TECHNOLOGY TRANSFER: MAXIMIZING THE EFFECTIVE USE OF RESEARCH AND ENGINEERING RESOURCES

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ABSTRACT

Mobil has undertaken a company-wide effort to improve its competitiveness by placing greater emphasis on transferring technology from its technical departments into its operating divisions. To accomplish this goal, a Technology Transfer Program was developed and implemented throughout Mobil's technical departments to provide the training and incentives to promote better technology transfer through improved interdepartmental communications. The program was based on actual case studies of successful technology transfer events within Mobil and a simple model of the technology transfer process. The program was packaged into a four-day workshop which has been given to over 500 personnel. As the emphasis on technology transfer has propagated through the organization, technology transfer to operating facilities in various parts of the company has improved substantially. The authors hope this article may stimulate others to consider how to utilize technology more effectively to enhance U.S. competitiveness in the changing global economy.

Technology Transfer and U.S. Competitiveness

In recent years the competitiveness of U.S. industry has become one of the most active topics of debate among policy makers as foreign competitors have taken over larger shares of global markets traditionally dominated by U.S. firms. The reasons for this shift in the global marketplace are numerous and controversial. But leaders in both government and business circles agree that U.S. companies could play a significant role in improving the country's competitiveness by making more effective use of their research and engineering resources.

This paper reports on the efforts of one U.S. corporation, Mobil, to improve its competitiveness by placing greater emphasis on transferring technology from its technical departments into its operating divisions. To accomplish this goal, a Technology Transfer Program was developed and implemented throughout Mobil's technical departments to provide the training and incentives necessary to promote better technology transfer through improved interdepartmental communications -- so that more of the technology that was being developed could be transferred into commercial processes, products and profits.

The Importance of Technology to the Oil Industry

Why all this emphasis on technology in a company whose main business is perceived to be fungible commodities? First, on the exploration/production side of the business, the oil industry is dependent on a finite and declining resource base in the form of crude oil. To remain competitive, an oil company must maximize existing oil fields through efficient reservoir management techniques, improve exploration techniques to find new sources of oil, and create production platforms that can produce oil in increasingly difficult environments such as the deep sea and the Arctic.

On the refining/marketing side, refiners must continually utilize more efficient refining technology, such as improved catalysts, to increase the quantity of high value products that can be obtained from each barrel of crude oil and reduce costs while meeting more stringent environmental standards. Improved fuels and lubes must be developed and marketed to keep pace with advancements in engine and vehicle technology. In summary, an oil company must have the right technology at the right time at the lowest cost in order to achieve a competitive edge.

The Evolution of Mobil's Technology Transfer Program

The initial phase of this effort consisted of evaluating how well technology had been utilized in the past at Mobil prior to the Technology Transfer Program. While there is no direct way to measure the impact of technology on the bottom line, for over 25 years Mobil has been conducting audits and post-audits of the major process and product technologies developed. These audits identified over 600 major accomplishments that contribute more than $1 million apiece to the company.

Judging from these results it appeared that technology transfer was progressing reasonably well. However, a closer review of the technological resources of Mobil's technical departments indicated a potential for even more technology to be transferred into operations than was actually taking place. This review also indicated that a large proportion of the technology that was being used in the operating divisions had been transferred by a relatively small number of technologists, which indicated that certain technologists were more effective at transferring technology than others. It was decided that a Technology Transfer Program should be developed so that the collective wisdom of Mobil's most successful technology transfer experts could be pulled together, packaged into an understandable format and disseminated throughout Mobil's technical departments.

Some 40 technology transfer experts were interviewed in this effort and they all agreed on one main point: *The key to effective technology transfer is **effective communications** between those who have developed the technology and those who can use the technology in operations*. Consequently, the primary focus of the Technology Transfer Program was to educate the researchers and engineers who develop technology, who will be called technologists in this paper, in how to improve their communication skills when dealing with personnel in the operating divisions who will be called clients. The resulting program consisted of the following elements:

(1) a set of **goals** that technologists could use to better judge how effectively they were transferring technology to operations;

(2) a general step-by-step **model** of the technology transfer process;

(3) a set of **case studies** based on successful technology transfer events within Mobil; and

(4) a set of typical **problems** encountered in the technology transfer process and the **solutions** to those problems that have worked at Mobil.

These program elements were tested on a cross section of high level research and engineering management at a three-day conference in 1986 and were enthusiastically endorsed. The program was packaged into a four-day workshop which has been given throughout Mobil's technical departments to over 500 personnel. The remainder of this paper is devoted to explaining these elements of Mobil's Technology Transfer Program.

The Goals of Effective Technology Transfer

One of the first elements taught in the Technology Transfer Workshop are the goals of effective technology transfer. While this may seem like putting the cart before the horse, it provides the technologists with a yardstick to measure how well they have been transferring technology to date and in most cases demonstrates why they need the workshop. The goals of effective technology transfer listed below may seem obvious and simplistic, but in practice they are difficult for a technologist to achieve under the best of circumstances. To achieve these goals without effective communications with the client and without the support of management is practically impossible.

1. **Develop technology that fits the strategic needs of the client**. It is much easier to sell a pair of shoes that fits the customer than a pair that does not. Similarly, it is also much easier to transfer technology into an operating division if the technology fits the division's needs. Consequently, an element of strategic planning must be utilized by the management of technology departments so that the level of effort in various technological areas fits the long term business needs of the corporation. For example, an outcome of this type of planning in the present oil industry business environment might be a decision to emphasize technology for recovering more oil from a reservoir, while de-emphasizing technology that allows one to extract oil from shale.

2. **Ensure that the quality and costs of the technology meet the needs of the client**. This issue is crucial to the eventual success of a given technology and trade-offs typically must be determined on a case-by-case basis between quality and cost. If the cost is unnecessarily high due to over-conservative estimates by the technologist, the client may be discouraged from trying a new technology that could have made substantial profit for the corporation. If the cost estimate is too low and the project goes over budget or the quality suffers, the credibility of the technologist and their management will suffer. Such projects often end up costing more in the long run than if they had been done right the first time.

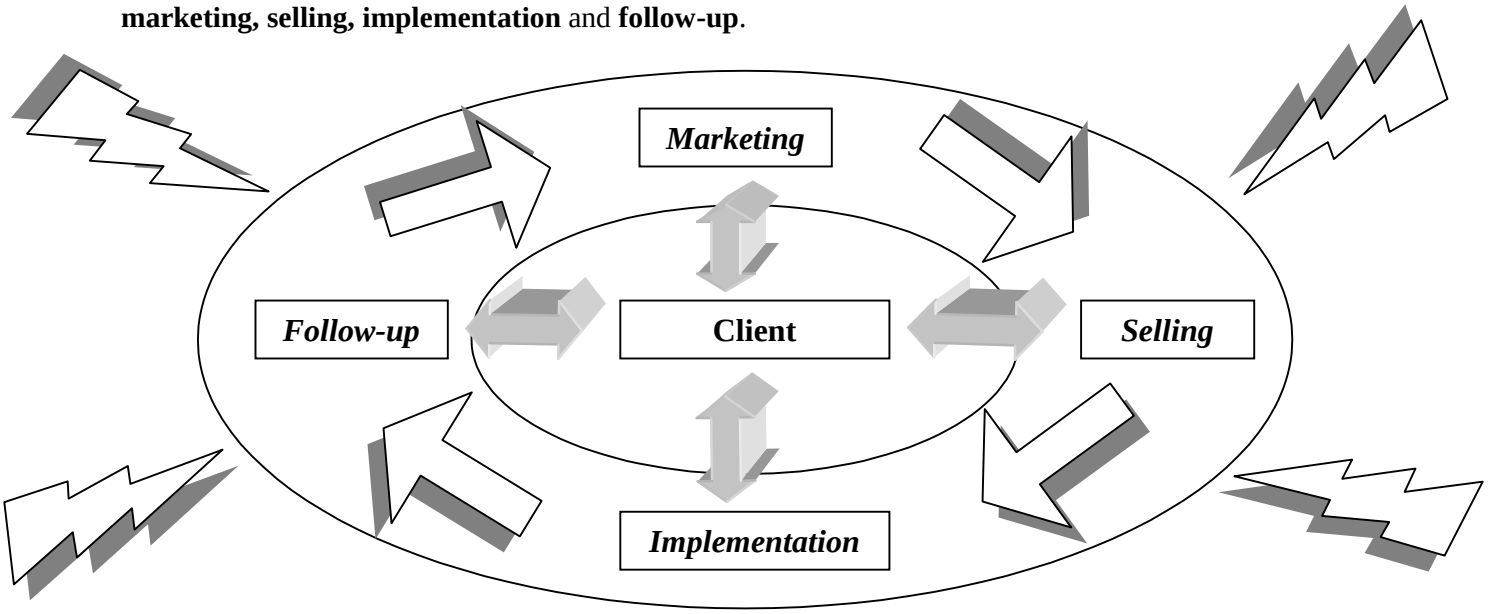
Often the definitions of "cost" and "quality" used by a technologist are substantially different from those used by the client. For example, to a research engineer, the "cost" of a new refinery process may mean the installation cost of the hardware, and "quality" may refer to the product yield advantage of the process. But, to a refinery engineer, "quality" may mean the on-stream dependability and "cost" may mean the loss in refinery throughput if the process fails and causes a major shutdown of the refinery.

3. **Implement technology in a timely manner**. One of the most enlightening discoveries in reviewing our case studies of technology transfer events was that even some of the greatest success stories took years to implement. The oil industry has gone through so many volatile changes in the last two decades that a few years delay in commercial installation time has made the difference between a technology that paid for itself many times over and a technology that was uneconomical by the time it was implemented. Failure to understand the complexity of technology transfer increases the chances that mistakes will be made that cause unnecessary, long delays in the use of the technology.

4. **Ensure that the technology is widely and routinely used**. Technologists often consider their job complete after the first successful implementation of a given technology into an operating facility. **Widely used** means making the extra effort to spread the technology to all viable users. While this may not be as interesting as creating something new, it improves the bottom line. **Routinely used** means the technology becomes standard practice in the client's operation. It is not uncommon to have technologies partially or seldom used, while technologists consider their job a success. Until a technology is routinely and effectively used in all applicable parts of the company the transfer process is incomplete.

Overview of the Technology Transfer Process

In attempting to describe the underlying process involved in the Mobil success stories, we have developed a simple but useful model of technology transfer as shown in the diagram below. At the center of the model is the client, to emphasize the concept that successful technology transfer is a client-centered process. The two way arrows connecting the various parts of the model are lines of communication, signifying the importance of good communication between clients and technologists. Around the client are the stages of technology transfer in which the technologist engages the client -- **marketing, selling, implementation** and **follow-up**.



The goal of MARKETING is to answer two questions: (1) How does the technologist find out what his client needs; and (2) How does the technologist let their clients know what technology may be available?

Once a client expresses an interest in a technology, the selling stage begins.
The goal of SELLING is to answer the question: How should the technology be presented to the clients so that they can make the best decision on whether to try it?

Technologists typically have a difficult time understanding the differences between marketing and selling. However, understanding this difference is critical to successful technology transfer. Marketing is similar to planning and advertising -- planning through interaction with clients to determine the most appropriate technologies to develop, and advertising the availability of various technologies to as many potential clients in the company as possible. Selling on the other hand is the focused communication that occurs after a potential client has expressed interest in a new technology.

IMPLEMENTATION addresses the question: How should the company's technical organization support the operating divisions while a new technology is being implemented? This is the most tangible stage of the technology transfer process.

Lastly, FOLLOW-UP addresses the question: What should the technologist do to help maintain the effectiveness of a technology once it is in place? We have found follow-up to be a general weakness in the technology transfer efforts we have studied. This may be due to the high degree of pro-activity

needed during this stage and that reward systems in technical organizations are not typically designed to encourage follow-up behaviors. However, effective follow-up leads back to the marketing stage, as the knowledge acquired during follow-up helps the technologist to identify new client needs and the interaction enables the client to keep abreast of new technology opportunities.

Technology development occurs throughout the technology transfer process, as shown by the lightening bolts bringing new technology into every stage of the process. Technology development provides the power to drive the wheel of technology transfer. Technology transfer is meaningless unless there is worthwhile technology to be transferred. While most technology development should occur between the marketing and selling stages, i.e., between defining client needs and the actual selling of the technology, additional refinements of the technology occur throughout the process. In summary, the model symbolizes an interactive process where technologists continuously work with the operating divisions to refine and improve the technology until it adequately fits the required need.

It is important for the managers of technical departments to realize that a delicate balance must be struck between the amount of effort placed on technology development and the amount placed on technology transfer. Too much emphasis on the transfer process can drain valuable time and resources from the creative efforts of technical staff, resulting in a shortage of long term technology in the pipeline to fuel the company's technology needs. Too much technology development without enough technology transfer can result in wasted corporate resources as technology sits on shelves. At Mobil, we have come to appreciate that this model is generic, because it seems to fit different parts of our business (i.e. marketing, refining, production, exploration), and varying technical disciplines (i.e. engineering, environmental, products and process research).

Each of the four stages of technology transfer present unique problems for the technologist. A brief case study will be presented below to demonstrate each stage of the process. Each case study will be followed by a list of the typical problems that arise during that stage along with solutions to those problems that have worked well at Mobil.

Stage 1: MARKETING

As mentioned above, the marketing stage can be thought of as a combination of **planning** and **advertising**. In order to **plan** the right technology development projects, the technologist requires information on the client's needs. Some of this information can be obtained directly from the client and some of it must be obtained from the external environment. To **advertise** what the technologist has to offer, they must be able to communicate the relevant information to the client in a timely manner.

The marketing stage can be illustrated by the case study of the Materials Engineering Section in Mobil's Engineering Department:

Marketing Case Study: Materials Engineering Group

Today's Material's Engineering Section of the Engineering Department can trace its roots back to a serious fire in a refinery unit in the 1950's. The investigation showed that corrosion had caused the leak that started the fire. A group was formed in the Research Department to further study the problem of corrosion. It was originally envisioned as a short-term "crash" program that would disband after appropriate solutions had been developed.

After the group finished their study of the fire and presented the results, most of the group was in fact reassigned to their previous technological areas. However, the Group Leader recognized that there was a need in the operating divisions for expertise in corrosion control and he and a few

associates stayed on to work in the corrosion control field. The problem, as he saw it, was that the operating division personnel were simply not in a position to develop the expertise to recognize certain types of corrosion problems in this emerging technological area nor did they know who to go to in the Research Department for assistance.

The Group Leader went to his management and proposed he be allowed to build a network of corrosion experts at major facilities to help bridge the gap, both geographical and managerial, between the personnel in the operating divisions who investigated corrosion problems and the Research Department who could provide the solutions. Management was skeptical at first. A few years earlier the Research Department had attempted to place one coordinator in each facility to improve communications on technical problems, but the concept failed. The Group Leader believed that the concept would work if diads were set up so that a coordinator in the Research Department could interact directly with a designated corrosion specialist in the operating facility, thereby eliminating the middleman.

Research management allowed the Group Leader to try his concept on a trial basis at one facility. The Group Leader chose a small refinery with no major problems where he was known and trusted by the management. Not everything tried in the first year of this pilot program was successful, but enough progress was made that the facility management wrote a glowing report praising the outstanding cooperative effort between Research and Manufacturing. The program was broadened slowly to include other facilities. The Group Leader continued to work with the other refinery managers and decision-makers to get their agreement to set up a similar program at their refinery. But as more refineries signed up for the program, the demands rapidly outpaced the capabilities of that one person. So, he shifted from technology coordinator to managing the activities of what had now grown to be a group of technology coordinators.

At one point it became obvious that many of the same problems were popping up at different refineries simultaneously. To provide a more comprehensive way to communicate common experiences with the facilities, a newsletter was set up which included a clients' section for cross fertilization of ideas. The group set up a training program at the Research Laboratory that was given on an annual basis to field personnel who varied from the hands-on operators to the managers. These courses were designed to create numerous opportunities to build informal networks and enable technologists to obtain information on clients' needs.

Today the Materials Engineering Section, now part of the Engineering Department, has 9 coordinators involved in 28 cooperative programs with major Mobil facilities around the world. The newsletter is now sent out to over 300 personnel throughout the worldwide Mobil system. The coordinators work with their respective counterparts in the facilities to identify needs in the facilities and to assemble programs to meet these needs. The objectives resulting from this program are incorporated into the facility's annual budget process. Progress in the programs at each facility is documented every quarter by the Materials Engineering coordinator and sent to the facility coordinator and management for concurrence. At the end of each year a meeting is held to review the results of the previous year's program and to plan for the following year. In some cases, headquarters personnel participate in these sessions. The original Group Leader is now retired but the group he started has become a model technology transfer program.

Problems Encountered in the Marketing Stage

Typically there are many problems that arise in the marketing phase of the technology transfer process:

- Technologists are not typically motivated to communicate effectively with their clients and fail to realize that they must communicate on a regular basis in order to fully understand the client needs. Communicating with operating personnel, some of whom have non-technical backgrounds and are often short on time, can be a frustrating and seemingly unrewarding experience for a technologist.

- Organizational boundaries and geographic separateness create inevitable communications barriers. In multinational companies as large and dispersed as Mobil, there is always a problem distributing relevant technical information to the right clients at the right time.

Solutions to Marketing Problems

While these problems are significant, they can be minimized by first recognizing that they exist and then taking appropriate action. This section focuses on some of the solutions we have adopted to deal with these problems along with examples to illustrate the concepts.

First, and most important, the management of Research and Development organizations must **provide appropriate reward mechanisms and training to motivate technologists to conduct effective technology transfer**. This overriding recommendation applies to improving all phases of technology transfer, not only marketing. In the Materials Engineering Case Study, both the technologists and the clients knew that their performance depended on setting up a satisfactory annual program and carrying it out jointly.

Second, Research and Development organizations need to **develop structural mechanisms which encourage and facilitate face-to-face, two-way communications between technologists and clients** about needs and about the technologies that potentially could be adapted to meet those needs. In the case of the Materials Engineering Program, several structural mechanisms helped facilitate communication: (1) the annual planning meetings between the technologists and the operating division personnel; and (2) the quarterly reports which were developed jointly between the technologists and the operating division personnel.

A structural mechanism that has been used successfully throughout Mobil's Research and Engineering portfolio are the periodic project proposal review sessions which always include representatives from operating divisions to help guide research priorities. Greater interaction between Corporate Planning and Research and Engineering Planning has been facilitated through transfer of personnel and more frequent meetings between planners and technologists on the technical components of long term strategic planning issues.

Third, Research and Development organizations must **encourage the development of numerous informal networks between technologists and clients**. Networks are critical to all phases of technology transfer. Technologists can develop these networks in a cost-effective manner by using every face-to-face interaction with their clients as an opportunity to network and ultimately enhance technology transfer.

For example, the Materials Engineering Group and most of Mobil's technical departments conduct some type of technical training for personnel in the operating divisions. In recent years, a concerted effort has been expended to couple the overt purpose of such courses (i.e., to train the clients) with the more subtle purpose of enhancing technology transfer. During breaks in the courses, meetings are scheduled between

visiting clients and in-house technologists to discuss client needs as well as the latest technological advances. Often, the opportunity for technologists to take an out-of-town client to dinner leads to social networks that in turn lead to more effective bridges for technical communication and, ultimately, enhanced technology transfer.

Fourth, **formal communication mechanisms must be developed** and honed for effectiveness. Newsletters have been the traditional means of communicating new technical developments to the operating divisions. However, some of our technologists have received high marks from their clients for some refinements in this traditional communications medium. Another refinement of the newsletter approach is the use of company-wide computer systems to maintain bulletin boards on the latest technological developments in certain areas.

In summary, the marketing phase of technology transfer presents some interesting problems in understanding client needs and keeping clients informed about technical developments. But our most innovative people have discovered some effective formulas to resolve these issues.

Stage 2: SELLING

The second stage of the technology transfer cycle deals with selling -- the manner in which the technology is presented after a client expresses an interest in the technology. As in the marketing stage, many aspects of effective selling apply to all stages of technology transfer, but there are some unique issues.

The selling stage can be illustrated by the case study of the introduction of Mobil's product safety information system to our Marketing Department:

Selling Case Study: The Selling of Mobil Product Safety

In 1978 the management of the Corporate Environmental Health and Safety (EHSD) Department (a division of Research, Engineering and Environmental Affairs) recognized that regulatory requirements in the product safety area would be increasing due to legislation passed that year. Mobil would need to provide our customers, employees and various government agencies with increasing numbers of product safety information bulletins -- lists of the ingredients in our products that include the relevant health effects data. At the same time, the amount of available health effects data was also increasing rapidly.

Rather than continuing to maintain a separate list of information for each of several thousand products, a technologist in EHSD developed an on-line computer system that would generate product safety data bulletins anywhere in the world by automatically pulling the necessary information from several data bases on the Mobil computer network. For example, as new health effects data on a given ingredient became available, the health effects data base could be updated for that one ingredient and, from that time on, the product safety data bulletins on all of the products that included that ingredient would automatically reflect the new information.

The Product Safety Manager in EHSD knew that the system satisfied an important need and that the system could well serve the long-term interest of the company -- but only if the Marketing Department strongly supported it. He also realized that new ideas do not just "sell themselves". So, he transferred a marketer from the operating division into his group to help sell the system to the Marketing Department. The marketer had a degree in biology and could speak the language of both the marketers in the field and the technologists in the Environmental Health Science Laboratory.

The marketer realized that sales people in the Marketing Department were under constant pressure to increase sales. Traditionally, these people used product quality as their primary selling feature. The marketer wondered if product safety could be used to sell products in the same way that product quality had in the past. To test his hypothesis, he set up a test marketing situation involving 12 large non-customers that Mobil desired as customers. He was able to demonstrate to a key executive in the Marketing Department that safety could help open the door to these customers. This executive became the key sponsor of this program by endorsing and promoting the use of product safety information to sell products. Today, customers buy Mobil products because they know the products are safe and because Mobil has the product safety information available to help customers meet their regulatory needs in every state in the U.S. The Product Safety Information System has also been translated into several foreign languages for use around the world.

The distribution of several hundred thousand bulletins over the last decade could not have been accomplished as efficiently or cost effectively without the cooperation between the technologists who foresaw the regulatory need for the system and the personnel in the Marketing Department who helped use it to competitive advantage.

Problems Encountered in Selling Technology

While the technology involved in this case study was relatively simple, the problems in selling this technology were typical of the problems encountered by technologists in an internal R&D organization in selling more complex types of technology to their operating division:

- Technology consists of ideas, which are intangible. Special selling techniques are required to convert the intangible concepts that embody the technology into concrete features and benefits that the client can understand. In addition, there will always be inherent risk in scaling up from the drawing board or prototype to commercial operation, regardless of how much pilot testing and simulation is performed prior to scale-up. Selling shoes is much easier than selling technology -- a customer can see a pair of shoes and even try them on for size...and a shoe salesman is never asked the question, "Will it work?"

- Technology often requires a champion or sponsor high in the operating division before it can be transferred. However, scientific progress is typically made by lower level specialists in a technical department in a different part of the company. Consequently, new technology often must be sold first to several levels of management within the technical department and then again to the operating division before it can be transferred. Unfortunately, the technology can be stopped at any step in this process if the selling is not done properly. (It is always comforting when faced with this problem to remember that when Edison invented electric lighting, people said, "What do we need this for when we have kerosene lamps?")

- An internal R&D organization has a closed and limited set of customers. This puts a premium on the quality of the service that is provided. Word about success or failure and good or poor service spreads rapidly through this closed system, making the next sale that much easier or more difficult.

- Technologists typically do not emerge from college as the world's best trained and motivated salesmen. In fact, they are usually untrained in marketing and sales techniques due to heavy overload of technical courses.

Solutions to the Problems of Selling Technology

The first solution to these problems is to train and motivate technologists to effectively sell their technology. This training should include formal classroom activities and on-the-job coaching. Technologists should develop writing, interpersonal and presentation skills needed to influence clients. In addition, they should be trained in sales strategies and should know techniques for finding sponsors and overcoming other sales barriers. And finally, they should learn to sell their technology from the point of view of their clients. In the product safety information case study, the marketer already had these skills and that was the key to the success of the effort.

Second, research teams should be structured so that at least one person on the team has good selling skills. R&D managers typically consider the blend of technical skills needed to complete a project when putting a research team together, but they often do not consider whether the team includes a technologist that can effectively sell the idea to potential clients. We have found that the technologists who are involved in the early stages of a research project are the ones most committed to promoting it through to implementation. In the above case study, a team was created by the Product Safety Manager that included the technologist who designed the computer system, the health effects experts who knew which data to included in the data bases and, most importantly from a technology transfer perspective, a marketer who could sell the system to the Marketing Department.

In summary, the key to effective selling of technology is for technical department managers to leverage the natural ability of their technologists by building the sales skills of these people and then structuring teams that combine the best creative technical talent with the best sales talent.

Stage 3: IMPLEMENTATION

The following case study demonstrates many of the critical communications-related elements of effective implementation. This case involved conducting an energy conservation study at a refinery and implementing the recommendations. This case study is actually a compilation of experiences that occurred at many different refineries, but it is written as though they happened at one facility.

Implementation Case Study: Refinery Energy Conservation Study

In 1981, Mobil's Engineering Department created the Energy Conservation (ENCON) group to develop a master plan for reducing energy consumption and improving product yields. Developing this technology consisted of pooling all of the ideas that had been implemented at different Mobil refineries throughout the 1970's as well as taking a fresh look at other changes that could be made to conserve energy through computer simulations and pilot plant testing. The case study began after the ENCON master plan had been marketed and sold to one of Mobil's largest domestic refineries and the technologists are preparing to begin the implementation stage with a kickoff meeting at the refinery.

The ENCON technologists had learned through their experiences at the other refineries that solving "people problems" was just as important to the success of the implementation effort as solving technical problems. The technologists had learned the importance of conducting themselves as consultants in all interactions with their clients. They had to behave in a very client-centered and service-oriented way. They had to feel and act as individuals with technical expertise who had been hired by the client to help the refinery staff solve problems and identify opportunities. They were participants in the study, even though they played leadership roles as they guided the activity.

The kick-off meeting between the refinery clients and the technologists covered the overall ENCON study approach, the study goals, introduction of the refinery personnel who would participate in the study, selection of the data that would be collected and the schedule for the study. Prior to the kick-

off meeting the technologists had to collect as much preliminary data on both the refinery operation and on key refinery personnel as possible. This gave the technologists a feeling for the type of environment they would be working in and provided a basis for preparing check lists for pre-study data collection. This was important to demonstrate the professional manner in which the study was to be conducted and to emphasize the refinery's full participation in the effort.

The kind of people working on the study team was critical to the project's success. The technologists needed both interpersonal and communications skills as well as technical skills. The plant personnel had to be at a high enough level and maintain sufficient credibility within the refinery to carry forward with the project without having to clear every minor decision with superiors. The plant personnel also had to be able to work full time on the project for six months. This latter item was typically the most difficult aspect of the kick-off meeting. Experienced plant personnel were at a premium. Often there was a tendency on the part of plant management to put a young, inexperienced engineer on the team so that he could be "educated". However, experience with previous ENCON's had shown that this could severely disrupt the progress of the study.

The initial data collection exercise was a joint team effort involving both refinery personnel and technologists. The initial data were screened to make certain they were accurate and the input of the refinery personnel was essential to this screening task. If special test runs were needed to generate new data, both refinery and technologist team members guided them. The final data was used to build and test the computer models which simulated the refinery. Working together in this manner molded the individuals from the two organizations into a team -- new ideas became the "team's ideas". The final list of recommendations belonged to the team, or more accurately, the refinery who had control over the final implementation of any recommendations.

An interesting aspect of ENCON was that recommendations often were implemented prior to the reviews and final report. As the refinery members of the study team discussed the study's progress with their associates at the refinery, some ideas seemed too good to keep for the final report. So, an idea would be tried on an informal basis and implemented before it became an official recommendation.

The final report and presentation by the study team was a formality that advised management at Headquarters and at Research & Engineering of the recommendations that the study team and management of the refinery had agreed to try. The physical implementation of the recommendations was largely in the hands of the refinery, guided by the refinery members on the study team. The role of the technologists on the study team shifted from a role as joint participant to the role of advisor as the refinery took over complete responsibility for the success or failure of the physical implementation. But communications between the study team members did not stop with the final report. The refinery engineers continued to call on the technologists for advice and support.

Problems with the Implementation Stage

Most of the potential problems that can be encountered in the Implementation stage of technology transfer had been anticipated and avoided in the Energy Conservation Case Study through careful planning and training on the part of the technologists. Some of these potential problems are as follows:

- Establishing credibility with operating and marketing people is a major hurdle at this stage. Inexperienced technical people must learn how to earn credibility from their clients and recognize that they have to earn their credibility every time they encounter a new group of clients.

- The problem of client confidentiality often arises when organizational boundaries separate technologists from the operating division personnel. Sensitive organizational issues are bound to arise in such situations and the manner in which they are handled can either enhance or harm the nature of the relationship between technologists and clients.

- Conflict within the operating division can be a deterrent to effective technology transfer. Different groups within a refinery, for example, have different objectives: operating personnel focus on crude oil throughput and keeping the refinery running for the short term; the maintenance personnel focus on keeping the refinery operating for the longer term; technical personnel focus on improving yields and product quality. There is typically a hierarchy of influence among these departments and technologists must be aware of this as they work to build a consensus in support of the project.

- Roles change during the planning, installation and start-up, near the end of the implementation phase. New people come into the project and technologists change from a role of joint participant to advisor.

While these are some of the typical problems that arise in the Implementation Stage, the list is by no means complete.

Solutions to the Problems of Implementation

Three solutions to these problems are presented below: (1) develop strategies to build commitment from the clients; (2) define how technologists and clients will work together; and (3) develop reward systems to encourage technologists to work in technical service groups, the "front lines" of technology transfer. First, develop strategies to build commitment from the clients. Commitment is needed at multiple levels of the client organization to implement technology effectively. The quality of the people supplied by the client organization is a good measure of their level of commitment at the beginning of the project -- if they commit quality, experienced people, they are demonstrating the importance they attach to the project. In addition, when the time comes to turn the project over to the refinery, the more experienced clients on the study team are likely to take a personal interest in seeing that the project is a success, long after the technologists have left the facility. In the successful refinery case study presented above, the experienced and technically competent operating people became the most persuasive sales people within their own organization to push the new ideas being proposed by the ENCON study team. These personnel already had technical credibility as well as the power to lend credibility to the technologists on the study team.

Second, define how the technologists and clients will work together -- both formally and informally. From the formal perspective, this means having some kind of internal system by which a written contract is drawn up between research and development and operating divisions. This system should not be overly bureaucratic as to slow down the transfer process. However, it should at least describe the scope of work to be done, objectives, costs and timing. In the ENCON case study presented above, the formal agreement was developed at the kick-off meeting. Without such minimal agreements the possibility for misunderstanding is too high. When unexpressed expectations are inevitably shattered, the trust and credibility of the technologists' entire organization suffers.

Just as important to the success of the implementation of technology is informally defining how the technologists and clients are going to work together. One should cover issues such as how the technologists and clients are going to communicate with the clients' management, often a significant issue when the technologists are part of a different division. Nothing creates barriers to technology transfer like having clients hear about problems from their boss before they know about it and can act on it. This issue of confidentiality is significant and potentially devastating.

Technologists must always remember that if the operating division went to an outside contractor for similar technology, there would be no question about keeping the confidence of the client. Technologists must be taught to honor the client's confidentially unless, in the technologist's judgement, serious problems would arise. In such cases, the technologist should alert the client of the need to communicate the issue to upper management to give the client an opportunity to communicate the issue to his immediate management first.

Similarly, it is important to reach informal agreement with the client on the frequency and mode of communication. Some clients may prefer to be kept informed in writing, others may prefer more informal oral updates or electronic mail. Part of this informal process should include sessions where the technologists and clients discuss how each thinks the project is going and share feedback.

Third, develop reward mechanisms that encourage technical service. In some technology organizations, technical service is not as highly respected or well rewarded a function as perhaps basic research in a rapidly advancing technical field, such as catalysis. However, routine technical service jobs are actually the front lines of technology transfer. Technical service personnel can serve the valuable function of keeping the lines of communications open with the clients in the operating divisions and set the stage for greater technology transfer. If the reward system is unbalanced, the bright people in the organization will figure it out quickly and work in the areas where the rewards are the greatest. At Mobil, we have attempted to balance this system by creating both a management ladder and a technical ladder and by ensuring that personnel in all technical areas receive equal opportunity for rewards and advancement.

Stage 4: FOLLOW-UP

Follow-up is the most frequently overlooked stage of the technology transfer process. Yet it is just as important to successful technology transfer as the other stages. If follow-up is performed properly, it can feed into the marketing stage and maintain the continuous cycle of technology transfer. Technologists who maintain contact with the client on the status of technology that has been transferred will know what the additional needs of the client may be. In addition, this type of interaction will enable the client to stay abreast of the any new technology that may be available from the technologist. Without effective follow-up, technology transfer can become disconnected, the quality of the end product can suffer and future attempts at technology transfer may become more difficult. The following story about the Drilling Data Center illustrates the value of proper follow-up:

Follow-up Case Study: The Drilling Data Center

An exploration and production technology group had developed an on-line computer system called the Drilling Data Center to enable the operations drilling superintendent in New Orleans to observe from his office the progress of various drilling operations in the Gulf of Mexico. The system had been installed and the directions and documentation had been passed along to the drilling superintendent and his staff.

A few weeks after the installation had been completed, the drilling superintendent visited the technologist and spent a considerable amount of time complaining vehemently about the deficiencies of the new system. The technologist, although somewhat taken aback initially by the negative reception his system had received, recognized that the client would not have taken the time and effort to come in and complain if he did not need the system and was not interested in working to make it better.

Consequently, the technologist and client agreed to meet once a week over the next few months until the system worked properly. This was a tortuous experience for the technologist at first. But gradually, as the dependability of the drilling data center improved, so did the working relationship between the two men and the format of the discussions took on a new focus. They began shifting from discussing only the deficiencies of the existing system to defining the ideal system. The technologist took many of the new ideas from the client and incorporated them into the system and this process significantly improved the quality and usefulness of the technology. After six months, the technologist was certain that all his follow-up efforts were worth it when the client asked to have the Drilling Data Center installed in his home.

Problems Related to the Follow-up Stage

The problems with follow-up are more pervasive than with any other stage of the technology transfer process:

- The "it's-not-my-job" attitude stems from the mistaken belief that a technology transfer job is completed when the final paperwork is done. In one sense, technology transfer is never done. Technologists are always responsible for the success of their technology, even years after they have left a plant. If a technology fails at some time after implementation, the word will spread to other potential users of the technology and technology transfer will cease.

- Technologists should view their job more broadly as facilitators on a team that wants to achieve results that affect the bottom line, not as limited technical specialists.

- In any large organization there are bound to be structural problems in the system that inhibit follow-up activities. One example that was uncovered in several case studies was the lack of money allocated to fund follow-up activities by technologists. In the Mobil system, much of the work that technologists perform with the operating divisions during technology transfer is charged back to the divisions. For a number of reasons, it is difficult to obtain funds from the divisions for trips to the newly implemented plant or process to see how it is operating. Yet, such trips are necessary and they must be made.

- Finally, some technologists view follow-up as a form of failure -- if the job had been done properly the first time, there would be no need for follow-up. Such an attitude fails to consider that effective implementation occurs along a continuum and that fine tuning can usually help coax more benefits from new technology. Additionally, the follow-up process is not just to remedy problems, but to discuss future possibilities.

Solutions to Follow-up Problems

We have developed three recommendations for solving the problems related to follow-up:

First, follow-up activities should be planned from the start of the project, rather than adding them on at the end of the project. It helps if these follow-up activities flow naturally out of the project. For example, in the ENCON case the client headquarters people scheduled periodic reviews of the progress made on implementing the study findings. The technologists who had done the study were invited to these meetings. These reviews encouraged the refineries to keep in touch with the technologists concerning ways to overcome implementation problems.

Second, gain the support of top management for engaging in follow-up as a legitimate activity. Without top management support the necessary resources for this activity might not be allocated, particularly at

the time needed to be effective.

Finally, as in the marketing stage, technologists should use every opportunity to interact with the client to check on the operation of technology that has been transferred. These opportunities include training sessions, operating division meetings and even social affairs. These interactions lead naturally to identifying new opportunities for enhancing existing technology or identifying new technical needs.

CONCLUSIONS

- Technology transfer is a process that requires management attention and support to be effective.
- The key to technology transfer is effective communications between the technologists who understand the technology and the clients in the operating divisions who understand how to convert technology into competitive advantage.
- The early establishment and use of teams of clients and technologists, as illustrated in the Refinery Energy Conservation Case Study, is critical to promoting effective communications.
- Technologists must be properly trained, directed and rewarded to engage in technology transfer activities.
- Follow-up must be regarded as an integral part of the technology transfer process.
- Technology transfer must be balanced with technology development in order to derive the maximum benefit from a company's investment in research and development.