TECHNOLOGY TRANSFER AND SUSTAINABLE DEVELOPMENT

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Summary

This paper discusses the emerging subject of Technology Transfer, its present and future definition and its importance to the future of our society and sustainable development. A historical background is given with examples of earlier technological development, including cases of "missed opportunities". Technologies for the third millennium are identified with typical development patterns for such technologies and two examples are discussed in detail, namely Information Technology and Energy. The importance of improving an expanded form of *holistic* Technology Transfer for the new knowledge-based economy is discussed and major policy shifts are suggested.

1. Introduction

The formalized subject of Technology Transfer is very recent and yet the process is as old as the inquisitiveness of humankind. While technological development was orderly and occurred at a relatively slow pace, technology transfer was natural and almost automatic. For example, no one was required to oversee the technology transfer of the wheel! It is, however, illustrative that it was not universally used until some 250 years ago. In the last two decades, as a result of the extraordinary explosion of knowledge and scientific and technological breakthroughs, it has become increasingly important to formalize the ultimate utilization of modern technology for the good of our global society. This is mainly an attempt to ensure that new technology is used and not overlooked and forgotten and that innovation is employed quickly and effectively in improving the economy. It is also required to overcome the sheer inertia of large companies which prevents technological breakthroughs from being utilized, either accidentally or deliberately, because of the lack of immediate economic benefit.

The present normal approach to Technology Transfer follows a pattern similar to that shown in Figures 1A and 1B.

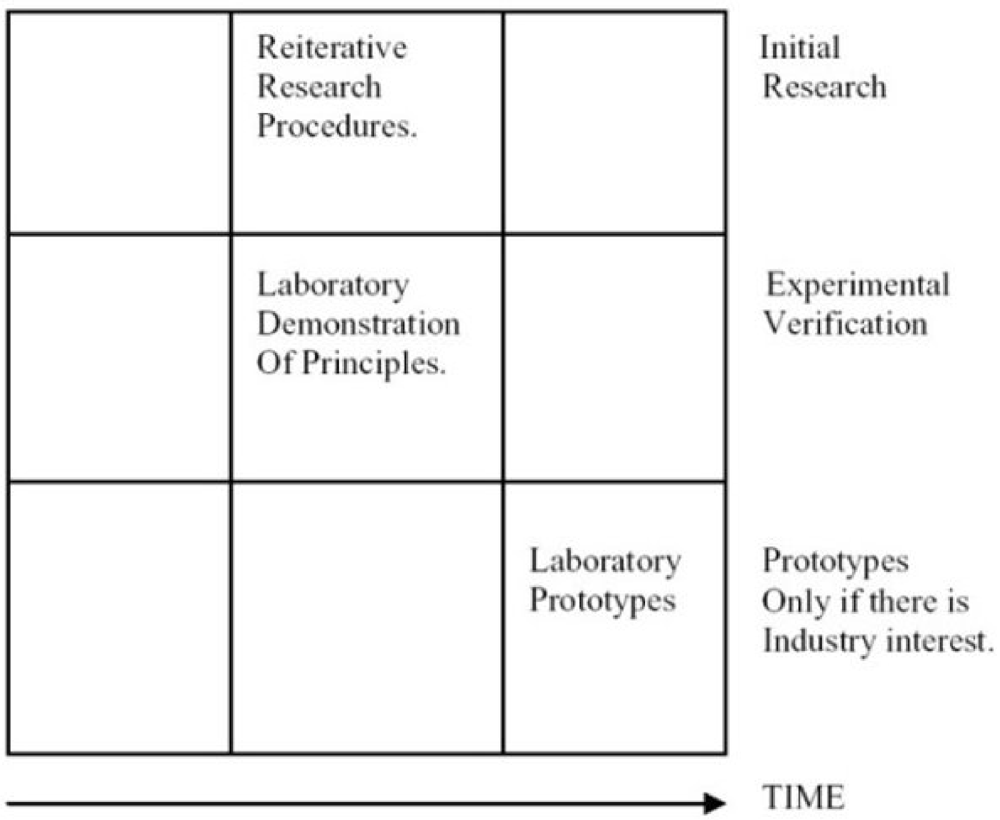

Figure 1A: Traditional research procedures leading to Laboratory Prototypes

If industry interest is there and the laboratory prototypes prove successful, then the next stage is entered into. The development of a manufacturing prototype can take up to ten times the manpower and budget that the initial research took. This is an aspect of the commercialization of fundamental research that is often overlooked and many first-rate researchers are unaware of the time and resources often required to commercialize what to them is "the next best thing to sliced bread"! This can and does create unnecessary tensions between fundamental researchers and industry. In many cases also, industry does not understand the time, effort and sacrifice that individual researchers have expended to pursue particular avenues of their research which have resulted in commercially interesting discoveries. This is one of the reasons that we strongly feel that the most efficient form of Technology Transfer, particularly in this age of rapidly expanding computer-related technologies, is the transfer of the people with the knowledge, at least for a short initial term. We will return to this proposition from time to time. Figure 1B shows a "traditional" pattern of manufacturing prototype development after the fundamental research has reached a laboratory demonstration stage.

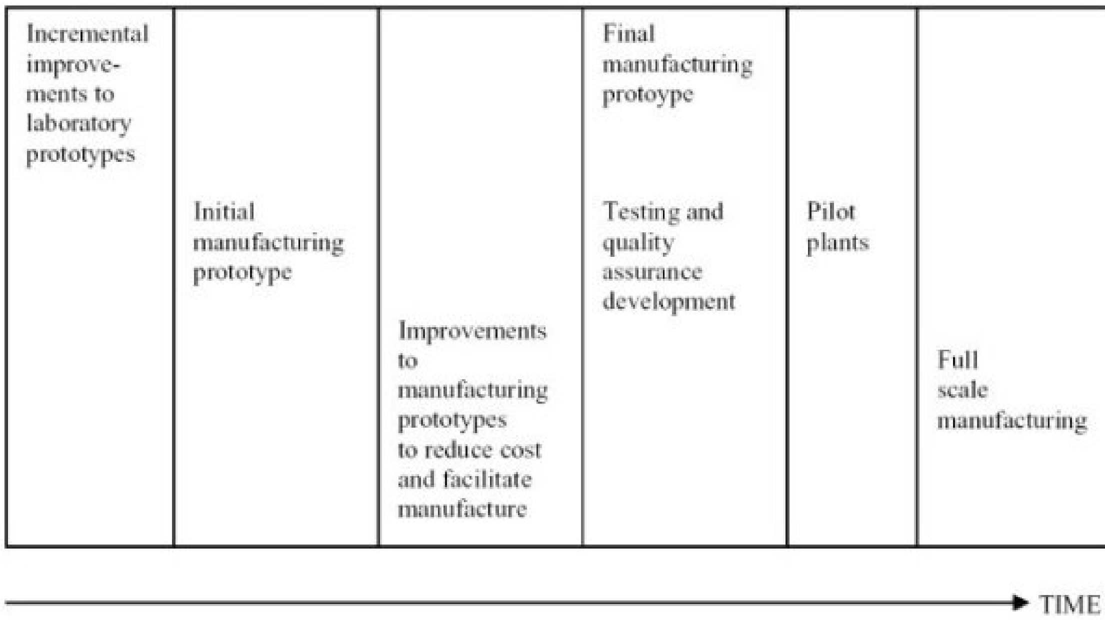

Figure 1B: Usual Technology Transfer form Laboratory to Industry

It is appropriate to look briefly at the history of scientific and technological development and the transfer of that technology into industrial practice and the details of how that has changed and is changing, particularly in recent years. The early, and extraordinary, scientific contributions of the Greeks were used more by the Romans than by the Greeks themselves. The Romans were excellent engineers and used and applied much of the “pure” science of the Greeks, not only to improve their living conditions but also *primarily* to help their powerful military machine conquer most of their known world. They also used it to improve the living conditions of their occupying forces and citizens in such inhospitable locations as England and Scotland!

The long hiatus in scientific and technological development during the Middle Ages came to an end as Europe emerged into the Renaissance. Scientists and mathematicians made extraordinary advances from the seventeenth century onwards culminating in the first industrial revolution. And so Europe, and by then North America, moved from an agricultural-based economy to our present natural resource-based economy. The transfer of technology during this change was natural and “unorganized” for the most part. The introduction of ever more sophisticated farm machinery, fertilizers and herbicides resulted in a change from 40% of the total workforce of the United States being in agriculture early in this century to about 3.5% at present. At the same time this greatly reduced workforce produced considerably greater amounts of food. There has been an attendant massive growth of the industrial sector. Accompanying this was the move of people from the countryside into the rapidly growing cities, usually with a noticeable drop in the quality of their lives, certainly until the next generation was capable of working effectively in the factories and in industry as a whole.

The present situation is one where again there is a change in the *primary* economy. In this case we have changed from a resource-based economy to a knowledge-based one, where well-educated people and their skills and knowledge are the primary raw materials. Thus education becomes increasingly important. The dangers and problems of having large numbers of citizens who are neither sufficiently well educated nor well enough trained to take part in the new economy are becoming increasingly apparent. It is, of course, easier to look back to what happened during the first industrial revolution and to see the mistakes made then than it is to see clearly what errors we are making as we go through the second industrial revolution. This second industrial revolution is driven by computers and information systems technology.

A very noticeable difference between the two situations is the care which society, certainly in the western world, now shows for all of its citizens as the economic driving forces change. It has become abundantly clear that we cannot simply ignore significant percentages of our population without adversely affecting our over-all quality of life and ultimately our productivity and economic performance. This is changing our narrow view of what technology transfer encompasses. Even within a narrow definition, *the most effective way to accomplish technology transfer is to transfer the people with the requisite knowledge* to the arenas where that technology is needed. As we move more rapidly into the full utilization of computers and related technologies this is more evident than ever before, but there is a broader aspect of technology transfer which is easily overlooked. That is the transfer of the fundamental scientific and technological knowledge and skills to the larger numbers of people required in the work place to ensure that the technology is successfully "transferred" and efficiently used. This is an educational problem and one that is only just being recognized by governments and industry. On the North American continent in particular, the emphasis has been on university education. While this is admirable in itself, it ignores the technological training that many individuals are more suited to and which they receive in the technical colleges. Part of this is a left-over preference for parents to have their children attend universities rather than technical colleges, in spite of the fact that many technicians and tradesmen earn more than university graduates do. This is an unfortunate type of educational snobbery.

A further aspect of "Technology Transfer", again used in the widest sense of the term and one which can and will have dramatic effects in the future, is the whole concept of the use of science and technology in such a way as to improve living conditions and the quality of life as well as to protect the environment. This of necessity involves a transfer of *knowledge* from the Humanities and Social Sciences which will help us to choose ways of using technology and scientific developments for the improvement of the economy, but in a manner which does not detrimentally affect our quality of life or our environment. Often this can be done without compromising our economic goals, particularly if a *holistic* point of view is taken.

For example, to save millions of dollars using an approach which marginalizes a percentage of the population only then to have to spend more on combating the resultant unemployment and the resulting social problems does not make good economic sense. However, the preservation of self-respect and motivation and self-responsibility means that this is no simple problem to solve. Recent findings and increased knowledge in many areas other than science and engineering are needed to understand and prevent such approaches being taken. As a further example, it is not “smart” economics to use new technology or even a mundane standard technology which ruins the local water supply and then requires massive expenditures to rectify the situation. If, of course, the company involved passes on the clean-up cost to local government and avoids its responsibilities, as was cited recently in a special winter edition of Time (1997-1998), then it makes *short-term* sense to the company in a shortsighted sort of way. Even then, in the long run, if that company intends to expand it will need to attract young educated employees who will be very aware of environmental issues and how they affect the quality of life in that location.

There is a general consensus emerging that the still-prevalent dog-eat-dog competitive stance taken by many companies and industries is only good for very short-term gain. In the long run a cooperative stance is much more profitable. This pertains not only to competitors but also to the environment and quality of life. What is fascinating is that this approach has received some interesting support from modern mathematics in the area of Game Theory. To win at all costs appears to be a natural outcome of Darwin’s Theory of Evolution. This apparent outcome is now being challenged by, among others, Stephen J. Gould. Now mathematicians have added their weight to the argument.

In the face of it, why do people cooperate at all? This intrigued Robert Axelrod, a Political Scientist at the University of Michigan. By and large people do tend to cooperate; they obey traffic lights and so on. Axelrod invited a number of Game Theory experts to tackle the old conundrum of The Prisoner’s Dilemma. This is described in detail in "*The Teacup and the Universe*" by Cole. The most effective approach was a simple strategy developed by Anatol Rapoport of the University of Toronto. In the end, although the cutthroat exploitative strategies appeared to gain initially, the long-term winning approach was always a more cooperative and “forgiving” one. “[I]n the long run, a strategy that is not nice, i.e. cut-throat and exploitative, can destroy the very environment it needs for its own success.” One further and relevant conclusion from this work was that “other’s success was virtually a prerequisite for your doing well in this type of situation.”

All of this has a deep impact on business strategy and involves a more complex type of technology transfer than has been considered before and in areas not often considered as candidates for technology transfer. Over all, the concept of technology transfer has to take on a much wider meaning than that outlined in figures 1A and 1B; that is, the simple transfer of scientific and engineering knowledge and know-how into industry, *if* sustainable development is to be successful. This will be addressed throughout the rest of this paper.

2. Historical Examples

To understand why Technology Transfer has become of increasing importance, a number of examples will now be discussed.

The first example, as described by Rosenfeld in his book on Irving Langmuir, is that of General Electric at the beginning of this century when they hired Langmuir. In a sense this is a somewhat unfair example in that the GE Laboratories were exceptional at the time by any standards. They encouraged so called *pure research* and were willing to fund it substantially. Under these conditions, which Langmuir found far more conducive to original thought than his previous academic appointment at the tiny Stevens Tech., he developed the neon filled light bulb and put in place technology which served later to put GE on the map in the area of vacuum tubes. It is illustrative in that in this instance the scientist discovering the new concepts and technology would normally have been in a university. In fact he had been actively encouraged to join academia. The technology transfer was very rapid because the individual with the knowledge was in the company where it was to be exploited. The ultimate impact on GE and on society is still being enjoyed.

The second example is also, deliberately, unusual. It is the discovery and development of the bipolar transistor, which took place from 1945 to 1951, although some of the basic work had begun as early as 1939. Following the work on point-contact diodes and transistors which were used successfully during World War II and looking at why and how they worked, as described in detail by John Kendall in his 1968 book on Transistors, Bardeen, Brattain and Shockley published a number of papers about the discovery of the bipolar transistor which revolutionized electronics and particularly computers. For this they won the Nobel Prize. What is again unusual is that at the time they were all working at Bell Telephone Laboratories. The technology transfer was swift and certain. The first transistorized computer was built in 1956. What is very illustrative is that General Electric, who certainly led the field in vacuum tubes at the time, handed the information of this new discovery over to their Vacuum Tube Division to examine and comment on. Their conclusion was “this will not go anywhere”. GE never regained its pre-eminence in electronic devices.

We have seen the same story repeated in the electronics industry. The decline of Fairchild, once the pre-eminent leader of the electronics industry, for not appreciating the developments in integrated circuit design, is one case. Another is the establishment and success of LSI Logic Inc. as the present leader in Application Specific Integrated Circuits (so called ASICs) in the world because it did appreciate the rapid developments in integrated circuit design and the move to large custom-designed ICs. Technology Transfer must involve the transfer of, or at the very least intimate interaction with, the people with the technological and scientific knowledge to be effective and efficient. That is why the transfer of technology and knowledge from universities is difficult and why the present move for industry and universities to work more closely together without threatening each others’ prerogatives is a very positive sign. This becomes crucial if technology transfer is to aid and abet sustainable development.

One further point about technology development and transfer is the sheer speed with which both now occur. For consistency's sake let us stay with the electronics industry. As we approached the year 2000, the so-called millennium bug was becoming a very real concern. This was the so-called Y2K problem. Early computers had very little memory either for storage or operating. Dates require four numbers for a complete description of a year. Each number requires, in for example ASCII code, seven bits and hence "1970" requires four bytes of code with seven bits in each byte. When a computer had a total of 48kbytes of operating memory it seemed appropriate to save two bytes by simply expressing the date by the last two digits, e.g. 1970 became 70. This in most cases was not rectified, even though computers were so much more powerful and we now talk in terms of Gigabytes and Terabytes of memory. In 1995 the LSI Logic chip that Sony used in its play station to be used by 9 to 13 year olds had more computing power than NASA had in its entirety when they first put a man on the moon! While the technology transfer that created these powerful integrated circuits is very impressive, it was less impressive to see that much software released even in 1999 was not initially Y2K compliant. This gives some idea of the present difficulties faced in fully and effectively using modern technology in the new millennium.

How do we then ensure the transfer of cutting-edge technology from our universities and research labs to industry? One thing is for certain; it will not happen directly. The driving forces and time schedules of the two groups are different. Industrial people have difficulty dealing with academics who cannot keep to a budget or a time schedule, and who are often distracted by other projects. Likewise academics do not interact easily with businessmen who demand deliverables, who do not have the vision to see the long-term potential of an item of research and constantly talk about salaries to be met, the bottom-line and deadlines! Yet it is essential that the technology be transferred effectively and efficiently and that some of the rewards of its exploitation be returned to support basic research.

There are three essential structures that must be put in place for the full and effective realization of technology transfer.

- The first is the creation of new institutions or new or modified sections of our universities, which concentrate on applied research and which exchange personnel with industry on a regular and formal basis.
- The second is to put an emphasis on the creation of spin-off companies with the expertise to take research and develop it into commercial, marketable goods and services. Again the exchange of personnel is an essential ingredient in this.
- The third is to establish a Government All-Party Committee that overrides partisan politics and that sets up and administers policies for effective technology transfer and utilization. These policies have to be long term and therefore be able to survive changes in Government.

Nothing motivates researchers more than being able to follow their own very personal project through to where it is of use to society and at the same time profitable! The U.S. has been very successful at this, and, while there are dangers and the integrity of the universities and pure research must be guarded, it is the only way to have a smooth flow of technology to industry.

3. Future Technologies

The forecasts concerning future developments in technology and where they will lead us abound. There is only one thing for certain and that is that most of those forecasts will be wrong. It is extremely difficult to forecast technological and scientific breakthroughs because they are just that -- "*breakthroughs*" and they are often not anticipated. Nevertheless, a recent consensus as presented by Coates is interesting. The six enabling technologies expected to lead us through to the year 2005 are predicted to be: Information Technology, Energy, Materials, Genetics, Environmentalism and Brain Technology. Strictly speaking "Environmentalism" is not a technology, but as it is emphasized in so many areas it will have such an all-pervasive impact that it must and should be included.

If there is a fundamental objective, it is to increase and enhance the degree of technology transfer considered in the fuller meaning of the term. That is, it is no longer acceptable to improve and increase technology transfer simply for the increased profits of multi-national corporations. It is now essential for this to be done in a *holistic* manner, considering the impact on society, the quality of life and the environment. Only then will sustainable development be effective. From a long-term economic point of view it also makes more sense, particularly for the large multi-nationals. The decisions about which technological developments to use must include these considerations.

4. Sustainable Development and Technology Transfer

One of the most debated topics in economics since the Club of Rome meetings and their pronouncements on "Limits of Growth" published in the 1970s is continued and sustainable growth. Surely growth has to cease in the end and we should become a conserver society? It would seem obvious that we do not have unlimited resources to feed ever-continuing growth. Hindsight is 20/20 and it is now clear that at the end of a resource-based economy where growth was seen to rely entirely on a supply of necessary raw materials the Club of Rome's approach was a thoughtful and wise. However recent considerations by leading economists have put a different spin on this and have introduced new concepts. Consider the arguments of Professor Paul Romer of Stanford University, California, who was also the Royal Bank Fellow of the Canadian Institute of Advanced Research, CIAR. He wrote, "The fact is that new ideas and innovations arise daily and keep building on each other, and simply aren't governed by such old rules as the law of diminishing returns. From now until the sun explodes we won't run out of new things to discover…. In other words there is no apparent limit to growth. The key is to understand knowledge or ideas as economic goods which usually have fixed costs. The overall message is that there are really great opportunities available for all of us around the world. And the anxieties that many face right now about innovation are quite real. So I try to convince people to look back historically and consider the process, and how we've been successful, say over the past 100 years, in harnessing technology. In future brains not brawn will drive economic growth." It was in anticipation of these ideas that the term "knowledge-based economy" was coined by Gaines in the mid-1980s.

There are two important aspects to this interesting and optimistic scenario which is ultimately based on a fixed amount of raw materials; they are, (i) the fundamentals of sustainable development, that is re-cycling and the minimization of the attendant harmful environmental impact and (ii) education. Education is by far the most essential factor. It is not possible to be innovative, to have and exploit new ideas, and to make discoveries and effectively transfer them into industry without an educated population. The cumbersome attempts to formalize technology transfer at a high level do not work when they fail to emphasize the movement of personnel with the necessary expertise. The underlying base of education required for effective technology transfer and the wider understanding of the term itself impacts all areas of education from primary school to graduate school.

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Biographical Sketches

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