Technology Transfer:
The IBM System/360 Case
by
Emerson W. Pugh

Introduction

The term 'technology transfer" is most commonly used within a company to describe the internal transfer of technical knowledge or devices from research to development, from development to manufacturing, and from manufacturing to sales and services. The term is also used to describe the less orderly processes in which new technologies flow backwards in the system (e.g. from manufacturing to research) or laterally (e.g. from one development laboratory to another development laboratory). In academic circles and international conferences, technology transfer is more often used to refer to the transfer of technology from one company to another or between different geographical locations and countries.

Multinational companies can be involved in all of these processes simultaneously; and companies in high-tech industries will only survive if they understand and manage these processes effectively. Indeed, this was the case for IBM during the 1960s when it introduced the IBM System/360 line of computers.

Defining the Problem

The problem IBM faced was the direct result of rapid changes in technologies, combined with dramatic growth in the computer market -- which was itself driven by the rapidly improving cost/performance of critical technologies. The success of the IBM 1401 computer, announced in October 1959, highlighted the problem. Equipped with discrete semiconductor logic circuits and up to 4000 characters of ferrite-core memory, it was the first computer to be inexpensive enough to replace conventional punched card equipment. By the end of 196 1, the number of 1401 s installed in the United States had reached 2,000; this was 25 percent of all electronic stored-program computers installed by all manufacturers to that time. As workloads of IBM 1401 customers increased, they would want to migrate to larger systems - but none of the first six IBM computers designed with transistor circuits could run programs written for another. Furthermore, no competitive computers were compatible with each other or with those of IBM.

Lack of compatibility was a serious problem for customers, but it was even more serious for IBM. The company had to train sales and service personnel and provide programming support for each of the incompatible systems. Economies of scale in engineering and manufacturing were reduced. Even peripheral equipment designed for one computer could not be used on any other without modification.

Addressing the Problem

IBM's president, Thomas J. Watson, Jr., took the first step toward solving this problem in May 1959 by separating organizationally the manufacture, sales, and service of computers from development. The man Watson put in charge of the new development organization was T. Vincent Learson.

In the past the loyalty of each development group was more closely coupled to manufacturing and marketing than to other development groups. Each development group worked to increase the market share for its own products - even at the expense of the other groups. The competition was intense. To achieve compatibility among future computer products, Learson would have to get an of the development groups that now reported to him to sacrifice some of their own more limited objectives. Beginning this process in October 1961, Learson established a task force with eleven representatives from research, development, and marketing, and led by two engineering executives. Operating under the code-name SPREAD, an acronym (for Systems Programming, Research, Engineering, And Development) meant to connote wide scope, the task force was asked to "establish an over-all IBM plan for data processor products."

Such task forces were frequently employed by IBM to facilitate internal technology transfer. In addition to identifying what technological direction was appropriate and what technologies should be transferred, task forces were a good means for achieving the necessary consensus. For System/360, the SPREAD task force provided the forum for exchanging technical information and for making the many hardware, software, and architectural decisions necessary for a unified product line.

The Transfer of Control Store Technology

John W. Fairclough, who represented the IBM laboratory in Hursley, England, made a particularly important contribution to the SPREAD task force: namely, use of a high- speed special-purpose memory to control the logical flow of information in a computer. This concept, known as a control store, had been proposed in 1951 by Maurice V. Wilkes of Cambridge University in England. However at that time, there was no memory technology with adequate cost/performance to implement the concept in a commercial product.

Operating under the constraint imposed by IUBM President, Watson, in 1957 that all future products would use transistors (instead of vacuum tubes), Fairclough and his colleagues began experimenting with ways to implement a control store in a commercial product. Although their product design was rejected, Fairclough had become convinced that control stores could be built economically. Based on his experience, he promoted their use in System/360 to help achieve software compatibility. Each program instruction of the System/360 instruction set would address a word in the control store that would in turn contain the information necessary to cause the wired-in logic of the computer to carry out the designated instruction.

The adoption of control stores for IBM System/360 computers was the result of a successful technology transfer activity. It involved a concept conceived at Cambridge University, researched and partially developed in the]IBM Hursley laboratory, and then transferred to other IBM development laboratories. Control stores proved to be a cost-effective way to achieve software compatibility among computers with differing performance and internal designs.

Discovery and Transfer of Emulation

Control stores provided several unexpected benefits such as greater ease of debugging computers during development. But the greatest unexpected benefit was in solving the problem of migrating customers from earlier computers, without having to rewrite all of their application software. Of greatest concern was the need to migrate users of the popular IBM 1401 computer to System/360 computers such as the small Model 30. One of the most promising approaches under consideration was called simulation, in which a software simulation program was written for the "host" computer so that it could run programs previously written for a "Target" computer.

In an attempt to make simulation software run more efficiently, IBM engineers in Endicott and Poughkeepsie began experimenting with adding a few extra words of microcode to the control store. So successful were the initial results that the engineers continued to add more words to the control store until simulation of the IBM 1401 by the IBM System/360 Model 30 could be accomplished entirely by the control store - that is, without any software portion. Such a dramatic performance improvement was achieved that the technique was given a new name: emulation. Emulation technology was quickly transferred to other IBM laboratories. Among these was the IIBM Hursley laboratory, where John Fairclough adopted it as a feature on the IBM System/360 Model 40 that he and his engineers were designing,

When the IBM System/360 announcement was made in April 1964, emulation was available as a feature on all but the largest model. The ability to emulate earlier computers was important to customers, who ordered more than one thousand systems during the first four weeks after the announcement. System/360 architecture soon became a de facto standard and dominated the worldwide computer market for nearly a quarter of a century.

Technology Transfers Due to IBM System/360

The transfers of control store and emulation technologies were only a small part of the worldwide technology transfers stimulated by System/360. The company's decision to develop and manufacture its own semiconductor devices and circuits, for example, transformed the company from the largest purchaser to the largest manufacturer of semiconductor devices. By the end of the 1960s, the company's plant in East Fishkill was producing more semiconductor devices than the plants of all other companies in the world combined. To meet the unprecedented internal demand for SLT (IBM's proprietary semiconductor device and circuit technology), manufacturing technology was transferred to IBM plants in Burlington, Vermont, and Essonnes, France. Always the transfer of technology was accompanied by the transfer of knowledgeable personnel.

The company also transferred SLT device technology and manufacturing methods to the Texas Instruments Company, which previously had been IBM's primary supplier of semiconductor components. This was done to help maintain a valuable business relationship and as a means for measuring IBM's internal manufacturing capability against an external supplier. Numerous venders throughout the world had been hired to build specialized equipment designed by IBM to manufacture SLT. In a significant unintended (but not unanticipated) transfer of technology, many of these venders began to sell modified versions of this equipment to other customers. And, of course, Texas Instruments made use of the information it received to strengthen its other development and manufacturing activities.

The standard interfaces for attachment of peripheral devices to IBM System/360 computers made it easier for IBM and its customers to upgrade and modify installed computer systems. But standard interfaces also made it easier for other companies to provide "plug-compatible" products. By 1968 plug-compatible products for System/360 included tape drives from the Telex Corporation and disk storage packs and drives from the Memorex Corporation. Trained personnel from IBM were frequently hired to transfer the technology and to keep the plug-compatible products up-to-date with IBM products. For example, Alan F. Shugart, was hired from IBM in 1969 by Memorex to serve as its vice president for product development. During his first few years at Memorex, Shugart persuaded more than one hundred IBM employees to join him.

Perhaps even more troubling for IBM were the employees who left the company to create their own companies to compete with IBM products they had been instrumental in developing. The first significant event of this type was the resignation in 1967 of twelve employees from IBM's San Jose product development laboratory to form a new company, Information Storage Systems. Less than 18 months after leaving IBM, these former employees had reached an agreement to supply the Telex Corporation with IBM- plug-compatible disk drives. Thus Telex, the first supplier of IBM-plug-compatible tape drives) was able to expand its product line to include disk drives. The lure of big money was breaking down the traditional loyalties between IBM and its employees.

Copying the entire System/360, rather than just plug-compatible parts, was also attractive. The first such offering was RCA's Spectra 70 series, announced only eight months after System/360; and in 1972 the Soviet Union and its Eastern European allies announced that production had begun of their System/360-compatible processors. Neither of these efforts was particularly successful. However, in 1975 the Amdahl Corporation (founded by ex-IBMer Gene Amdahl) announced the first of its high-end, System/360-compatible computers. Funded by German and Japanese computer companies, the Amdahl Corporation provided a significant means for transferring IBM- compatible technologies to IBM competitors in Germany and Japan.

References

E. W. Pugh, 1995: *Building IBM, Shaping an Industry and Its Technologies*, MIT Press, Cambridge, Mass. (405 pages)

E. W. Pugh, L. R Johnson, and J. H. Palmer, 1991: *IBM's 360 and Early 370 Systems*, MIT Press, Cambridge, Mass. (819 pages)