# APPLIED ANTHROPOLOGICAL METHODOLOGY

# AS A CONTRIBUTION TO

# TECHNOLOGY TRANSFER PROGRAMS WITHIN NATO

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APPLIED ANTHROPOLOGY AS INTERFACE
AS A CONTRIBUTION TO
TECHNOLOGY TRANSFER THROUGH [illegible]

by

David F. Evans

Evidence from the past—both from archaeology and the fossil record—clearly indicates that technology is nothing new, but rather is as old as man himself—however he may be defined. Technology began for man approximately two million years ago, along what were then small streams wandering through African savannahs. Technology transfer, admittedly a much simpler process in those early days of our ancestors than it is today, has existed in Europe at least since the beginnings of our species, some two hundred thousand plus years ago. The process began when small bands of hunters and gatherers returned from summer foraging trips to weather long winters in caves in the vicinity of the relatively warm waters of the Mediterranean. These shelters served as meeting places for returning families and kinsmen, places where new hunting tools and techniques, as well as other practical information gained during the short summer's travels, were shared around fires flickering along the cliffs of southern Europe.

While man could not exist and would never have evolved into his present form without technology, archaeological evidence also reminds us that technology has greatly altered the natural environment—man's only habitat. Whole societies have withered and vanished because of the misapplication of technology. Silent ruins stand to remind us of this in the eroded plains of the Middle East, in the wind-swept Andes, in the valley of Mexico, in the jungles of Central America and South East Asia, and elsewhere. And, lest we [illegible] [illegible] the most advanced technologies of their time!

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Human behavior is the least predictable of all animal behaviors on this planet. The interactions of most non-human life-forms with their environments are primarily the results of biological evolution, and, to varying degrees, their behaviors are the products of innate instincts programmed by natural selection during their evolutionary past. Mankind, however, for two million years, has been increasingly under the pressures of at least two evolutionary selective forces: biology and culture. It is the latter, the evolution of human culture, that makes man the behaviorally unpredictable animal that he is. It is culture, far more than biology, that one must be keenly aware of, and always take into careful consideration, when one desires to plan for and engage in directed change programs in any form. To design action programs, and to effectively channel and coordinate the individual strengths and resources that best serve the needs and goals of NATO members, involves directed socio-technological change. All technology transfer programs are dual in nature. They are dual because they almost always involve changes not just in the physical environment but changes in the attitudes, and thus in behavior, of people.

It is a well-established fact in the cross-cultural literature that if the socio-cultural costs outweigh the technical or economic advantages of a new "to-be-transferred" technology, that specific technology will simply be rejected outright, or, at best, not be accepted without first undergoing great modifications. Sometimes the modification reaches the point of nullifying the effects of what was originally envisioned as superior technology by the change agent, or innovative country.

As a brief example, an article in my local paper, on the morning I was [illegible] these words, [illegible] that the [illegible] the Concorde for landing in New York City. It is apparent that the objections to the Concorde, a beautiful bit of cooperation by the British and the French, are not based

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on whether or not this splendid aircraft will fly. The [illegible] of the Concorde are not in question. Rather, the whole issue has become something like the collective nightmare of countless sanitation and landfill engineers in crowded cities everywhere: no one really objects to them picking it up, but everyone seems to have a strong aversion to them putting it down anywhere. This is not to equate the graceful Concorde with city garbage, but rather to point up again that decisions on technological transfer are seldom based on the quality of the technology itself.

The methodologies now utilized by applied anthropologists to implement comprehensive technological change cross-culturally initially grew out of field work in the less-developed countries about the world, and are the results of directed change experiences between developed change agents and less well-developed "target" or "client" groups. The results of the data gained nevertheless apply equally, and could be quite effective in the implementation of directed technological transfer between industrialized countries. Moreover, the same analytical approach may be effective in studying the change agency involved in the planning, development, and implementation of technology transfer policies and programs. In addition, the methodology that developed from these asymmetrical interactions between developed and less-developed countries has resulted in theory which offers considerable potential for predicting the success or failure of action programs, and can thus make substantial contributions to directed transfer programs within NATO.

George Foster, a leading American applied anthropologist, long ago noted that "cultural phenomena occur in cross-cultural patterns that can be defined and analyzed." [illegible] events, and he suggested that "once significant patterns have been isolated and are understood, they will have predictive value of a generalized nature," [illegible]

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intent to furnish useful guides to program planners of administrators" (Foster 1973, [illegible]).

It is obvious that whether or not technical transfer programs meet with failure or success will in great measure depend on the ability of administrators to forecast the attitudes and reactions of the target groups regardless of whether the target groups consist of industrialized or more traditional societies.

When one thinks of Anthropology one may think of scientists working with people in out-of-the-way corners of the globe--perhaps people living in primitive or at least "underdeveloped" conditions. When one thinks of "Applied Anthropology", one envisions anthropologists working with programs designed for, or oriented toward, newly-developing and largely non-industrialized countries. An example of the above would be the now-famous Point IV Program. It is indeed true that anthropologists have focused upon the "holistic" approach, and that smaller, less-developed societies have been the target areas for the vast majority of their basic research. Nevertheless, applied anthropologists everywhere are involved in programs that relate to behavioral changes designed to ameliorate contemporary social, economic, and technological problems, and it is clear that applied anthropologists have a wealth of data and experience to offer policy makers and industry managers who are involved in the practical aspects of technological transfer between more developed, industrialized countries.

It should be apparent today to those involved in the development and/or implementation of programs designed to meet the challenges of rapidly changing societies about the world (both industrialized and non-industrialized), that any social and economic progress in one society affects others. It is also evident that socio-economic progress often requires the technological ap- [illegible] as the "hard" sciences to distinguish them from the "soft" behavioral

societies about the world (both industrialized and non-industrialized), that any social and economic progress in one society affects others. It is also evident that socio-economic progress often requires the technological ap- [illegible] as the "hard" sciences to distinguish them from the "soft" behavioral

or social sciences. Most administrators would agree that "hard" science and resulting technology is needed to implement the kinds of socio-economic changes necessary to meet the growing problems and challenges of modern society. But not all would agree that the "soft" sciences can make the kinds of data input necessary--data of practical import--that the solutions of those burdensome problems require.

Today's parents, unlike those before World War II, no longer take it for granted that their children and grandchildren will live out their lives under steadily more desirable conditions than those existing at present. In other words, for the past several decades, it has become obvious to any thinking man that "progress"--regardless of how defined--"is not automatic and inevitable" (cf. Foster 1962: 5) and it has become apparent that such progress will require not just technological solutions derived from ever-more-sophisticated physical and biological research, but the intelligent application of socio-cultural concepts as well. Only through the full utilization of all knowledge available to us can we hope to work toward rational solutions for some of the awesome problems facing the only bio-cultural animal on earth.

Most anthropologists carefully avoid using the term "rational" in describing man. Man is a "bio-cultural" creature, and culture, by definition, is the result of learned behavior. Man's cultural evolution includes his technology, and technology is man's unique way of adapting to his environment. All men must adapt to survive, but how they adapt--whether they will bury, burn, or eat their dead, or eat snails or cheeseburgers--will be determined by what their cultural values tell them is the proper and appropriate thing to do. [illegible] they have been taught to perceive. Men pose questions in ways in which they have been taught to think. It is often easy to posit the wrong answers. It is sometimes quite difficult to be sure that we

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Consider the farmer in New York, [illegible], when it was pointed out that the large [illegible] were becoming extinct, replied: "Yes, it's true they are dying out, but think of the price that last one will bring!" Or consider the cases of various industries with vested interest in specific animals. These industries negotiate, year after year, to increase the quota of animals killed, even though all evidence indicates that the raw materials of these industries, the animals themselves, are on the brink of extinction.

My point is a simple one: man not only does not run on instincts and hasn't since he emerged from the caves a fully bi-pedal but socialized creature in the dim past of the Pleistocene, but he also does not run on pure technology and cold, calculated reason. This cultural fact has given rise to the 'anthropological axiom: "In order to work with a people it is essential to understand their culture". It is from the [illegible] of applied anthropologists around the world that such understanding has come, and these same anthropologists can make substantial contributions by translating socio-cultural data into terms that are meaningful to administrators involved in the planning and implementation of technology transfer policies and programs.

It is my contention that it makes little or no difference whether administrators are transferring technology to industrial or non-industrial societies. The cultural dynamics in areas of technological and economic change, [illegible] and the effects of cultural dynamics on the innovative process [illegible] transfer. It is apparent, also, that [illegible]

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Every technological transfer involves, to varying degrees, subtle shifts in the attitudes and motivations of the people participating in change--both those initiating the transfer and the recipients of the new technology. It is well known in the behavioral sciences that human attitudes and motivations are notoriously difficult to measure, regardless of whether they are held by peasants undergoing the stress of modernization, or industrialized societies exchanging various new ideas and technological hardware (cf. Cates 1976: 641-665). The attitudes of both participants in any cultural exchange may become either barriers or stimulants to the acceptance and application of the new technology in question. Merely possessing a superior technology does not mean that others will perceive the fruits of that technology in the same light or that the successful transfer and acceptance of the innovation will be automatic or inevitable.

Among the member nations comprising NATO it seems likely that some may place a high or positive value on change, while others may not. "Newer and better"--"bigger and better than ever before"--"welcome to Booneyville, the fastest growing city in our state"--these are expressions Americans encounter every day. It is probably true that a majority of the people living in the United States are greatly attracted by the "new" and "improved". One has but to turn on television or listen to radio to realize that this attraction is a part of American culture. Considering this point, Foster once wrote, "In general, the positive attraction of the new and novel seems to be associated with industrial societies. Whether peoples with the most interest in novelty [illegible], or whether an industrial system produces these values, we cannot be sure". Like Foster,

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I suspect the latter. He went on to say that "...[illegible] the [illegible] through the opportunity to [illegible] itself" and that "The relationship between a productive economy and a tradition for change is so close that it cannot be thought of as being due to chance" (Foster 1962: 52).

The above is not an attempt to place a value on change for the sake of change or to suggest that all of the western nations comprising NATO, because they are more or less developed and industrialized, hold the same values and attitudes toward change as do Americans. On the contrary, to arrive at such an assumption would be to ignore the ethnic background, the geographic and climatic conditions, and the history of these fifteen nations completely. It may be true that since World War II these nations have been developing and have become more industrialized relative to parts of Latin America, Asia, or Africa. Nevertheless, it should be taken into consideration that underlying the industrialized surface of all member nations of NATO there may be basic values and traditions that date to a time before the Industrial Revolution, and that industrialization, and its effects, both good and bad, on ancient values and traditions, has advanced at differential rates within the NATO nations themselves.

It is well known among anthropologists that all cultures are constantly undergoing change and that no culture is completely static. This, however, is not the same thing as saying that all cultures, even those of industrialized societies, change at the same rate. Moreover, the various parts of any given culture never fit or mesh perfectly like gears of some sort of social machine. All cultural components, whether those of tribal peoples, rural peasants, or sophisticated urban dwellers, change at different rates.

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[illegible] plays an important role in [illegible] a society", and "this essential conservatism of values serves as a brake on uncontrolled change, usually slowing the process to the point where a society can assimilate innovations without threatening its basic structure. The security of value orientation is one of the points to which greatest attention must be paid in planning and executing programs of technological change" (Foster 1962: 19).

When faced with a new innovation, as with the Concorde's landing in New York, people do not ask "will it fly" or "is it technologically sound", but, unconsciously perhaps, they ask, "what effects will this have on what I value?" "How will this change my lifestyle?" Specifically, what is being suggested is that we know a great deal more about technology than we know about the cultural, social, and psychological aspects involved in any successful transfer of that technology to another culture, regardless of economic or political ties that may exist between the cultures involved. It is precisely here that anthropological data may be applied, and make substantial contributions to innovating organizations in at least two ways: (1) By suggesting specific methodology to conduct an in-depth analysis of the Recipient Group's culture, outlining pitfalls and stressing cultural aspects that may be utilized, perhaps through syncretism, as stimulants to successful technological transfer; and, (2) By suggesting methodology for conducting an analysis of the culture of the innovating organization itself (cf. Foster 1969: 95).

It has become increasingly apparent that it is as important, if not more so, to know the cultural dynamics of the innovating organization as it is to know the culture of the target group. Cultural barriers and stimulants are to be found not just in the recipient group's culture but also in the [illegible], values, and traditional operating procedures and [illegible] of the bureaucratic organizations initiating change. These same bureaucracies [illegible] be studied in all their "structural and dynamic aspects", utilizing the

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methodology of applied anthropology, just as one can study a peasant village in the Andes, a mountain tribe in South East Asia, or a nomadic pastoral people of Africa. Bureaucracies are social and cultural systems, organized in a hierarchy, with lines of authority, interpersonal relationships, with specific statuses and role behavior. Bureaucracies do have value systems, traditions, and, if one but scans the various abbreviations appearing in any NATO publication, they obviously possess languages specific to their own organizations as well.

Barriers to technological change as studied by the applied anthropologist are often broken down into cultural, social, psychological, and economic (cf. Foster 1962: [illegible]-142). In reality it sometimes becomes difficult, and quite academic, to make a distinction, since many barriers appear to be a blending of these cultural dynamics. It might serve just as well to refer to all such barriers as "cultural" and be done with it. Nevertheless, some of the most common barriers encountered by applied anthropologists working in the field are factors such as fear of ridicule, vested interests, and factionalism within the change agency or the target group. Other barriers include public opinion, traditionalism, fear of economic loss, misunderstood lines of authority by the change agency, political structure, and, all too often, differential cross-cultural perception and differing perception of the purpose of the innovation itself. It has long been apparent to those involved in technological transfer that communication problems[3]--even when the two groups involved speak the same language--present major barriers to successful transfer. Such barriers can constitute serious problems for those desiring to initiate any specific [illegible] in industrialized or research. Ways must be devised for innovative organizations to fully understand not just barriers located within the culture of the target group, but barriers within [illegible]

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these innovating organizations themselves.

In writing to this point, [illegible] notes that "a bureaucracy further resembles a natural community in that it is an integrated, functional unit in which the parts fit together, if not with perfect consistency, at least well enough to make it viable". He further notes that they are "too viable" at times. "Nothing is harder to kill off", he wrote, " than a bureaucracy whose reason for existing has disappeared" ([illegible] 1969: 96).

Within NATO itself one would expect to find varying world views and cultural and professional premises that underlie specific bureaucratic practices. Anthropological research and methodology could be applied to uncover these premises. It would then be useful for NATO to determine whether or not these premises in fact reflect the collective goals of the organization or the various established values, customs and traditions of its members. It is only after they have studied carefully their own basic assumptions toward one another, as well as their own national aspirations, that the members can decide which of the organization's "cultural" elements are functional and which no longer reflect the contemporary conditions in which NATO finds itself. It may then be possible to determine which of these aspects of the bureaucratic systems allow for the best understanding of NATO as an innovating organization and discard those that no longer play a functional role.

What is needed is a methodology for studying NATO as a society with a unique culture. The knowledge gained would then serve to reduce the various socio-cultural barriers involved in technological transfer within NATO while enhancing [illegible] [illegible] [illegible] will not be simple and it will not come quickly. The [illegible] for such an analysis exists, however—it has but to be applied. A [illegible]

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the organization, its structure, and its functioning as a [illegible] with a specific "culture" would make for much smoother operation and help avoid repeating many of the grave and costly [illegible] errors of technological transfer programs in the past.

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## Centralized versus decentralized management structures in technology transfer

B.B. Goodman

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This panel session concerns the management of National Technology Transfer Affairs, which can be interpreted in a number of ways. I shall assume we are dealing mainly with technology transfer involving the public sector on a purely national basis, although no responsible government can be oblivious to the vast transfer of technology which takes place within the private sector or internationally, and we may wish to consider those aspects of technology transfer as well.

According to Harvey Brooks *, "whenever systematic rational knowledge developed by one group or institution is embodied in a way of doing things by other institutions or groups we have technology transfer..."

We are therefore concerned with just some of the innovative activities on which our well-being so vitally depends.

In technology transfer, as in so many fields of activity, the management structure must respond to a number of somewhat conflicting requirements and the optimum solution will always have both advantages and disadvantages. The table below suggests some of the advantages of centralized and decentralized technology transfer management systems involving the public sector.

Centralized

- Greater scope for specialization by technical discipline, patents, marketing and legal skills, etc.
- Greater awareness of the overall national picture

Decentralized

- Better local acceptability and communications, particularly important when dealing with small and medium size firms
- Greater flexibility
- Greater scope for initiative and better motivation.

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* H. Brooks, "National Science Policy and Technology Transfer" in Proceedings of a Conference on Technology Transfer and Innovation, National Science Foundation, NSF 67-5, Washington, 1967

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In seeking the optimum solution it will also be necessary to consider

- the degree of novelty and sophistication of the technologies being transferred
- their geographical availability
- the geographical distribution of their users and of the markets for them
- the optimum size of the activity.

Three examples will serve to illustrate possible solutions

- If a given industry is concentrated in a small region and is served mainly by a specialized local research institute, that institute, if its output is large enough, would probably gain by having its own tehcnology transfer activity.
- In the case of small or medium size universities and research institutes scattered over a wide area, producing a diversity of technologies of interest to a wide range of markets, a centralized organization would probably provide the best service.
- The technological updating of small and medium size industries is often best entrusted to regional organizations which play the role of advisors in technology and possibly in other disciplines (management, finance, etc.) as well.

In many instances the optimum solution may well be a hybrid one. For example in the United Kingdom the Atomic Energy Authority has its own technology transfer activities, but the National Research Development Corporation caters for most universities and other public sources of new technologies and also for private inventors. And, as we heard from Dr. King on Tuesday, the Research Associations are in close contact with their respective industries.

In any case it is vital for the chosen structure to ensure good internal and external communications and personal contacts.

At the level of the European Community the problem of technology transfer is compounded by the differences in language and custom which exist between the Member States.

In the public sector technology transfer takes place at intergovernment level through major technical programmes and also through collaboration between bodies such as NRDC in the UK, ANVAR in France, Garching Instrumente and KFA Jülich in Federal Germany, TNO in the Netherlands and the Commission's Direc-

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torate-General XIII, which promotes the exploitation of inventions arising out of Community funded R+D.

In order to realize as many as possible of the objectives which I showed in the table Directorate-General XIII has a central nucleus of legal and patenting skills but it relies increasingly heavily on a network of technical and marketing consultants, each with good local contacts, which we have built up recently.

Outside the Community these organizations have good relations with similar bodies such as the Research Corporation in the United States, NRDC of India represented here by Dr. Ratnam, the Research Development Corporation of Japan and so on, notably through a series of conferences which are held every year or two. In this whole area there is a healthy and constant comparison of the results being obtained and, as we are doing today, a search for more effective structures and methods.

# Innovation in Industry and Technology Transfer

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"Technology Transfer in Industrialized Countries"
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October 1977

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1) <u>The changing economic situation and its implications for industrial activity.</u>

There are many indications that the current recession marks the end of an economic era. Developments that more in particular are leading to this view are:

- the changed terms of trade for energy and for industrial raw materials
- the breakdown of the international exchange rate system and the shift to "managed floating"
- the changing international division of labour and wealth
- the increased emphasis on factors such as environmental protection, safety, humanization of labour and conservation of resources.

In a market economy, the development of new technologies and their application in production are being carried out primarily by business enterprises. At the same time performance of research and promotion of the development of new technologies can be regarded to serve a public purpose. This under the assumption that an active government policy in this respect can be appropriate for maintaining or raising public welfare.

An active government innovation policy however will only promote the necessary structural change if it helps to provide new possibilities for the factors of production disadvantageously affected by the pattern of structural change. It seems obvious that such an offensive policy is to be given priority over a strategy oriented at preserving existing structures.

Developments of recent years have led to a reduction, or disappearance of the comparative advantages which have provided the basis for the rapid industrial expansion of the present industrialized countries. These countries have become less attractive for the location of a number of industries, particularly those based on elementary technology. A process is well underway to relocate production capacity in lower wage countries. This tendency can be regarded as being in the long term interest of the present industrialized countries both politically and economically. In the medium term however it will give rise to problems of adaptation and structural unemployment.

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At the same time, changes in monetary parities have led to a declining attractiveness of European countries as host countries for inward investments from other highly industrialized countries. This has led to a decline in those technology transfers that are the result of such inward investments and that played such a major role in helping Europe to attain a large degree of technological parity.

For high-wage industrialized countries the consequence of these developments is the extension of the means of production and services with high added value and often high technology content and adjusted to the comparative advantages of these countries.
Given the developments that are leading to the new international economic climate it can be concluded that there is no escape from problems associated with technological change, even in a "zero-growth" society.
Consequently it is realistic to maintain that policies for innovation in industry including technology transfer will become more important during the remaining part of the century.

## 2) Evolution of the role of government in the promotion of innovation in industry

Until rather recently, government programmes for the promotion of innovation in industry have been concentrated on measures of a general nature.
This, in fact, corresponded best to the classic conception of the role that public authorities ought to play in the economy, since such measures offered equal treatment to all and did not involve any particular advantage for individual enterprises.
For a long time the financial responsibility of the state was limited to university research. The majority of the great technological breakthroughs of the 19th century were financed by private means, and public authorities limited themselves to such general incentives as the patent system.
Recently, all industrialized countries have been producing the beginnings of more or less clearly formulated policies regarding the promotion of innovation in industry. These policies are now being raised from the administrative to the political level. A recent OECD survey (1975) of government measures and policies concerned with industrial innovation found that OECD member countries have created a wide variety of programmes for the stimulation of innovation, with many new measures adopted only in the past years.

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Although governments in the western industrialized world do not have primary responsibility for the performance of industry, they are concerned in it as representatives of the community as a whole that depends on the performance of industry.

On the one hand some economists and businessmen are worried by the proliferation of government measures of all kinds. "Laissez-faire" theorists have persistently argued that government intervention in industry is usually, if not always, inefficient and that the entrepreneurs are the ones in a position to make rational choices about alternative investments in new equipment and new products.

As against this, others argue that the costs and complexities of technical innovation in many branches of industry are now becoming so great that an even higher degree of government involvement at all levels will be quite inevitable. Moreover, it is argued that government-backed international competition is also becoming so universal that economic survival dictates state involvement here too. Government involvement in new product development, new plant investment, procurement, overseas marketing, and other aspects of innovation would logically lead to a strategy of total state involvement.

Even in socialist economies the debate on the role of the market continues and so too does the debate on centralisation versus regional or enterprise autonomy in major areas of policy-making. A general problem for all economies therefore seems: What types of government intervention and regulation are most effective in stimulating and sustaining the desired type of innovation in industry? What types of institutional filters or assessment can best discriminate between desirable and undesirable types of innovation?

Both market-economies and socialist-economies face some similar problems of technical and economic choice in relation to such issues as future of nuclear power, supersonic aircraft, introduction of new drugs, location of chemical plants, the future of the private car and so forth.

Both welfare economists and most managers have long accepted that the divergence between private and social costs and benefits necessitates some adjustment to the free market mechanism in many areas of economic policy, most obviously in relation to environmental pollution and safety.

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In conclusion it can be said that overall government policies should be aimed to derive the maximum social benefit from a continuing flow of innovation whilst simultaneously foreseeing and averting many, if not all, of the potentially damaging social and environmental consequences.

3) The principal forms of government influence on innovation in industry.

There are a great many specific ways in which governments may affect innovation in industry. Among the most important forms of government influence are: demand-pull by central and local governments and by government agencies; legislation; development subsidies; the existence and functioning of an infrastructure including government financed research and development organizations and the universities.

- Government- and public markets for goods of relatively high technological content are substantial and can be utilized as an important market-pull instrument. New products for use by government agencies and the corresponding promotion of infant industries, market aggregation programmes concerning requirements of local governments and the establishment of governments' long term objectives are the most important elements in this respect.
- Governments are in a position to influence innovation in industry to a considerable extent through laws and regulations regarding environmental quality, safety, energy conservation, consumer protection etc. These measures substantially influence the provision of a service or the supply of a product. Studies performed at the Center for Policy Alternatives of MIT and at the Worchester Polytechnic Institute have shown the importance of this form of government action towards innovation.
- Governments have a variety of schemes in operation under which subsidies are granted to individual firms for product development activities. Studies performed among others within a multi-national programme with participation of France, Germany, Ireland, U.K., Canada and the Netherlands show that the effectiveness of government subsidies leaves much to be desired.
- Government may influence the course of innovation to a substantial extent by support for background basic research and for applied scientific research in the scientific and technological "infrastructure". Organizations within the infrastructure contribute to inventions, to exploratory development, to the introduction of new technologies within industry and to the demonstration of technical feasibility of new products and processes. The latter becomes important when such developments would mainly have benefits external to the industrial firm.

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Relatively little insight has been generated sofar as to the effectiveness of the application of these principal forms of government influence on innovation in industry. More study should be performed regarding the selection of both individual and combinations of instruments for specific purposes.

4) Innovation and Technology Transfer.

Having established a framework for the requirement of innovation in industry and the main instruments of government involvement, I shall now turn to the powerful and necessary agent in the innovation process namely technology.

Technology transfer, in broad terms, takes place whenever technical knowledge, a technique or a device which emerges from, or is developed by one group is taken up and used or applied by another. The first group can be referred to as the technology source, the second as the technology receiver. This definition is in fact general enough to include the transmission and reception of scientific information and know-how, as well as the transfer of technology in the narrow sense. Impediments to technology transfer can be devided into categories depending upon whether they arise mainly at the source, at the receiver or in the interactive process linking source and receiver.
It is easy to identify the conditions in the source and the receiver which will favour successful technology transfer. The basic requirement is that the source possesses technical knowledge and/or a capability which could be useful to the receiver. In addition, the source must understand the needs and limitations of the receiver.
The conditions that should apply at the receiver are essentially complementary to these. Thus, the receiver should have complementary knowledge and capability; should understand the circumstances and potential contributions of the source, should demonstrate interest and support this with its own incentives. If these conditions exist at the source and the receiver, and if there is mutual confidence, then the way will be open for successful technology transfer. It then becomes a matter of considering in what ways and to what extent source and receiver interact.

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Larger firms usually are in a more advantageous position from a standpoint of technology transfer than small and medium sized firms.
Larger firms have staff to communicate with universities and with government sponsored research organizations. They are also in a position to interprete and value the information out of computerbased information systems.

Small and medium sized firms have a more serious problem in obtaining technology for the purpose of production and product development. In addition to procurement of technology a major problem here is also whether the product to be developed with the subject technology would fit the, most times unwritten, strategy of the firm in question, and whether licensing, joint-ventures and acquisitions should not be considered as well.

Small and medium sized firms provide an important part of employment in the production and service sector of the economy; in most industrialized countries 50% of the employment in the production sector is covered by firms of less than 500 employees. It is generally accepted by now that the functioning of medium sized and small firms should be made better possible. Government programmes are being bent into that direction in most industrialized countries.

Some of the more recent programmes aimed at fostering technology transfer and innovation in medium sized and small firms are:
the establishment of innovation centres at a number of the universities in the U.S., the establishment of the enterprise development programme in Canada, the liaison offices established at the universities in Sweden, the know-how and licensing fairs, the experimental small and medium sized industries assistance programmes in the Netherlands and in Germany, the establishment of regional centres in France.

It will take time until these and other programmes will be taken to a point where they can be properly evaluated. The success throughout the world of the agricultural extension services is well recognized. These services are integrated with the research activities, they are organized on a decentralized basis and their financial expenditure about equals that of the research effort.

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Although the situation within the agricultural field is different from the industrial one, especially on the marketside, I am convinced we can and should learn substantially by analysing the concept and the operation set-up for the agricultural sector.

Insight into the problems of innovation in small and medium sized firms, results of the current experimental programmes and a good look at the successful agricultural extension services will together provide a solid basis for improving technology transfer to the weakest part in industry in this respect namely small and medium sized firms.

5) <u>Issues</u>.

- Colombo in a recent paper for the Science Policy Foundation has drawn an interesting comparison of the attitudes towards innovation in the United States of America, Japan and the industrialized European countries.
  Cultural differences between Europe with its great tradition for scientific research and its former colonial markets, the United States of America with high social mobility and entrepreneurship and Japan with a societal system that allows co-ordinated action of political, financial, productive, commercial and social forces – make that the approaches to be taken towards innovation will vary. Although much can be learned from others, it is the pertaining cultural setting that will determine possible and effective action.

- The transfer of technology can in most cases not serve as a substitute to industrial R & D. The most advanced technologies cannot be learned in a formal way, and can only be absorbed in laboratories, gathered in a manner very close to R & D activity. Even bought technologies require adaptation to local conditions or products, and this adaptation most times requires R & D.
  Moreover, the absorption of new technologies requires early preparation. The absorption of novel and sophisticated technology demands the establishment of a research-team which would develop its know-how towards the new field. The more novel technology is important, the more activities closely resemblant of R & D are needed.

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- The acquisition of technology should be determined by the overall strategy of the industrial firm. Product/market strategy including product life time are important factors in this respect.

- With respect to technology transfer the role of the technological infrastructure is becoming more and more important, both towards industry and government.
  The infrastructure faces serious problems of adjusting itself to these tasks. Whereas it is most times an absolute requirement to judge the transfer of technology to the industrial firm in the light of the firms' overall strategy, technology transfer to government departments and government agencies will only be successful when based on an understanding of the overall problem that government is faced with.
  Activities to be undertaken by governments towards for instance humanization of labour and the role that technology can play in that respect should be based on a broad understanding of the overall problem involving physical working conditions, participation, risks and wage structure.
  Policy analysis can be regarded as a prerequisite towards successful action in this respect.

It can be concluded that the requirement of innovation in industry will become more pressing and that governments will adjust their policies accordingly.
Technology is a major factor in the innovation process and so is its transfer. In order to be effective, technology transfer will have to be based on ample insight into the overall problems of both industry and government.

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ENGINEERING SCIENCES DATA UNIT

# REFINING DATA RESOURCES TO ASSIST TECHNOLOGY TRANSFER

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Dr Anthony J. Barrett

Preprint of paper for :
NATO/USA, USN, USAF International Conference on
"Technology Transfer in Industrial Countries"
Estoril, Portugal, November, 1977.

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# REFINING DATA RESOURCES TO ASSIST TECHNOLOGY TRANSFER

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Engineering Sciences Data Unit, London

## The background

The circumstances facing the fast expanding British aircraft industry in the dark days of 1938/39 have a familiar ring about them today. Forty years ago that industry needed to design advanced products the performance of which would be tested against highly skilled competitors. Though present day competition in industrial products may not yet be so dramatic, competition is no less severe. Forty years ago materials were in short supply and increasingly expensive both in money terms and in the loss of life incurred in bringing them to Britain's factories. The same was true of fuels and energy. Apart, fortunately, from the loss of life involved the free industrialised nations are facing these same circumstances once again - and probably for ever more. In 1938/39 industry was under pressure from society to produce effective and reliable products for the preservation of their freedom; in the late 70s social pressure is aimed at the preservation of the quality of life and of our environment.

Those responsible for British aircraft production in those early years of World War II realised that crucial to the success of design was the rapid and effective transfer of technology which already existed; this meant the transfer of knowledge and data in a form convenient for immediate application by many engineers who, though of considerable ability, had but little experience in the design processes of what was then the high technology of the aviation world. We face the same pressures now in the need to transfer technology in order to found new industries, to regenerate older industries or to assist the newly industrialised nations among our allies. The solution found in 1939 laid the foundation of the procedures I shall describe and which I believe are highly relevant to present day needs.



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There is one significant difference in the circumstances of 1977 compared with those of some 40 years ago. In the intervening years the scale of the resource of knowledge has increased out of all recognition. Engineers have developed their analytical abilities and science has increasingly been employed to extend the physical laws and principles which engineers may exploit. Scientific investigations have produced enormous quantities of data which, in effect, provide the fuel for the application of those laws and principles. In the second half of this century scientific activity has been on such a scale that most of the knowledge and data, needed by engineering designers and analysts to enable them to cope with the problems they will face well into the 21st Century, must already exist.

Technology transfer and application involve the utilisation of this existing resource of knowledge and data. But although these data exist there are several difficulties to be overcome before engineers can use this resource. Scientific knowledge and data are just like other raw materials. They are widely scattered, of variable quality and require extensive and often expensive refinement and combination before they can be exploited efficiently.

So I shall be explaining, from the background of my experience, how raw data may be refined for engineering use to support technology transfer. I shall be looking first at the nature of this resource, at the raw data it comprises and at the refinement necessary. The consequences of inadequate data use by engineers will be touched upon before turning to the processes and management techniques used in data refinement. The circumstances under which success is achieved will be discussed. Processes which have been found to work, and some which do not, will be outlined.

Technology transfer hopefully results in technology application. Engineers apply technology and my viewpoint is therefore that of an engineer. Others have a contribution to make in the process; some of these are under pressure to take part by playing an unfamiliar role and such human factors are of considerable importance. But first, let us examine the resource itself.

## Information resources and raw data

I find myself using the terms "information" and "data" interchangeably though it is advisable to refer to data in its strict sense, laid down by the lexicographers, as "factual information (as measurements or statistics) used as a basis for reasoning, discussion or calculation", (Ref. 1). Engineering data are characterised by being essentially numerical in form. Further, they are usually inseparable from the design or analytical procedures in which they are used. Insofar as these procedures often exist as part of the same basic resource of knowledge, and have the same need of refinement as do discrete numerical data sets, the term 'data' will be used to embrace these procedures

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also. Engineers need much other information, of course, which is mostly qualitative in nature and which originates in accumulated practice and experience. But I am largely concerned here with numerical data which both crystallise and make usable the physical laws which the engineer exploits in his products.

Data originate from the basic research of the scientist and from the more applied research which is undertaken during the development of products or from the tests made on finished products. Data are recorded not only in the research and professional literature but also in company internal reports and many other unpublished records. One of the principal characteristics of this resource is that on almost any topic the records, exemplified by research literature, are extensive and widely scattered both in time and space.

Another characteristic of the literature is that it was designed primarily for communication between research worker and research worker and, as a consequence, is often in a form unsuitable for direct application. The research worker is frequently more preoccupied with the scientific method than with the practical significance of his results and his use of language is not familiar to many engineers, (Refs. 2 and 3).

Further, any particular piece of literature may appear to present a data set which is at variance with sets of data extracted from other pieces. This is because, with the passage of time, an increasing range of relevant parameters affecting the results may have been identified or the precision of research techniques may have changed. In other cases, the results presented may have been affected by personal bias or error.

These characteristics of what I call "the raw data resource" present few difficulties to the research man. He is well served if one can arrange to notify him of the existence of the literature, and retrieve it for him when he needs it, for he is capable of making the necessary judgements in the circumstances of his need. The remarkable achievements of documentalists and information scientists in building up computerised bibliographic files (the so-called 'bibliographic data banks'), while of great value to the research man, can do little directly to assist the application of technology by the engineer. Indeed, from the engineering point of view, I have heard it advanced that the efforts of the documentalists and information scientists may even be counter-productive, (Refs. 4 and 5).

To summarise, the resources of raw data are:

VAST

WIDELY SCATTERED

PRESENTED BY RESEARCHERS FOR RESEARCHERS

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To summarise, the resources of raw data are:

VAST

WIDELY SCATTERED

PRESENTED BY RESEARCHERS FOR RESEARCHERS

INCONSISTENT

PRONE TO ERROR AND BIAS

TIME VARIABLE

But within this vast, untidy resource is our raw material. How do we extract from it, and refine, data to assist engineering progress and the purposeful application of technology? Clues to help us address that question will be found if we look at the needs of engineers and the environment in which they work; this is the sharp edge of technology transfer.

## The engineering requirement

Surprisingly few studies of the means by which engineers may be connected to the global store of knowledge start with the engineer himself! But I have no experience which would recommend my starting anywhere else.

Most engineers are employed in industries which survive by serving identifiable market and social needs. The consumer in this market defines a specification, or has one defined for him, which lays down the required performance of the product. On this specification the manufacturer will superimpose cost targets, the company philosophy (somewhere in a spectrum which runs from high quality/high price tag to planned obsolescence) and the manufacturing/market time scale. Upon this specification there are increasingly being overlaid legislative requirements concerning safety, environmental acceptability and energy saving.

In the real world, of course, the specification, in the broad sense in which I am using the term, inevitably changes during design and manufacture but we shall ignore this in the interests of simplifying our study. From the basic specification there is no unique process of design to be followed. However, there are two broad classes of activity into which, or between which, most design activities fall, (Refs. 6 and 7). One of these I call "development design" and the other "critical design".

In development design a more or less successful existing product is scaled up or tailored to new requirements on an almost empirical basis. This process draws heavily upon the engineer's mechanical sense and practical experience. The product preceding the one to be designed is its father and mother, laboratory and test house. The physical laws governing the performance of the new product are modelled in the previous version to a degree which is quite adequate if the customer does not call for non-linearly scaled performance increases (leading to over-development), if competitors do not start to offer novel features in their products, if materials costs do not fluctuate



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dramatically, if the same energy resources remain continuously available and if the scaling up of any environmental damage which the product can cause remains acceptable to society.

In an attempt to remove some of the uncertainties of design by development, engineers have recourse to the quite different process of critical design. Drawing on the engineer's mechanical sense and practical experience it requires intuitive and creative flair to produce, first of all, a more or less novel concept in response to the original specification. This concept will be set down first in schematic form. Then the engineer, or teams of engineers, will undertake an essentially intellectual exercise. In this the schematic is analysed quantitatively against as many of the physical laws as it is known the finished product must comply with. On reams of paper and miles of computer tape engineers will, in fact, simulate and test every aspect of performance which the product is to provide, simulate and test the effect of the product on the environment and so forth. Having found where the original schematic is inadequate, for example in terms of performance, materials usage, or cost, the schematic is refined. Then the process of analysis is repeated until after perhaps many iterations there is sufficient confidence for a prototype to be built and tested under more or less representative service conditions.

There are, of course, other processes of design. For example, ab initio design or true synthesis goes a stage beyond critical design by removing the need for intellectual intervention at all stages beyond the specification (or some part of the specification). The computer is now frequently employed to go around the same iterative loops in critical design as those otherwise followed by human hand. But I do not regard this as true synthesis; such processes are as yet rare though examples exist such as those propounded by Michell, Cox and Hemp for structural design (see Ref. 8).

There is considerable scope for technology transfer to take place during critical design. The key tools in this process are a sound knowledge of the physical laws which the product must obey and the numerical data which enable those laws to be applied. From this admittedly simplified look at the basis and nature of the engineering environment and design process we may summarise the circumstances in which the modern engineer finds he is working, and the consequent qualities he must seek in the data he uses, as follows:-

Modern design is a time consuming process. Time spent in searching for, or up-dating, data is time lost from creative effort. So, engineering data must be:

CONCISE

CONVENIENTLY FORMATTED



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The quality of the engineering product reflects the quality of the data used in its design. To find the best data available means looking at the data available from all available sources or as many of them as can reasonably be found. So engineering data must be:

COMPREHENSIVELY BASED

BACKED UP BY ACCESSIBLE PERSONAL SERVICE AND UP-DATING

The engineer's company is at risk not only from its competitors but increasingly from the consequences of liability suits. Further, many large customers, government agencies, insurance interests and licensing bodies are demanding evidence of 'third party objectivity' in the data used in design. So, engineering data must be:

AUTHORITATIVE AND INDEPENDENTLY VALIDATED

## Inadequacies in data and the consequences

The industry of the free world has done well enough, one might think, on the basis of the data available and this is not always of the quality specified above. So is there a need to do better? I believe that the current concern with technology transfer and technology application is largely a reflection of the economic, social and political pressures to do better and to do more. What was adequate in times of cheap materials and energy and in times of lax social concern will not be adequate very much longer if the free world is to maintain its political, economic and military stability. The point is perhaps best made by reference to actual case histories within the experience of my own organisation.

A public utility company had designed and built several lattice towers and a long established code had been used to estimate the wind loading on them. After designing and building several towers the engineers concerned got 'the gut feeling' that the wind loading estimates were wrong; subsequently wind tunnel testing indicated that their estimates were some 30% too high. At about the time this was discovered my own organisation had just completed preparing a set of evaluated data relating to the estimation of wind loads on lattice structures (Ref. 9). This was a more widely based and highly refined set of data than had previously been available. These data confirmed the wind tunnel testing and provided a confident basis for the design of future towers. But more than this, they enabled a cost saving on the initial tower building programme of nearly one million dollars in materials costs alone. So more adequately refined data enabled first costs savings and also enabled savings in raw materials.

It often comes as a surprise to find the variability in the quality of the data used by even the largest and best equipped companies. Some years ago we undertook an exercise to compare the data in use by six

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It often comes as a surprise to find the variability in the quality of the data used by even the largest and best equipped companies. Some years ago we undertook an exercise to compare the data in use by six

different, quite large, companies relating to just one common design problem. The data actually being used by the six companies for estimating the buckling strength in shear of sheet metal components containing flanged lightening holes were applied in turn to a typical design of specified dimensions and material. The strengths estimated by the six sets of company data varied widely; there was a two to one ratio between the greatest and least strength. Yet, as far as was known, no premature failures had been recorded for any actual design based on any of these data; almost certainly some of the design teams using these data were overdesigning. The type of component involved is very common in lightweight structures including those of aeroplanes. To illustrate some of the cost consequences of this variation an estimate was made of the differences, due to weight, in the revenue earning potential of two hypothetical medium sized transport aeroplane designs which were identical except that one would utilise the heaviest and the other the lightest components designed in accordance with the extremes of the data in use. For a fleet of ten aircraft, the difference in revenue earning capability was found to be close to $100,000 per year. In this case, better refined data would have led to considerable operating costs savings and savings of the energy needed to transport excess weight.

The quality of data available at the design stage can often permit cheaper production methods to be employed. For example, data relating fatigue strength to surface finish and geometric stress concentration (Ref. 10) show that minor changes in geometry enable turned finishes to provide fatigue lives in some components equal to those achieved by more expensive ground finishes. Accurate assessments of such effects depend upon the careful collection and evaluation of fatigue and stress-concentration data. Small inaccuracies could lead to erroneous conclusions.

Data which are adequate one year may be woefully unacceptable some years later. Science is constantly making more precise evaluations of all the physical phenomena and industry must be able to take advantage of this progress; regrettably it does not always do so as quickly as circumstances demand. Let me illustrate this.

In estimating the load which a tidal current will impose on the support for a marine structure one might employ a simple physical law of the type

$$\text{Load} = \tfrac{1}{2}\rho V^2 S C_D$$

in which V is the velocity of the current and S is the cross-sectional area of the support normal to the tide.

The data values required to perform the calculation are $\rho$, the density of the water, and the drag coefficient $C_D$. Back in the early 1920s, the only value known for $C_D$, at Reynolds Numbers typical of a large cylindrical body immersed in a tidal stream, was 0.7 based on tests of smooth cylinders. Researchers such as Fage and Warsop (Ref. 11) then showed that the roughness of the cylinder would affect

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the value of $C_D$. By 1970 my organisation was able to refine, from a 50 year accumulation of raw data on these effects, a reliable compilation of $C_D$ values for different surfaces and permitting designers to take account of such things as roughness due to marine growth (Ref. 12). These 1970 data show that cylindrical marine structures of large scale should be designed for a $C_D$ of about 1.05 where back in 1920 the best estimate would have been 0.7. Even as recently as last year, one of my colleagues found that some designers of oil rigs for the North Sea, noted for the fecundity of its marine flora and fauna, were still using the pre 1920 value of 0.7 quite unaware that they were underestimating their loads by about 50%.

In the previous example, ignorance of 50 years' progress in data leads to a 50% design error. One per cent per annum as the possible drift in the best design data available is not unusual and corresponds closely to the magnitude of drift which we find over a wide range of the subjects upon which my organisation works. As a rule of thumb, I advise all designers to assume that the data they are using is 1% in error for each year since they were established or last corroborated.

In summary, the foregoing case histories illustrate that inadequate data can:

WASTE TIME AND MONEY

HAZARD SAFETY AND DURABILITY

WASTE MATERIALS AND ENERGY

OBSCURE POTENTIALLY CHEAPER AND SIMPLER PRODUCTION METHODS

UNDERMINE THE PROFESSIONAL INTEGRITY OF THE ENGINEER

We must also note that:

THE BEST DATA MAY EXHIBIT A 1% PER ANNUM DRIFT

THE DATA IN USE FOR A PARTICULAR PURPOSE MAY VARY BY AS MUCH AS 100% BETWEEN EQUALLY COMPETENT COMPANIES

## The management of data collection and refinement

Improving the data available for industrial application requires total commitment to the goal of technology transfer and positive management to that end. A full description of the human and physical factors in play, and the communication functions involved, is beyond my present scope though I have described them in some detail elsewhere (Ref. 13).

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There are two basic ways of looking at the global resource of raw knowledge from which data are to be collected and refined. The first way involves looking at the total resource, identifying sets which comprise a common scientific category or discipline (say crystallography, electronic properties of materials, thermophysics of aqueous solutions), collecting all the published information within that category, and organising it (usually still in the raw form) so that each piece may be efficiently retrieved in answer to a specific request from a potential user. Refinement, other than in terms of organisation, is usually minimal. This is a management system which recommends itself strongly to documentalists and information scientists for obvious reasons. It operates in various forms; typically the well-known abstracting services, computerised bibliographic files (bibliographic 'data' banks) and some information analysis centres are based on this view of the world. It is popular with researchers and scientists, who work generally only within one discipline and frequently read scientific treatises. But it has only fitful success with engineers (who do not). It has the built-in economic problem that, to be viable, the cost of any enquiry of the system has to bear a share of the cost of all the enquiries which could be made but which never are. For this reason, and for the reason that refinement of the output is minimal, this way of looking at the resource of knowledge and data has but limited possibilities as a means of serving the industrial engineer. Put more succinctly from his point of view, "solutions in search of problems rarely pay off"!

A derivative of this philosophy has also led to the idea that scientists should leave their laboratories and take limited term posts in industry. This is quite an old idea, recently refurbished under such catch phrases as 'technology on the hoof'. Quite apart from the lack of sensitivity which the promotional catch-phrase shows towards the personnel actually involved the idea overlooks a very common industrial experience. No matter how well qualified a staff man may be, it takes a great deal of time before he becomes productive after entering industry. My own experience of this idea is admittedly jaundiced by finding that the productivity of personnel seconded to me from research establishments became acceptable at just about the time their secondments ended!

The engineering way of looking at the global resource of knowledge is virtually the inverse of that previously described. We now start by looking first, not at the knowledge available, but at the industrial or engineering need. We specify the need, involving the engineer who has or who can foresee that need, then define the information and data required, confine our search within the global store to the data actually required at the time, evaluate the resulting collection and refine it into a package carefully tailored to the need which was specified. This approach has, of course, obvious economic penalties if the need specified is not common to a reasonably wide range of users. It relies upon users having some foresight of their needs for it can never provide ready-made responses

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to all the needs which might arise although its response clearly improves continuously with time. When carefully managed to select needs of widest relevance and operated throughout on a basis of co-operation with all the interests involved it has proved itself, for nearly 40 years, to be a most adequate and flexible philosophic basis and one which is capable of considerable development.

What tasks have to be performed in such a system and who is best fitted to perform them?

In the task of identifying the need the eventual users, or a representative group of users of the refined data product, must be closely involved. If they are not then the economic viability of the system will be at risk and there will be little assurance that the data compilations produced will actually be used. Similarly, a representative group of researchers and academics must be involved. Without their advice there is a likelihood of embarking upon a search for knowledge which does not exist or of the misinterpretation of the knowledge which is found. In some areas a very wide range of interests may need to be involved and my own organisation is developing into fields where not only engineering and scientific interests are at play but also those of legislative bodies and of licensing and certification authorities; the time may not be far distant when consumer and labour interests may also need to be embraced in some subject areas.

But all these interested parties have neither the time nor often the training necessary to undertake the detailed technical work of data collection, evaluation and refinement.

Of the interested parties which might undertake the tasks following the identification of the need, only the engineer/designer and the researcher/academic have the necessary basic technical qualifications. But none of these has an optimum combination of the attitudes and background which have to be brought to bear during the processes of raw data collection, evaluation and refinement. Most practising engineers and designers would not claim that they had a sufficiently detached outlook for the purpose or even an interest in such work because it is rather removed from the actual hardware of industry which is generally the centre of interest of their lives. Until quite recently, most scientists and researchers have also shown little interest in such work for the very practical reason that their status and preferment were closely dependent upon the discovery of new knowledge and the publication of their findings in a form acceptable to their peers. I find this attitude is that which most practising researchers still take, at least in private, and I applaud it; the side effects of diverting their energies towards the day-to-day application of their work are likely to be to the detriment of scientific objectivity and lead to a deterioration of job satisfaction.

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to demonstrate 'relevance' in the eyes of funding bodies, and to earn funds from industry by selling ad hoc experimentation, many of them have entered the newly fashionable arenas of 'technology transfer' and 'technology application'. Insofar as technology transfer relates to the use of basic knowledge the scientist has an important role to play - but as a scientist and not as the active transfer agent.

We have noted in the requirements of data for application the need for impartial assessment and independent validation. So the person best able to take the leading role in data evaluation is not likely to be someone who was intimately involved in the preparation of the raw data, as a researcher for example. Too close an association with one set of raw data can prejudice the objectivity of even the most disciplined worker when attempting to correlate his own results with those of others. It's like parenthood; the peculiarities and imperfections of one's own child are often difficult to see! But in any case, many of the characteristics of the raw data resource which make it unsuitable for direct application are a consequence of the researcher's attitudes and environment. He is hardly the man to employ in order to amend these shortcomings.

So, in the part of the task where the raw data are collected, analysed, evaluated and distilled down to the best set for application to a specified need, we find a new sort of professional being. Having trained upward of a hundred of these over the last 25 years I can give you a brief specification. Such a person needs to have a sound academic training covering a limited spectrum of the disciplines to which the data being handled relate. After academic training a period of about three years in industry, involved in the practice of engineering, provides a suitable basis for understanding the circumstances under which the refined data will eventually be applied. An imaginative, flexible outlook and an absence of preconception are required characteristics and this will mean that such staff are still young when they enter this work. Special training beyond that obtained in their academic careers must be given for several purposes. The techniques of managing the various interests which will be at play during the data refinement process must be imparted. A total commitment to the goal of technology transfer must be induced; this often involves gaining an acceptance of the belief that communication in a form which has a high signal-to-noise ratio from the point of view of the engineer is in every way as respectable as the quite different form of communication which is appropriate to the scientific community. Finally, the techniques of data refinement must be learned. What are some of these techniques?

Having identified the need, the raw data appropriate to this need have to be located and collected. Libraries, bibliographic retrieval services and all other means available to collect as much of the published raw data as possible are used. Beyond this, on most topics, there are a great many raw data which are not published - sometimes the greater part of the raw data which is available on a topic

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exists only in the files of companies and individuals. Such raw data can usually be released by careful management to obtain the holder's co-operation and interest and this can best be done by staff based on 'neutral ground' and of proven integrity.

When sufficient sets of raw data have been extracted they invariably present a conflicting and confusing picture. Digging into the circumstances under which experimental data were derived, making a full technical assessment involving available theoretical treatments, or involving the construction of new mathematical models, are just some of the time consuming and expensive processes which have to be undertaken if the job of data refinement is to be sound. It isn't just a matter of drawing the best fit through a cloud of conflicting raw data points. Even when the sets of raw data appear not to be in conflict the simplest processes of combining them may lead to surprising results. Sets of raw data which are simply pooled may appear to lead to completely different conclusions from those drawn from the results of the individual sets. Bizarre effects, such as those demonstrated by Simpson's paradox (Ref.14), are never far away!

To summarise briefly at this point, data refinement to assist technology transfer must:

START WITH SPECIFYING THE NEED FOR DATA AND NOT WITH THE DATA RESOURCE

INVOLVE ALL INTERESTED PARTIES IN SPECIFYING THE NEED

BE CONDUCTED BY SPECIALLY TRAINED STAFF

BE CONDUCTED IN A 'NEUTRAL ENVIRONMENT'.

As the refined data package is produced it requires validation and this process I shall consider next.

## Validation of data

We must bear in mind the potentially high cost of failure in many of today's larger engineering enterprises, the increasing social pressures in connection with the avoidance of environmental and other accidents not to mention the increasing extent to which manufacturers and designers labour under the spectre of liability suits. Contemplation of such issues very early in the life of my own organisation led to the conclusion that data distilled from the mass of sources must be monitored as they are produced and not be applied in practice until they have been objectively validated.

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reaction was sought to the suggestion that "there is no such thing as objective technical advice". In his answer he observed that the best an individual could do would be to present the known biases along with his advice. That probably is the best that an honest individual can do; but on the basis of my experience I know that the powers of judgement possessed by the individual can be magnified many times when applied as part of a carefully managed consensus seeking group. The application of such a group is what has to take place in the process of data validation.

The validation group must address itself to a number of questions. Has all reasonable care been taken to find relevant data; have all known sources been tapped? Are the correlation processes which have been used sound, have any philosophical or mathematical traps been fallen into? Are the necessary limitations on ranges of applicability of the data and other cautions specified? Is the presentation which has been used clear and convenient remembering that application of data is made by engineers and not by scientists?

And each individual in the group must ask himself if he is prepared to stake his professional reputation on the belief that the refined data package represents the best data on the topic in question, at the time of issue and within the limitations specified.

I mentioned the amplification in power of individual judgement when applied as part of a consensus seeking group. By consensus I mean what was originally meant by consensus, that is, an accord of minds or unanimous, rather than majority, agreement. Thus the process I am describing is only superficially related to the polling techniques so elegantly investigated by Dodgson (Ref. 15) or the Delphi technique succinctly reviewed in respect of its implications as more than a technological forecasting method by Bernstein (Ref. 16). Obtaining consensus is often a long and expensive business - but well worth it as can be demonstrated from a simple modelling of the process (Ref. 17). The reliability of the judgements made by a consensus group increases roughly as a power related to the number of members involved in the group. The time they take also increases with the number of individuals involved due to having to rephrase and modify the issues addressed until all members are satisfied. But the time taken increases far less dramatically than the rate at which the reliability of the consensus judgement increases. At least, this is true when the group is comprised of individuals of roughly equal and high ability. It is a common experience that the introduction of but one dull or unreasonably biased member onto any sort of committee extends the time taken to reach decisions to an alarming degree!

These validation groups need to be composed of people external to the permanent staff who are concerned with the tasks of raw data collection and refinement. Typically, in my own organisation, they comprise practising engineers, researchers, academics, representatives of government bodies, certification authorities and other interests. They

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have a high level of recognition within their own professions and are prepared to devote considerable real time to the validation process.

## Costs involved

Data refinement to the standard necessary for modern industrial application does not come cheap - at least in absolute terms. The major cost heading is, of course, the labour cost of the specially trained engineering and scientific staff and of the technical support of that staff by mathematical and other service groups. General overheads are not excessive for there is no requirement for large capital equipment; in-house modern computational equipment of the type required to cover the majority of needs is remarkably inexpensive these days and when large computational facilities are required they can now be easily and cheaply accessed via a good terminal.

The costs of the validating groups are additional to all this. But, with careful management of the work on a properly constituted international co-operative basis, it is my experience that there are sufficient motivations for the external practising engineer, researcher or other expert to provide his time voluntarily. And there are sufficient attractions for his company or other employer to provide the support necessary to get him to meetings or to assure the rapid communication of comment via 'phone, telex, or mail.

The cost in absolute terms may seem high; but if topics have been carefully selected in the first place and if the results are made widely available these costs can be spread over many recipients. Each will then pay far less for the final refined and validated data package than would normally be expended in finding the raw data alone.

There is considerable economy of scale if these tasks are performed on an international basis, as in my own organisation. I believe there are many possible developments of the philosophy which I have presented, particularly in the international setting. I will describe one of these.

## A possible development

In the NATO alliance we have a range of nations at different stages of industrial and technological development. Very little has changed in the disparity between the technological abilities of most of these nations since 1949 although the technological ability of all of them has increased considerably. The Alliance has always been aware of this disparity and has done much with the aim of minimising it. For example one of the NATO agencies, AGARD, has run a successful consultant and exchange programme, (Ref. 18). In practice this is not unlike 'technology on the hoof' though it has far more limited and

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credible expectations. As I have noted earlier, the potential for technology transfer via an arrangement involving the temporary secondment of personnel is debatable. In the international setting, personnel returning to their own workplâces after a spell in much better endowed facilities abroad can become frustrated and may often gravitate permanently to a technologically more advanced nation. The nett benefit to the Alliance of such a consequence is small or even negative.

At a recent meeting of the AGARD Structures and Materials Panel we faced, once again, the problem of the less technologically advanced nations and how the Alliance could best assist them. But this time we started by asking how these nations could play a more positive role in the technological well being of NATO - what could they offer? An informal audit of the assets of one such nation revealed little in the way of advanced physical facilities, although there were some of great eminence in highly specialised areas. But the audit did reveal an intellectual resource of considerable importance coupled with most of the computational resources which would be needed in data refinement. Now, as I have noted, the more advanced nations have generated enormous resources of raw data. It is to the advantage of the larger nations and the Alliance as a whole to have these raw data refined. But beyond this, many of these data, when refined, are applicable to the sort of technological endeavour which some of the less advanced nations could develop to their own economic and social benefit.

Accordingly, it would seem possible and mutually beneficial to set up a management system whereby data topics of mutual interest were identified, supply the raw data from wherever they existed, carry out the process of refinement by staff within the less advanced nations under the guidance and monitoring of validating groups composed internationally and make the resultant refined packages available to all. The staff undertaking the technical tasks of refinement would have the advantage of serious working contact with their opposite numbers abroad while carrying out a task within and to the eventual benefit of their own nations. The larger nations, and the Alliance as a whole, would benefit by having some of their resources of raw data refined and validated independently. Although the possibilities are only now starting to be investigated it seems a further advantage that such a scheme might be operated without calling for extensive financial support beyond that needed for limited travel, overall management and short term training.

## In conclusion

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based, not on some recent conversion to a fashionable idea such as technology transfer, but on actual personal and organisation experience in the business of what I prefer to call "profitable research - engineering interaction" (Ref.19). During that experience we have tried many paths, have made many mistakes and, I hope, learned from some of them.

The present socio-technological climate, which is likely to persist well into the 21st Century, demands that we make the very best use of information and data which are already available. Making the best use - indeed making any use - demands that we refine and combine the known data based on the philosophies and techniques I have been describing. In brief, these follow the now established and proven process of first identifying the need, the collection of raw data from world-wide resources (both published and unpublished), the careful selection, correlation and evaluation of those data by specially trained staff, their refinement and presentation in an engineer customed package, validation by an appropriately qualified world-wide group of experts and the continued interest of the special staff to ensure back-up service and up-dating.

Science, from about the 15th Century onwards, was a new intellectual pursuit which transformed man's understanding of his world. Engineering technology enabled man to transform that world. Just as surely does data refinement represent a new intellectual thrust which will enable man's understanding of the world to be applied to its future transformation in a way that is based on incontrovertible fact and reason. The last 50 years have been notable for the extent to which a tangible asset in knowledge and data has been built up. It is to be hoped that the next 25 years will be notable for the extent to which the profits of exploiting that asset will be returned to us.

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S.p.A. OTO Melara

INTERNATIONAL CONFERENCE ON

"TECHNOLOGY TRANSFER
IN INDUSTRIALIZED COUNTRIES"

ESTORIL, PORTUGAL - 7 - 11 NOVEMBER 1977

# TECHNOLOGY TRANSFER RELEVANT TO CO-OPERATIVE DEVELOPMENTS AND/OR PRODUCTION OF SPECIFIC WEAPONS

Report compiled by Rear-Admiral I.N. (Rtd.)
G.AZZONI (Firm OTO MELARA - ITALY)

S.p.A. OTO Melara

There is no attempt in this Report to formulate a general theory or to assemble a collection of rules or recommendations to be applied to industrial cooperation, in order to obtain optimum results from the technology-transfer viewpoint.

We have instead set our sights much lower: namely, to illustrate some aspects that have emerged from the experience acquired by OTO Melara in recent years.

Each of the instances has originated from specific situations and no single instance can be directly extended to all cases.

The observations can however be incorporated in a statistical elaboration which, by considering a multiplicity of conclusions reached separately from individual specific situations, could enable the formulation of general statements and an evaluation of the probability of their meaningful application to individual situations in the future.

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During the past fifteen years OTO Melara has been involved, both as recipient and supplier, in transfers of technology with European, American and Asian firms. These transfers have taken place in the course of industrial cooperation undertakings relating to specific products.

The experience covers the following typical forms of cooperation:

- production under a licence, acquired by the goverment and passed on to the armaments industry;
- production under licence obtained under the terms of agreements between armament-industry firms;

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- co-production under licence, with sub-contracting of some components to the firm which developed the product;
- multinational design and development based on intergovernmental agreements, followed by joint production;
- multinational design and development followed by joint production based on joint private ventures.

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The first three types of cooperation fall within the category of "granting of licence", the last two in the "multinational design and development cooperation" category.

In our experience, the undertakings involving the granting of licences have given rise to the transfer of a larger volume of technology, and of more advanced technology, than in the case of design and development cooperation. In this latter form of cooperation, there is observed, right from the start, a subdivision of the sectors of activity and their allocation among the various participant industrial firms.

In general, this results in a restriction on the systematic reciprocal flow of technical information, and therefore on technology transfer, which is therefore limited to the extent necessary for compatibility between the interfaces of the various sectors: and only rarely, and then synthetically and rather superficially, is there an exchange of technological information relating to the intrinsic content of the various sectors assigned to the individual industrial firms.

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technology transfer is co-production under licence directly agreed between firms, with sub-contracting of some components to the firm which developed the product.

The volume and quality of technology transfer are only slightly less in the case of co-production under licence obtained under the terms of direct agreements between firms, without subsequent sub-contracting.

Technology transfer is least efficacious where the production licence is obtained by the government and passed on to the armaments industry. In this case considerable delays arise from the emergence of problems, not always rapidly solved, associated with interpretation of the documentation received. Where interpretative doubts call for resort to the licensor firm, the fact that the related questions and answers have to be transmitted through a government (and, in some cases, two governments) is a source of appreciable delay.

If the problems arise, and the consequent temporary pauses occur, at a time when the production line has already been activated, the resultant slackening in the industrial activity constitutes a not inconsiderable additional cost factor.

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In the granting-of-licence type of cooperation, the following factors and measures have proved to be essential:

a) Quality of documentation.

   At parity of technical level of the firms transferring the know-how, it is observed that government-owned documentation (especially in the case of the USA), drawn up to enable the invitation of competitive bids for production contracts, is

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distinctly more valid than that owned by individual firms. The superiority of the former over the latter is particularly manifest in two respects:

- elimination of the inevitable errors and gaps in the initial drafting, thanks to revision effectuated by other parties (government and other firms);
- drafting of documentation with a generally accepted language reflecting generally accepted technical principles and standards (an indispensable condition if the documentation is to be understood by firms participating in bids), by contrast to documentation drawn up for use within a firm, containing terminology reflecting technical theories and standards that will vary from firm to firm, but which will be difficult for others to interpret.

b) Establishment of direct contacts between firms immediately a start is made to definition of the constituent items of the documentation, so as to eliminate, right from the beginning, the possibility of ambiguities, gaps, misunderstandings. It is the usual absence of this possibility that detracts from the efficiency of the method envisaging acquisition by the goverment of licences to be passed on to the armaments industry.

c) Direct, rapid and immediate contacts between the two firms are invaluable at the stages of establishment of the cooperation arrangement and start-up of production, as well as during the production run. In our experience, both as licensee and as licensor, this objective can be achieved merely by the <u>continuous</u> presence of a liaison group at the

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licensee's plant: or even of a single liaison officer, provided that he is versatile.

This continuous presence must however be backed up with occasional reciprocal short visits, also upon request, by highly specialized technicians: the licensor's technicians to provide advice and help to solve problems; the licensee's technicians to ask for advice and to describe the nature of difficulties that have been encountered.

Obviously, these mutual visits will be all the more routine and comprehensive when the licensor is also a sub-contractor to the licensee for certain components.

In the light of the experience acquired by OTO Melara, it would not seem that the size of the liaison group, or the frequency of visits by technicians, is importantly influenced by the difference in technological level of the two partners, always provided, obviously, that they are firms operating in industrialized countries.

The liaison arrangement should run from the beginning of the cooperation agreement through to completion of product qualification.

In the event of product evolution at licensor level, however, the liaison arrangement should continue as long as necessary, even if up to 20 ÷ 15 years.

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largely revert to the advantage of the transferor of the technology.

1. Thanks to the concreteness of the matter involved (a marketable product) the build-up of confidence in the transferred technology takes much less time: the new technology can quickly be extended with confidence to its application to other products of current pre-eminent interest to the licensee country. This results in a saving of time in new sectors, also to the advantage of the licensor, who will obviously be kept informed of the extension of the technology: if only, he will be requested of suggestions and of encouragements.
2. Besides this feed-back, there is a more direct and immediate advantage: the correction of errors in, and the supplementation of, the documentary information, after the licensee has studied the documentation.
3. Almost always the licensee brings occasional improvements to the product or to the technology, consequent upon the finding of other, nationally-produced components (as alternatives to the original components) which can with advantage substitute the related original components, also in the licensor's production.

   In some cases the advantage has been one of technical performance, when the substitute component is better than the original; in other cases the advantage has been financial and logistical, when availability of the substitute component, thanks to removal of a monopoly situation, has enabled the lowering of the purchase cost and has assured, with the

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plurality of supply sources, maintenance of supply and production schedules.

4. Other variants which result in improvement of the initial designs and technologies, improvement which can also be extended to the licensor's country, usually derive from the fact that the licensee studies them with a completely fresh mind and is not conditioned by factors that arose in the research and development stage.
   The practicability and validity of the variants is guaranteed by the fact that they have been conceived for incorporation in a product that must be sold.

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Turning now from the granting-of-licence type of cooperation to the type envisaging multinational design and development, it has been observed that there is a greater transfer of technology in cooperation schemes based on inter-governmental agreements than in those based on joint private ventures. In these latter cases, the smaller availability of finance and the vital need to minimize the technical risk of the venture tend to lead to the allocation of activity sectors among the various partners on the basis of the most advanced specialization.
Thus, for each partner the contributions which the others could provide are insignificant, since each partner is the most advanced in the particular sector so assigned. The exchange of information, and therefore the transfer of technology, is limited to the extent necessary for interface congruity.
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the work is allocated rather more on the basis of political and economic considerations than of technical criteria. Therefore, besides the interface dialogue, it normally happens that no one partner is so further advanced in his assigned sector than the others as not to accept technological information and suggestions from them which could be useful in the accomplishment of that partner's tasks. Indeed, exchanges of information are usually promoted by the partner himself, who requests the others for confirmation of its expectations, in the light of their similar precedent experience.

Moreover, in inter-governmental programmes there is a further technology transfer, which we could define as "cross-transfer"; this occurs at the production stage, where the allocation of work among the partners almost always varies a little compared with the development stage. Thus, each partner transfers to another the technology developed in the particular sector, to him assigned during the development stage, but not re-assigned for the production phase: and each partner receives from the others the technology pertaining to the sector assigned to him only in the production stage.

In the context of inter-governmental development programmes it is also easy for firms to exploit, in a new programme, a technology developed, or also only acquired during a previous programme: many patents are in fact the property of governments, not of private firms, and, as a consequence, no constraits emerge when the same governments are engaged in both programmes.

Rome, October 10th, 1977

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