Kmart store, or as raw materials for other industries to use (e.g., plastics). A typical refinery looks like an organized bowl of spaghetti with many miles of pipes going every which way and attached to large, tall containers that do the transformation of crude to various products. The key notion to keep in mind is that all the work is continuous. The industry places a premium on uninterrupted operations, and on absolute under-standing of what is happening at every stage of the process. Long before the arrival of the computer, the industry had developed a raft of analog-based instruments to support these objectives. Computers and software applications tailored to specific configurations of petroleum industry technologies were then deployed to take control of these instruments, monitor and manage them, and redirect activities as needed to optimize continuous production. Over the entire period we are looking at, firms continuously upgraded instruments, digitizing many of them, and optimizing the whole process.

Refineries are large, complex, and expensive installations, providing perfect locations for computing so it should be of no surprise that some of the earliest installations in this industry were housed at refineries. By the middle of 1963, nearly fifty refineries in the U.S. had installed one or more data processing systems for the purposes of increasing production of products, helping reduce operating costs, and improving quality control. Standard of California used its system to control catalytic cracking operations; American Oil Company in Indiana used a computer to manage 437 tanks controlled by 13 pump houses; while American Oil used theirs for more traditional inventory control, production management, and shipments. How things changed from the 1950s to the 1960s can be gleaned from this description of what occurred at American Oil's refinery in Whiting, Indiana:

> There was no scarcity of basic data at the Whiting refinery. During 70 years of operations, such information had been developed each day through the use of gauge sheets, unit morning reports, weekly stock reports, routine staff reports and similar documents. These items of information, however, arrived at different times and were difficult—if not impossible—to assimilate.

Management elected to install computer systems to integrate this data and better time its delivery:

> The system today [1960s] involves a smooth and rapid flow of data from 13 reporting locations to a computer system. Supervisors at the various pumphouses mark sense tank inventory and shipment information onto cards. These cards are collected periodically, automatically translated into standard punched codes and fed into the computer system. Final result: a daily IPS (inventories, production and shipments) report providing all the information needed by management, ready and waiting by 8 a.m.[23]

The same location next upgraded to online systems, feeding data into its applications in real-time. In time, all refineries connected their various analog instruments to computers, translating analog readings into digital data.

Deployment in these early years proved impressive. Refineries had five computer systems in the U.S. in 1959, ten by early 1961, and by mid-1968, 110.[24] Rapid deployment of computing in process industries was normal in the 1960s, and not limited just to refineries. Between 1963—the year in which a significant number of systems were installed across the nation in process industries—and 1968, the installation rate averaged 48 percent per year, and around the world 55 percent.[25] In short, this was the era when computing arrived in volume in all process industries. In the 1970s and 1980s, refineries filled up and upgraded and enhanced their systems, but in the 1960s they had figured out what to use computers for and began to invest in them. By the start of the 1970s, the U.S. Bureau of Labor Statistics (BLS) was able to report that about 25 percent of all American refineries, which constituted about two-thirds of the entire industry's production capacity, used computers.[26]

Increasingly, process control involved all refining processes, from crude distillation to online gasoline blending. In the 1960s and 1970s, open-loop processing was wide-spread across the industry. Open-loop processing involved data gathering by instruments which software turned into reports presented to supervisors. These reports informed their decision-making. Their decisions were then relayed back to equipment through computers. Increasingly in the 1970s and throughout the 1980s, the industry moved to closed-loop applications in which humans were taken out of decision-making steps, delegating these to software, which used decision tables to automatically make many more, incremental operational decisions and adjustments. This approach took advantage of the growing experience the industry was acquiring with software and the fact that refineries were becoming increasingly large, hence more complex to operate. BLS economists in the 1970s observed that it was not uncommon for a refinery to have over one thousand instruments and sensors linked to a computer system. Some of these collected complex data, such as chromatographs, mass spectrometers, and octane analyzers. Computers helped with the complexity, but as in other industries, speed in resolving problems proved an essential benefit of such systems.[27]

The third sector of this industry, wholesale and retail sales, is perhaps the most visible part of the industry to any American because its companies sold the bulk of their products either through gas stations or to fuel oil companies that, in turn, delivered gas and heating oil to homes and businesses in trucks. Increasingly in the 1980s, and extensively during the 1990s, products also were sold through non-industry controlled retail outlets, such as oil in quart containers at Kmart, 7-Eleven stores, and so forth. The most visible application, and in a sense novel in the 1950s and 1960s, was the deployment of the gas credit card. It is unique because the retail industry as a whole embraced the credit card later than the petroleum industry at large, with the two exceptions of restaurants and hotels. Much of the early experience with credit cards on a massive basis, therefore, came out of the work of such oil companies as Mobile, Esso (later Exxon), Gulf, and so forth. Credit cards were developed in the 1950s,[28] and by the early 1960s, sixty petroleum companies were issuing gas credit cards; in fact, they had issued seventy million of them. A quarter of all purchases made by the public in the U.S. via credit cards in the early 1960s came from gas credit cards, involving billions of dollars in small transactions. In the late 1950s, only ten percent of all Americans had a gas credit card, one-third of all adults did by the mid-1960s. It was also not uncommon for Americans to have multiple gas credit cards.[29] In short, credit cards brought about a major change in how petroleum companies interacted with their customers in post-World War II America.

These cards exposed millions of American adults to credit cards in general, conditioning them for bank-issued cards before the major expansion of the likes of American Express, Mastercard, and Visa that took place in the 1970s and 1980s.

We know a great deal about the early history of this application, thanks to a well informed report presented at the 1964 annual meeting of the Data Processing Management Association (DPMA) by James C. Beardsmore, Sr. At the time he was employed in the marketing department of the Gulf Oil Company. He indicated that the reason it was such a significant application grew out of the fact that the volumes of transactions, and the dollars involved, were so extensive. Simultaneously the number of billing centers and personnel involved to process these transactions had grown so very quickly, that his industry faced huge costs and managerial issues. At the same time there was intense focus on providing high levels of customer and dealer services because of growing competition in the American market. The application was not always computerized, but became increasingly so to reduce costs and improve service. One major consideration was quickly getting bills out to customers, leading to processes and software programs whereby a certain number of bills were created and mailed every day.

He characterized Gulf's operations as typical for his industry. The extent of computer technology deployed was impressive. In the period just prior to IBM's introduction of the System 360—which Gulf installed—it used first IBM 1401s and then IBM 1460s to support this application, along with early bar code readers, and punch card peripheral equipment. He said the firm borrowed time on the company's 7070 and 7074 systems to do processing. Prior to 1961, the firm did not use a credit card imprinter and had to develop one with various suppliers because that became the critical data gathering instrument needed to capture information about an individual sales transaction. His company's credit card accounting system consisted of a customer master record, which triggered the billing and accounts receivable processes. Once data was in the billing system, the application was typical of what existed in most companies during the 1960s.[30] These firms also implemented incremental changes in the application. The most visible for customers arrived in the mid-1990s when they could insert their card into the gas pump machine and have it authorize their purchase by credit without requiring signatures. It was fast and paperless, saving gas companies and retail outlets the expense of handling millions of small transaction documents. Use of credit cards by American drivers has remained to the present an essential sales tool for the industry.

The actual form of the credit card—a plastic document just slightly larger than a calling card—illustrates the interaction between applications and technologies. As one group of observers in the 1960s argued, “the optical scanner was one of the factors which made possible the introduction of credit cards.”[31] The problem this industry faced with credit card sales prior to the arrival of the plastic card and optical scanning was serious:

> The conditions under which the credit slip is filled are often difficult. The card might be exposed to rain, be covered with grease from the station operator’s hand, be bent or mutilated during handling, and so on. The imprinting on the card must be clear and uniform in order to be scanned.[32]

Moving from paper stock to plastic (itself a petroleum-based material) and to pressure-type imprinters resolved the problem. With uniform lettering impressed on the slips from the card, a scanner could be used to read these little documents, regardless of whether or not the slips were dirty or otherwise in less than pristine condition. Initially 80 to 92 percent of all documents submitted to scanners were read; later versions of the scanners read higher percentages of these papers. Companies outside the Petroleum Industry made arrangements allowing customers to use their gas cards to make purchases in stores. That capability forced all card issuers to standardize on lettering and design of cards, and in the use of both scanners and the software applications supporting this billing process.[33]

The fourth area of the petroleum industry, and also one that relied extensively on computing, involved transportation of oil and natural gas. The industry needed to transport crude and natural gas (which could be liquefied for that purpose) to refineries, and then to regional wholesalers and dealers. Local wholesalers using trucks made deliveries to homes and businesses. Companies delivered natural gas almost universally by pipelines. The vast majority of all transportation occurred in one of two ways. Ever-larger tanker ships would move crude oil from overseas sources (e.g., the Middle East) to American refineries or via pipelines from wellheads. Refineries normally shipped their finished products by pipeline around the U.S. or, for specialized products, by tanker trucks. In the years following World War II, the industry integrated its network of pipelines from all across the North American continent, and regularly increased the diameter of the pipes themselves in order to expand the volume of product it could ship. Software could help by minimizing the expense of running oil and its various derivatives through the system and to ensure their continuous flow to the right refinery or wholesaler. The entire industry created whole bodies of practices and policies, and inter-firm trade agreements, and so forth to optimize the use of the pipeline network.[34]

For the same reasons that computers appeared in refineries, they did in transportation, often first applied by the majors. While simulation applications were tried in the 1960s, it was not until the 1970s that enough computer capacity existed to make simulation tools sufficiently effective. Yet warehouse location studies were successfully simulated in the 1960s, largely because they required less data for analysis than, for example, geological studies.[35] At the same time that automation came to refineries, such approaches were applied to the management of pipelines: flow monitoring, notification of emergencies, and so forth.[36] Prior to the arrival of the computer, the industry had trunk line stations along the entire network, staffed with employees monitoring what was happening within their section of the pipeline. Increasingly, instruments communicated with computers housed in centralized facilities, displacing workers in the field. The key strategy was to automate the operation of the trunk stations as much as possible. By 1958, nearly a third of all trunk stations were controlled remotely and by the end of 1966 half of them. That number climbed to over 60 percent by 1970 and in the 1980s to nearly 100 percent.[37]

Tied to this deployment were a series of other uses of software and hardware. Delivery scheduling was an early application that remains central to the entire network. Field process controls linked to more traditional applications evident in other industries, such as administrative business, accounting, financial, and auditing work. The major changes in the 1970s were the industry's initiatives to computerize scheduling and link online and central control processing in order to move greater volumes of product through existing pipelines.[38] Economists at the BLS reported that "productivity for complex pipeline scheduling is being increased through better computer programs for database updating, original and revised scheduling, and shipment report preparation." Pipeline engineering design also became more widespread, while firms continuously upgraded pipeline instrumentation throughout the 1970s and 1980s, using an ever growing combination of commercially available products and home grown software and instruments. The result was that by the end of the decade as one commentator declared, "for many pipelines, monitoring and regulatory tasks, including the operation of unmanned pumping stations, are performed by headquarters dispatchers using solid state electronic telecommunications equipment and computers." Minicomputer systems at online stations could be activated to take charge of the operations of a specific section of the pipeline.[39] About 10 percent of all pipeline operators used computers to schedule flows in 1971; that number rose steadily throughout the decade. The industry learned early on to centralize its computer operations as much as possible, and to link applications together, for example, from scheduling to inventory control. They also added pipeline-specific applications, such as computer-controlled leak detection systems that reduced the number of human inspections needed.[40]

It is easy to dismiss accounting applications as being so ubiquitous and uniform in all industries, and also with little industry differentiation. However, because these are ubiquitous applications, we should acknowledge them. If only briefly, we should recognize that in the late 1950s many manufacturing firms, including members of the process industry, moved their applications from tabulating and accounting equipment to computers. The Ashland Oil and Refining Company typified many firms. In October 1956, it installed an IBM 650 computer system, one of over 1,500 firms to do that over the life of this product line. In addition to using the system to do scientific and engineering applications, it also ran accounting work through the same computer. Early applications involved billing and payroll, which held out the promise of saving on the costs of labor. By 1958, the company had written software that allowed it to run a series of accounting applications on this system: accounts receivable aging analysis, depletion, depreciation and amortization schedules, daily refinery inventory, and other programs. The programs were batch, and the data entry occurred with cards. Many of these programs were essentially sort/merge operations, which accounts for why this system had 10 sorters, 7 collators, and 17 card punches. As occurred in so many companies, the strategy was to weave computing into existing accounting practices. The report from which this paragraph was written originated in 1958 and noted that the company "was able to integrate the machine [meaning the IBM 650] into the present machine accounting section with a minimum of change." The technical staff then moved on to the installation of magnetic tape and later RAMAC storage.[41]

In the late 1950s, others did the same. For example, Standard Oil Company of California also installed an IBM 650 and had an IBM 704 for the purpose, as stated by Comptroller W.K. Minor, "of utilizing these machines whenever they will effect savings over the best manual or punched card system or render improved or more timely service."[42] In those days, prior to the time when a software industry existed, a "system" included a variety of software tools provided by the vendor of the installed computer, in this case IBM. Systems included system control software (also known as operating systems), utilities (such as sort/merge programs), compilers (e.g., for Assembler and Fortran and by the early 1960s, a new generation of compilers, as for COBOL). All application software, however, was written by the EDP programmers of the firm or by contract programmers from consulting firms. General Petroleum Corporation, located in Los Angeles, installed a Datatron-Cardatron system in November 1956 to run a payroll accounting system, and a production lease profit and loss application. Like other firms, it often had to anticipate savings from the installation of computers, but expectations were similar. As one employee put it, "we remain convinced that we will save time and money, and produce for management information not now available. The degree to which success in these areas is finally reached will not honestly be known for perhaps another year."[43]

The applications described above were cataloged by the major functions within the industry. However, a few observations about the source of these various types of software are in order. There existed essentially three classes of software: the first which provided monitoring functions, second were basic accounting applications, and third were advanced, complex modeling tools. Accounting applications were quick rewrites of tabulating applications in the 1940s or 1950s, enhanced with tools provided by key computer vendors, such as Burroughs and

IBM, for such things as sort/merge packages, compilers, file managers and TP access protocols (e.g., VSAM) and operating systems. By the 1970s, commercial accounting packages widely available across all industries began to appear in this trade, along with such widely used database packages as IMS and DB/1 by the early 1980s. Commercially available accounting software has remained the norm to the present. Reports on business applications were usually home grown affairs written using COBOL in the 1960s through the 1970s. After that the distribution of business applications took place either through the use of commercially available products, or internally created reports written in RPG, COBOL, and C++, to name a few programming tools and languages.

As for monitoring software, the earliest tools were developed in the years prior to the existence of programming. One of the major providers of such software tools were companies that were predecessors to Texas Instruments. Originally formed in 1930 as the Geophysical Service, later the Geophysical Service, Inc., by J. Clarence Karcher and Eugene McDermott, the firm developed aids to help explore for oil, relying on methods for measuring seismic waves to map conditions under the surface of the earth to determine the possibility of oil deposits existing in an area. The business proved successful, and in a later reiteration during World War II it acquired a substantial amount of expertise in electronics, much as happened to many other firms, such as IBM and NCR. That newly acquired knowledge led Geophysical Service, after the war, to concentrate more on electronics, although it remained committed to geodetic explorations in the industry. In 1953, it acquired Houston Technical Laboratories, which specialized in gravity meters used in geophysical work, selling its services and products to petroleum firms around the world. Beginning at the end of the 1950s, and extending over the next two decades, Texas Instruments (TI) also manufactured and deployed integrated circuits designed to conduct seismic studies under contract to the industry. Applications and software from TI were initially, to use a later term, real-time. Over time, increasing use of digital technologies, and both batch and online software tools characterized the collection of software packages used by TI and the petroleum industry.[44]

Across the entire industry, beginning in the l950s and extending into the 1960s, batch reports of monitoring applications were written internally within its firms, in such languages as Fortran and Assembler. When online processing became available in the 1960s, a long process of converting monitoring applications to computer-based software began. In the 1980s, specialized software vendors began offering software products to the industry for various monitoring applications.[45]

Finally, we have that large class of applications called modeling tools. These were the most complicated packages in existence within the industry. They came from a variety of sources. Individual companies wrote some of the earliest modeling tools in the late 1950s and in the 1960s. CDC, and later Cray, and more specialized software firms also wrote modeling tools, often in conjunction with joint development projects with the largest firms in the industry. In fact, each of the major firms had one project or another with a local university or a computer vendor at one time or another, a pattern of development that has continued to the present.[46]

While going through a description of a series of these projects is a worthwhile exercise, they could easily fill another paper. What is important to understand is that because these firms were large, often having hundreds of IT professionals working for them, even as early as the 1960s, they were able to combine a number of strategies for the acquisition of software. Simple software tools such as compilers and database managers were either acquired from computer vendors as part of renting hardware in the 1950s and 1960s, or were bought on the open market in subsequent decades. Complicated, industry-specific software tools were either written entirely in-house or later acquired from software firms, although always there were internal software development projects in the areas of monitoring and business applications. Simulation applications normally were acquired from joint development projects or as products from other software and hardware firms. These were complicated, called for extensive knowledge of algorithms, and scientific knowledge, such as of geology. In their most advanced stages, this scientific knowledge existed in universities and in a few specialized software and hardware firms, much as it had in the 1920s and 1930s with the companies preceding Texas Instruments.

Effects of software on the industry's productivity

Increases in productivity in this sector of the industry grew, as in refining. In the latter, productivity grew all through the half-century at rates of between 2.9 and 3.2 percent, despite oil crises, but also in part due to increased demand. Occupations became far more complex, increasingly technical and IT-centric throughout the entire period.[47] Pipeline transportation productivity grew at annual rates of ten percent in the years 1958 to 1967 as demand and pipeline management practices improved dramatically. It then dropped to low levels of 1.9 percent between 1967 and 1986, largely due to relative declines in output and to various international oil crises, which periodically reduced demand. Automation in the earlier period actually caused an annual decline in employment of 3.5 percent, evidence of the effects of automation, and more specifically, of the increased centralization and complexity of the control systems used to manage the network of pipelines.[48] This sector of the industry, as well as the other three, installed many of the new computer systems that came out in the 1980s and early 1990s, largely because of their increased capacity and versatility which proved so essential to the centralized applications embraced by all four sectors of the industry. Larger systems also made possible simulation applications in all four sectors, and especially in pipeline management practices in the 1980s and 1990s. A BLS economist in 1988 concluded that, "the petroleum pipeline industry has attained a high degree of automation."[49]

We can quickly summarize the complex history of computing in pipeline management. In the 1950s traditional accounting applications were the norm. The first use of data processing with computer systems to manage the flow of petroleum came in the early 1960s and expanded over the next two decades. Upgrades to all major applications occurred continuously, but most dramatically in the 1980s and 1990s, as major improvements in computer capacity and their sophistication occurred. By the end of the 1980s all firms operating in this sector of the industry relied on computers and industry-specific applications to do their daily work. Intelligent terminals and PCs were in wide use by the early 1990s, while programmable control logic units were embedded in many monitoring instruments and machinery by the late 1980s. The “hot” applications in the 1980s included improved scheduling and dispatching, leak detection systems, power optimization, and shipment documentation. All were infused with extensive upgrades in telecommunications across all four sectors in each decade.[50] As in the other sectors, as one labor economist noted,

> because of the increasing use of centralized computer control systems involving the operation of almost all the functions of a major pipeline, there has been a shift away from operators involved in such manual operations as opening and closing valves and switches, checking tank levels, and reading meters. These functions have been almost completely taken over by the computer. Pipeline personnel tend to be skilled in computer operations and programming.[51]

The petroleum industry’s dependence on telecommunications to support many of its strategies for centralized computing meant it would be an early user of Electronic Data Interchange (EDI) and later the Internet.[52] Common IT systems and industry-wide practices facilitated the spate of mergers that occurred in the 1990s. They were designed to further operational efficiencies and to expand global reach to sources of crude oil, natural gas, and to markets. IT issues in these mergers were now news items.[53] Standardization, therefore, once again became a high priority within IT organizations in the industry for such application areas as telecommunications, ERP packages, and desktop computing.[54] IT was seen as an essential component of what was happening in the industry. The *Oil and Gas Journal*, clearly not a computing publication, acknowledged the role IT played in helping companies to survive the commoditization of energy that occurred in the mid-1980s, a lesson that it again reminded readers about at the end of the 1990s.[55]

At the start of the new century, the petroleum industry’s expectations included further global consolidations of what by then many called the energy trade. This consolidation was often facilitated by the kinds of software applications already installed in the industry. The industry had many very large players who had the resources to continue optimizing computing. In 1990, Royal Dutch/Shell Group and Exxon were on the list of top ten global companies, as measured by market capitalization; in 1998 they were still there. Both had been leaders in the industry in transforming major segments of their businesses in the 1980s and 1990s, despite oil spills and wildly fluctuating prices for crude oil, and increased competition from ever-larger rivals.[56] As they entered the new century, oil company executives reached out again to IT to help support their strategies of consolidating and expanding markets.

The petroleum industry is an example of an industry in which IT effectively supported corporate strategies, but only in collaboration with industry-wide coordination of such activities as prospecting and transportation. As one observer in September 2000 wrote, "IT and the information it drives are making it possible for energy companies to expand their reach into remote pockets of the world, to understand the consumers that buy their products, and to align their supply chains and procurement efforts with partners."[57]

The Internet became the next enhancement to the variety of telecommunications tools already in use. It became especially useful in expanding communications and sharing of information with retailers who used it to order products, and to communicate levels of supplies in their tanks. Purchasing practices changed, much along the lines evident in the steel, automotive, and aerospace industries and for the same reasons. Communications with tankers expanded, making it possible to send information back and forth in graphical, audio, and textual formats.[58] In this industry, as in so many others, the Internet emerged as a basic component of the infrastructure of the supply chain management process.

Some final observations

This case study of the petroleum industry has both strengths and weaknesses. On the plus side, it is a useful approach for conducting an *initial* inventory of what applications there were and to measure the extent to which companies deployed them. While this exercise is primitive, it nonetheless needs to be done first to establish the rationale and scope for further research. One of the pleasant surprises for an historian of software coming out of such an approach is the extent to which software applications can be placed in the mainstream of more established topics, such as business and economic history. It begins to suggest the true importance of software beyond the circle of technologists, computer scientists and engineers, and their historians. In a long-term study I am conducting on nearly fifty industries, the evidence already demonstrates that computing profoundly changed the nature of work across the entire American economy. In fact, it was as determinative an influence as any other offered by economists or business historians, particularly by the 1980s. This case study on the petroleum industry hints at what is possible to uncover.

Another finding from this study is the need to consider the role of hardware and software together. Historians seem to be dividing into two the study of the history of machines and now an emerging subfield on the history of software. Each topic has issues of sufficient differentiation to warrant specific examination of them separately. But when applications are discussed, and specifically from the perspective of the user community, it makes more sense to combine the two because that is the way companies and the DP departments treated them. Both were components of systems installed for the purpose of generating answers or performing tasks. The fact that systems were made up of software and hardware were fine points of differentiation that only became of intense concern to the technicians installing components of a system, or the vendors who supplied hardware and software. In other words, the closer an historian moves toward a discussion of the business history of computing, perhaps the less it matters that some of the technology were machines and others software.

Finally, this approach to the study of software applications makes it possible to use largely untapped bodies of research materials that are also rich in other evidence regarding a wide variety of topics, such as programming experiences, features of specific hardware devices, and role of computing in specific companies. Each of the major oil companies has various types of archival material, however, none of these were examined for the purposes of writing this article. While that material would have been useful, it would not have necessarily changed the basic scope of this essay, namely to provide a short, cursory view of the major applications in use in this industry. Armed with the general inventory of applications, it now becomes easier to examine in more detail, by company, what their specific experiences were with software over the half-century, and to do that would require a careful examination of corporate records and interviews of retired members of the industry, because the published record cannot take us much beyond what was presented in this paper. In short, this little exercise in providing an overview of the industry suggests that there is much yet that can learned both about computing in this or any industry, and about the nature of software over time in its various forms.

The approach described in this essay, however, appears initially to have some important limitations that historians need to be aware of. As with the historian who wants to study how clock mechanisms worked, scholars who want to learn what programming languages were used or how applications were run, will find that, like modern historians of the clock, they are pushed almost too soon into discussions concerning society, economics, and business and away from the pros and cons of using COBOL versus Basic, or one programming methodology over another. Another topic that this approach tends to push historians away from, yet is profoundly important for the history of software applications, is the role of file management systems. But, as hardware capacity increased over the decades, and database management systems came on stream, these two developments made it possible to write more sophisticated applications, stimulated changes in already installed software packages, and changed the architecture of new systems. The petroleum industry relied on vast quantities of data to perform some of its most essential work; geological modeling and management of credit card accounts are two examples. One cannot fully understand the history of software in this industry without a clear appreciation of the role of file management systems, and in particular, databases. Yet, as the case above demonstrates, we have an inadequate understanding of the history of database management systems (DBMS), let alone their role in this industry. The reader will note that in this article I did not discuss databases; it is a gap, one that cannot be rectified, however, without specific studies on database tools in general.

Without a detailed study of the internal managerial operations of the key firms in the industry we are left with the impression that the adoption of computing in this industry occurred uncritically, that is to say, without the normal battles among "systems people" versus already-established communities that might have seen computing as a threat to their fiefdoms or views evident in such industries as automotive manufacturing, airline transportation, and in retail. Part of the problem historians face is that by relying on industry publications, they perforce use sources that tend to gloss over frictions as authors attempt to provide optimistic accounts. That does not mean that this material is not useful, but it does mask some of the internal struggles and debates that probably took place and that will not become evident until company-level studies are done. A new generation of historians is providing examples of how to begin to study some of the institutional-centric issues, which can be applied neatly to the study of computer applications within an industry.[59]

One of the byproducts of an industry-centric study is what it points to as promising future research topics. Just looking at the subject of software history, the petroleum industry strongly demonstrates the urgency of examining the history of file management and database management systems. Other industries point to different topics. For example, in an industry that requires high levels of rapid transaction processing applications, such as the retail industry, databases remain important, but not so crucial as, for example, the role of transaction processing software. In that latter case, channel speeds of computers, in combination with smart and "dumb" bandwidth telecommunications control software becomes an important topic, as does the role of TP access software (like IBM's VSAM of the 1970s and 1980s) in concert with operating systems.

Studies of any major industry make it possible to connect various disparate aspects of the history of computing. In the last decade of the 1990s, historians began to examine a variety of managerial and operational aspects of the history of computing, such as how systems were designed, the role of technical staffs, and the relationship of government, universities, and corporations in the development of computing technologies. In addition, since technologies—and hence one can say software too—are conditioned by the social and political forces at work within any organization or industry, we can learn about the influences that played on software coming from outside the computing communities, primarily from users and their managers. This line of research will go far in linking the evolution of software to the greater historical patterns in the transformation of various technologies. In short, the possibilities presented for the study of new questions is quite formidable. These opportunities are particularly exciting since we are really at the threshold of the study of the history of software in general by professional historians.[60]

There is also the basic question of how circumstances varied from one industry to another. Each has its own personality, particular economic circumstances, business models, and handed-down values and practices. Each influence all technologies used within its member enterprises and institutions, and thus can add to our understanding of possibilities. For example, because the retail industry needs high speed transactions and data collection, the role it played in the development of the bar code and its relevant software systems is a dramatically different experience than how the military encouraged the development of software to provide high levels of "up time." Then we have petroleum companies deeply concerned about modeling systems that used vast quantities of data. Manufacturing companies prized data collection systems and the use of robotics. In other words, we have hardly begun to explore the role of all these various influences on software's development, use, and effects on modern society.

James W. Cortada, "Studying the Increased Use of Software Applications: Insights from the Case of the American Petroleum Industry, 1950-2000," *Iterations: An Interdisciplinary Journal of Software History* 1 (September 13, 2002): 1-27.

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[1]We do not have, however, a modern general history of software. Rather, there exist many accounts of individual software projects and programmers. The most recent one is by Steve Lohr, *Go To: The Programmers Who Created the Software Revolution* (New York: Basic Books/Perseus, 2001).

[2]For examples of this literature, see James W. Cortada, *A Bibliographic Guide to the History of Computing, Computers, and the Information Processing Industry* (Westport, CT: Greenwood Press, 1990): 343-491, and the sequel, *Second Bibliographic Guide* (1996): 276-278.

[3]There are several dozen books and a few dozen articles, most, however, not written by historians but rather by economists or veterans of the world of computing. Two accessible examples of books are, David C. Mowery (ed.), *The International Computer Software Industry: A Comparative Study of Industry Evolution and Structure* (New York: Oxford University Press, 1996) and Jason Dedrick and Kenneth L. Kraemer, *Asia's Computer Challenge: Threat or Opportunity for the United States and the World?* (New York: Oxford University Press, 1998). Professor Martin Campbell-Kelly, an historian, is just finishing a history of the American software industry which will include discussions of the economic literature on the subject.

[4]I am just completing a large study on the use of application software in manufacturing, process, transportation, wholesale, and retail industries that describes various types of applications and their role in the American economy.

[5] For a recent answer to the question, see Martin Campbell-Kelly, "Software Preservation: Accumulation and Simulation," *IEEE Annals of the History of Computing* 24, no. 1 (January-March 2002): 96-96.

[6]The major example on clock history is David S. Landes, *Revolution in Time: Clocks and the Making of the Modern World* (Cambridge, MA: Harvard University Press, 1983); but see also on another widely studied example, the

wheel, Richard W. Bulliet, *The Camel and the Wheel* (Cambridge: Cambridge University Press, 1975); and on automobiles (a favorite example for many historians), see John B. Rae, *The Road and the Car in American Life* (Cambridge, MA: MIT Press, 1971). For an extensive bibliography on other examples involving stone tools, combustion engines, electric motors, and other artifacts of technology and for an appreciation of the argument in favor of studying specifics artifacts to enrich the traditional scope of historical research on technologies, see George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988). The significance of Basalla's work is that he has profoundly influenced how historians go about looking at the history of technology, including that of computers.

[7]For a sense of what it was like, see John Backus, "Programming in America in the 1950s. Some Personal Impressions," in Nicholas Metropolis *et al*. (eds.), *A History of Computing in the Twentieth Century: A Collection of Essays* (New York: Academic Press, 1980): 127.

[8] Atsushi Akera, "Volunteerism and the Fruits of Collaboration: The IBM User Group SHARE," *Technology and Culture* 42, no. 4 (October 2000): 710-736.

[9]"The Digital Hand," forthcoming.

[10]The case for organizing views of business and technical issues within industry constructs was made by Alfred D. Chandler, Jr., in a series of books; however, for the application of this approach to IT, see his *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries* (New York: Free Press, 2001):1-12, in which he also integrates recent economic literature on the notion of path-dependency.

[11]For an early example of cases, see James L. McKenney, *Waves of Change: Business Evolution through Information Technology* (Boston: Harvard Business School Press, 1995).

[12] Franco Malerba, *The Semiconductor Business: The Economics of Rapid Growth and Decline* (Madison, WI: University of Wisconsin Press, 1985): 111-117; T.R. Reid, *The Chip: How Two Americans Invented the Microchip and Launched a Revolution* (New York: Simon and Schuster, 1984): 90-95; Hans Queisser, *The Conquest of the Microchip* (Cambridge, MA: Harvard University Press, 1988): 97, 98, 115, 148; Ernest Braun and Stuart Macdonald, *Revolution in Miniature: The History and Impact of Semiconductor Electronics: The History and Impact of Semiconductor Electronics Re-explored in an Updated and Revised Second Edition* (Cambridge: Cambridge University Press, 1982): 55, 58-59, 88-90, 94-97; Michael S. Malone, *The Microprocessor: A Biography* (New York: Springer-Verlag, 1995): 13-14, 16, 54, 130-136, 143, 146, 148, 150, 210, 279; Paul E. Ceruzzi, *A History of Modern Computing* (Cambridge, MA: MIT Press, 1998): 179, 182, 187-188, 213, 215, 217.

[13] For a summary of the modern history and economic realities of this industry, see Stephen Martin, "Petroleum," in Walter Adams and James W. Brock (eds.), *The Structure of American Industry* (Upper Saddle River, NJ: Prentice-Hall, 2001): 28-56.

[14] Ibid., 32-34.

[15] Ibid., 41.
[16] For a summary of how the industry functions within its four parts, see Thomas G. Moore, "The Petroleum Industry," in Walter Adams (ed.), *The Structure of American Industry* (New York: Macmillan, 1971): 117-155.
[17] U.S. Bureau of Labor Statistics, *Outlook for Computer Process Control: Manpower Implications in Process Industries*, Bulletin 1658 (Washington, DC: U.S. GPO, 1970): 1.
[18] For a description of how these applications worked, see IBM Corporation, *System/7 for Computer Production Control of Oil and Gas Wells* (White Plains, NY: IBM Corp., undated, circa 1971), DP Application Briefs, Box B-116-3, IBM Archives.
[19] "On-Site Instruments Help Avoid Troubles, Optimize Drilling," *Oil and Gas Journal* (September 24, 1973); W.D. Moore III, "Computer-Aided Drilling Pays Off," Ibid. (May 31, 1976): 56-60; U.S. Bureau of Labor Statistics, *Technological Changes and Its Labor Impact in Five Energy Industries*, Bulletin 2005 (Washington, DC: U.S. GPO, 1979): 19-20.
[20] Donald C. Holmes, "Computers in Oil—1967-1987," *Computer Yearbook and Directory*, 2nd edition (Detroit: American Data Processing, 1968): 168-169.
[21] T.E. McEntee, "Computers in the Petroleum Industry," in Edith Harwith Goodman (ed.), *Data Processing Yearbook* (Detroit: American Data Processing, 1965): 246-247.
[22]Comments made in the last sentence are drawn from a reading of dozens of articles on the industry published in the late 1990s in *Oil & Gas Investor*, *Computerworld*, *Oil & Gas Journal*, *Informationweek*, and *Petroleum Economist*. *Oil & Gas Journal* published several articles each year on these kinds of publications, and is a rich source on applications for the 1990s, including the now emerging area of e-business.
[23] Ibid.
[24] BLS, *Outlook for Computer Process Control*, 12.
[25] Ibid., 50.
[26] BLS, *Technological Change and Its Labor Impact In Five Energy Industries*, 26.
[27] Ibid., 28-29. These economists described life before and after the arrival of open loop computing: "The duties of an operator of a fluid catalytic cracking unit before computer control were to manually adjust automatic analog controllers at the control console and to monitor automatic data logging equipment. After installation, the computer controls and monitors a large part of the process and automatically logs the data, although the operator still performs manual control. In case of emergency, the operator can take control of any part or all of the process."
[28] For its history, see David Evans and Richard Schmalensee, *Paying with Plastic: The Digital Revolution in Buying and Borrowing* (Cambridge, MA: MIT Press, 1999): 61-68.
[29] James C. Beardsmore, Sr., "Credit Card Accounting," *Data Processing Proceedings 1964* (New Orleans, LA: DPMA, 1964): 2-3.

[30] The material for the last two paragraphs came from Ibid., 1-19.
[31] Robert H. Church, Ralph P. Day, William R. Schnitzler, and Elmer S. Seeley, *Optical Scanning for the Business Man* (New York: Hobbs, Dorman & Company, Inc., 1966): 122.
[32] Ibid.
[33] Ibid., 122-125; includes a flowchart of the application, p. 123.
[34] Moore, "The Petroleum Industry," 135-136.
[35] J.C. Ranyard, "A History of OR and Computing," *Journal of the Operational Research Society* 39, no. 12 (December 1988): 1073-1086; Albert N. Schriber (ed.), *Corporate Simulation Models* (Seattle, WA: University of Washington, Graduate School of Business Administration, 1970); Ron Wolfe, "Evolution of Computer Applications in Science and Engineering," *Research & Development* 31, no. 3a (March 21, 1989): 14-20.
[36] Holmes, "Computers in Oil," 169-170.
[37] The American Petroleum Institute tracked this form of automation very closely throughout the half-century. For data on early implementation of unmanned trunk line stations, see Hugh D. Luke, *Automation for Productivity* (New York: John Wiley & Sons, 1972): 262-263.
[38] There is an extensive contemporary industry literature documenting these, see James W. Cortada, *A Bibliographic Guide to the History of Computer Applications, 1950-1990* (Westport, CT: Greenwood Press, 1996): 206-207.
[39] BLS, *Technological Change and Its Labor Impact in Five Energy Industries*, quotes from p. 39.
[40] Management could increasingly then rely on visual inspections done from low flying aircraft augmented with ground-based inspection teams looking at segments of the pipeline that either those flying overhead called out for further examination or which had a history of problems, based on reports from pipeline management software.
[41] Automation Consultants, Inc., "The 650 Used in Refinery Sales Billing," undated case study (circa 1958), quote, p. III c1-8, full case study, III C1-1-8, CBI 55, "Market Reports," Box 70, Folder 1, Archives Charles Babbage Institute, University of Minnesota.
[42] "EDP at Standard Oil of California," Ibid., III C2-1.
[43]"Datatron in Petroleum Accounting, Ibid., III C3-6.
[44] For the early history of TI in the petroleum industry see *Texas Instruments, Inc., 50 Years of Innovation: The History of Texas Instruments: A Story of People and Their Ideas* (Dallas: Texas Instruments, 1980). While there is much published material on TI dealing with its development of computer chips, its pre-chip history has yet to be fully explored.
[45] See for example, Dale O. Cooper, "Advances in EDP in The Petroleum Industry," *Data Processing Proceedings 1964* (New Orleans: DPMA, 1964): 20-30; "BP, Amoco Merger Marries IT Opposites," *Computerworld* 32, no. 33, August 17, 1998, p. 76; Stuart J. Johnson, "IT Fuels Speedup in Energy Industry," *Informationweek* (September 14, 1998): 139-146.

[46]The Charles Babbage Institute at the University of Minnesota houses the corporate archives of CDC, which are replete with material on this subject. However, there is limited historical literature on the topic, but see, J.C. Ranyard, "A History of OR and Computing," *Journal of the Operational Research Society* 39, no. 12 (December 1988): 1073-1086. Hundreds of articles and dozens of "how to" books were published that included sporadic case studies of this application across many industries, including petroleum.
[47] Rose N. Zeisel and Michael D. Dymmel, "Petroleum Refining," in U.S. Bureau of Labor Statistics, *A BLS Reader on Productivity*, Bulletin 2171 (Washington, DC: U.S. GPO, June 1983): 197-206.
[48] U.S. Bureau of Labor Statistics, *Technological Change and Its Labor Impact in Four Industries*, Bulletin 2316 (Washington, DC: U.S. GPO, December 1988): 34.
[49] Ibid.
[50] Ibid., 35-38.
[51] Ibid., 40.
[52] Bob Tippee, "Electronic Data Interchange Changing Petroleum Industry's Basic Business Interactions," *Oil and Gas Journal* 96, no. 28 (July 13, 1998): 41-47.
[53] See for example, Julia King, "BP, Amoco Merger Marries IT Opposites," *Computerworld* 32, no. 33, August 17, 1998, pp. 1, 76.
[54] Start J. Johnston, "IT Fuels Speedup in Energy Industry," *Informationweek*, September 14, 1998, pp. 139-146.
[55] John Kennedy, "In Global Energy, Information Technology Knits It All Together," *Oil and Gas Journal*, "Windows in Energy Supplement" (Spring 1999): 1.
[56] "The Middle East, New Super-Majors, and More Industry Consolidation," *Offshore* 60, no. 4 (April 2000): 124ff.
[57] Jeff Sweat, "Information: The Most Valuable Asset," *Informationweek*, September 11, 2000, pp: 213-220, quote, p. 213.
[58] Don Painter and Robert Dorsey, *e-Business: Refining the Petroleum Industry* (Somers, NY: IBM Corp., 2000).
[59] See, for example, Thomas Haigh, "The Chromium-Plated Tabulator: Institutionalizing an Electronic Revolution, 1954-1958," *IEEE Annals of the History of Computing* 23, no. 4 (October-December 2000): 75-104, which describes how first generation computers were sold and acquired; Nathan L. Ensmenger, "The 'Question of Professionalism' in the Computer Fields," Ibid., 23, no. 4 (October-December 2001): 56-74, on the roles of programmers; Thomas Haigh, "Inventing Information Systems: The Systems Men and the Computer, 1950-1968," *Business History Review* 75, no. 1 (Spring 2001): 15-62, which is an important study on the ideas and role of "systems men" of the 1950s and 1960s, people who wanted to take over the management of computers.
[60] For examples of current historiography, see the entire issue of the *IEEE Annals of the History of Computing* 24, no. 1 (January-March 2002).