TECHNOLOGY TRANSFER AND REMOTE SENSING: MODELS FOR SUCCESS AND MODELS FOR FAILURE

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ABSTRACT:

Over the past fifteen years the authors have been involved in remote sensing and technology transfer activities in over twenty countries. Through direct involvement and/or direct observation, a number of conclusions have been reached on the most appropriate models to lead to the beneficial use of remote sensing, whether working in developed or developing countries. These are discussed in this paper.

The paper also describes a technology transfer model and the key factors associated with this model which lead to successful technology transfer. In addition to the routine factors which can contribute to success in technology transfer, the authors have identified a number of other important building blocks believed to be essential for successful technology transfer in remote sensing. In this context this paper discusses the role of the private or non-government sector, the need for national and international co-operation and co-ordination, the role of academe, the role of central R&D organizations, and a number of other factors generally not well discussed in the literature.

In closing the paper discusses the fragility often associated with successes in remote sensing technology transfer. A slight change in the balance of factors may turn a dramatic success into an abject failure - or vice versa. For those who have not yet had success in seeing remote sensing applied beneficially in their country or region, the conclusion provides hope. To those who have had success but are tempted to change the mix of factors, the paper may provide useful guidance.

KEY WORDS: Remote Sensing, Technology Transfer, Model

1. INTRODUCTION

This paper will provide and then illustrate a technology transfer model based on over fifteen years experience in remote sensing and technology transfer activities in over twenty countries. Through direct involvement and/or direct observation, a number of conclusions have been reached on the most appropriate models to lead to the beneficial use of remote sensing, whether working in developed or developing countries. These are discussed below in Section 2, with the key factors associated with this model. The remaining sections discuss the role of the private sector, the fragility of the technology transfer process, and some suggested approaches to improve the chances for success.

2. MODELLING TECHNOLOGY TRANSFER

2.1 A Model

A model is a simplified description of a system to assist in the organization, comparison and, in the geographic sense, the visualization of information. (Chorley and Haggett, 1967) A system is in turn defined as a complex whole, set of connected things or parts. The difficulty in building a model is immediately obvious. It must be at the same time simple and complex. A technology transfer model must take into account the complexities of human interactions related to the adoption of technical innovations. This is a topic long discussed in both marketing (McCarthy and Shapiro, 1983) and sociology. (Rogers, 1962)

2.2 The Challenges of Modelling Remote Sensing

The nature of remote sensing leads to further complexities in attempting to model related technology transfer and adoption. Remote sensing is not an exact science. Its relative youth and lack of standards leads to confusing and often conflicting claims about its capabilities from various proponents. For example, one finds advertisements about systems and imagery which all claim that their product is the best one for a given application. This problem is related in part to the fact that environment, technology and experience vary widely over the range of remote sensing applications. It is therefore very difficult to find consensus in the technical literature on methodology, standards, results or application recommendations. Indeed, the technical literature contains many papers which seem to claim results that are almost diametrically opposed to those presented in other papers.

Since most users or potential users do not have a sophisticated understanding of the technology and its application, there tends to be some uncertainty in the face of the conflicting claims from various vendors and proponents in academe, governments or industry. In some cases these claims can lead potential users to abandon any idea of using the technology, reasoning that the field is not yet mature enough to be used effectively. Others may adopt a particular technology based on the strength and nature of arguments of a particular vendor or proponent. In some cases pressure is brought to bear through either aid or diplomatic channels. Others may use the technology suggested by a trusted advisor. Still others may decide to adopt an approach which they have seen applied successfully in similar environments.

Any model for technology transfer must assume that any or all of these decision-making influences are, or can be at play. For that reason it would seem reasonable to suggest there must be a built-in feedback mechanism which continuously evaluates success and which can stop or restructure a project which carries unacceptably high levels of risk. However, in the authors' experience, such action has rarely been taken and may not be feasible in practice. The nature of decision making, particularly in areas of new technology, suggests that no project, however risk-encumbered, will ever be completely stopped once it has begun. In reviewing thirty-one papers on technology transfer drawn from the CCRS RESORS system, every paper resulted in a positive conclusion concerning the efficacy of remote sensing, almost independent of the technical results presented. It is therefore essential to have built into any technology transfer activity a thorough evaluation of the approach as a case study before any larger application is attempted. This phased-in approach has also been identified as a key element by Itten et al (1990)

The nature of human interactions is often hard to predict, particularly if at the same time one is trying to describe the interactions in simple terms. Regardless of the complexity of human interactions, the model must be able to account for real-world behaviour.

2.3 Key Factors Associated With the Model

A number of the key factors associated with modelling technology transfer may not be surprising. They are generally well known and well documented in the literature on the diffusion of innovations. (Rogers, 1962; MCarthy and Shapiro, 1983.) For example, there must first be a need which can be cost effectively met with the innovation. There must also be a champion and that champion or early innovator must be supported by early adopters, adequate training, adequate flow of information, etc. In addition, any technology transfer activity must take into consideration local social customs and the political-economic situation. These routine factors are reviewed and cases are cited. A number of other authors have specifically addressed what they consider to be the key issues involving technology transfer and remote sensing. Many of these are concerned with the issues of education and training (Milne, 1990), financial concerns and institutional arrangements (Forster, 1990), obstacles (Specter, 1989), and the need for phased introduction of technology (Itten et al, 1990).

3. TECHNOLOGY TRANSFER AND REMOTE SENSING PROGRAM DEVELOPMENT

3.1 Background

A model for technology transfer in remote sensing has evolved at the Canada Centre for Remote Sensing (CCRS) over a number of years. The model is based on direct experience in and observation of the processes of development and implementation of remote sensing technology and applications across Canada and in a wide variety of settings internationally. (He, et al, 1991; Ryerson, 1989) This model embodies the recognition that technology transfer is not a single process but a complex of interrelated processes which is influenced by these process interactions, by pre-conditions and by environmental conditions.

3.2 Overview

The CCRS model suggests that technology transfer programs be defined in terms of a series of essential program elements which can be grouped logically into phases of program development. This structure is illustrated in Figure 1, and described below.

The model recognizes that perhaps the greatest single influence on technology transfer is resistance to change. It further explores the sources of resistance in both organizational and human contexts.

Resistance in both contexts is then linked to the concept of risk as it applies to the adoption of technology. The model promotes the importance of understanding and measuring sources of technology risk as a key priority for any technology transfer program or effort. It provides a logical structure for the classification, integrated assessment, and management of risk.

The analysis of risk is presented in the context of a risk management equation. The risk management equation has been developed as a mechanism to encourage the deliberate, structured and realistic analysis of risks. It is based on the recognition that available expertise and experience in risk assessment varies significantly among the categories of risk; and assessments of risk can conceal significant inconsistencies as a result. Within each risk/source category the model provides a basis for estimating the level of associated risk.

3.3 Program Elements

Effective technology transfer is a very demanding activity. Of great importance to the process is recognition of the program elements which must be in place to implement and support the scientific and technological activities which are necessary. These ideal program elements can be grouped into logical phases or stages which build upon one another toward the goal of self-sustaining technology transfer. The program elements and phases of program development are summarized graphically in Figure 1.

3.3.1 Enabling Phase At the earliest stage of remote sensing program development it is essential to focus upon establishing prerequisite or enabling elements:

Policy Policy at the highest political level should specifically empower the efforts to implement remote sensing. This is rarely, if ever, the case in practice. If an empowering policy does not exist, technology transfer activities must at least be supported within a more general enabling policy. In other words, existing national policies would not likely specifically anticipate and empower the establishment of a remote sensing program. However, policy might exist which supports goals of technological advancement, sustainable development, economic growth or environmental stewardship which could, in turn, result in opportunities for the use of remote sensing tools.

Mandate Remote sensing technology has generally been established or focused within one organization or administration, often a national remote sensing centre or a national remote sensing program. In either case it is important that the institution be created with, or negotiate, an appropriate mandate. Technology will not thrive long in an organization which cannot count technological responsibilities within its formal mandate. Lack of mandate clarity with respect to technology has often slowed or otherwise frustrated the development and adoption remote sensing. At the same time, the remote sensing organization should not be competing within mandated areas of other groups responsible for the various natural resources being evaluated.

Management Management of technology transfer requires unique skills. Such skills must be nurtured over time and must be regarded as desirable within an organization. The existence and development of the required management skills is a fundamental enabling requirement for successful technology transfer. If the required skills do not exist or are not valued or encouraged within the organization, technology transfer potential would be significantly reduced.

3.3.2 Empowerment Phase The enabling phase establishes the preconditions for a successful program of remote sensing technology transfer. The empowerment phase establishes and embodies the conditions and authorities required to nurture development of the expertise and capability upon which sustained technology transfer will depend.

Information Access to information is often overlooked as a fundamental element of the empowerment phase of technology transfer. Adequate and continuing access to current information on technology, applications and program management are essential to sustained technology transfer. This has been clearly recognized in the successful ESCAP/UNDP program in the Asia/Pacific region. (He et al, 1991)

Education and Training In recent years the importance of education and training to innovation and technology transfer has been widely recognized. (eg. Milne, 1990) To date, however, recognition has not generally been confirmed by level of effort or funding in remote sensing programs. This situation will have to be addressed through careful assessment of training needs and intensive program and curriculum development. In Canada a number of workshops have been developed for a variety of audiences. These materials are now being used internationally. (See Bruce and Press, for example.) Similarly the Regional Remote Sensing Program run by ESCAP, has developed an approach to disseminating information through workshops and published records of meetings. (He et al, 1991.)

Infrastructure The element of technology transfer which has traditionally received the greatest attention has been infrastructure. Infrastructure development is the program element which is most associated with tangible and visible results. It is also one which tends to appeal to national concerns in the areas of sovereignty, sustainable development and assured access to data on natural resources or information of a potential strategic nature. Nationalistic justifications may help account for the fact that for large parts of the globe a larger number of satellite receiving stations have been established than may be needed to provide a secure source of data.

Hardware and facilities have always competed very aggressively and successfully with the development of the "soft", less visibly impressive, infrastructures of information and education and training. Redress of this imbalance is essential to minimize the risks associated with technology transfer.

Experience No combination of facilities, information and skills can be expected to sustain technology transfer without the opportunity (time and budget) to develop experience appropriate to specific operational needs. Experience is something which, once gained, is always relevant, particularly in a rapidly evolving technology setting an ever changing problem spectrum.

3.3.3 Implementation Phase The consolidation of program and capability are only the beginning of the technology transfer process. Unless these elements are embodied in a proactive and self-sustaining applications environment little operational technology transfer can be anticipated.

Demonstration It is essential that the promise of technology, infrastructure and capability translate into physical demonstrations relevant to perceived needs. These demonstrations must also be sensitive to the issues of technology availability and acceptability addressed below, as well as to the cultural aspects of the specific applications environment. This local sensitivity is a strong feature of successful programs. (He et al, 1991)

Application While the Geomatics literature boasts literally thousands of demonstrations, it has been observed (Failloux, 1989) that very few of these have been translated into operational applications. Weakness or absence of linkages between technology development, applications and problem-related needs and a parallel imbalance in technology vs applications funding have been common and seemingly unavoidable characteristics of remote sensing programs in developed and developing nations alike.

Integration For many years remote sensing applications were simply explorations of but one technology applied to natural resource problems. Recently, with heightened awareness and new technology capabilities, the need to integrate remote sensing with other technologies as well as with existing mapping and management systems has been addressed more frequently.

Domestic R&D The development of an independent R&D capacity is essential to sustain the processes at work during the implementation phase of technology transfer. This capacity may not and perhaps should not be fully independent of outside influences or contacts. However, sufficient indigenous capacity must exist to ensure that trends in research are responsive to domestic needs, priorities and conditions. This has been a particularly important thrust of the International Development Research Centre (IDRC) program in remote sensing. (Valantin, 1991).

4. RISK MANAGEMENT

Technology Doesn't Transfer Itself

Early in the development and demonstration of most technologies, the obvious potential benefits of its application seem evident and compelling to all - *except* those who might employ the technology as a tool. In remote sensing the level of resistance to innovation from traditional resource management disciplines was severely underestimated during the 1970s and much of the first half of the 1980s. Applications which may have seemed self-evident to the technologists and repeated demonstrations which have appeared definitive have often failed to overcome resistance to change.

Experience has demonstrated that beyond careful program development, structuring and management; successful technology transfer will require deliberate efforts to earn the confidence of potential adopters. Simply showcasing the specifications and potential performance of the new tools has proven consistently insufficient. (Plourde, et al, 1983; Dobbins et al, 1983; Ryerson et al, 1983; Ryerson and Arnason, 1981).

These efforts must approach the question of resistance to change from the adopters' perspective.

The technology transfer strategy must address the following questions:

-How do we RECOGNIZE resistance to innovation or change?
-What is the relationship between RESISTANCE and RISK?
-What are the SOURCES OF RISK?
-How can we MODEL technology risk?
-How can we MANAGE technology risk?

These questions are dealt with in the second component of the technology transfer model described here.

4.1 Resistance to Change

Resistance to change must be recognized for what it is - one of the natural human and organizational reactions to the "threat" or the "promise" of change. Resistance is not necessarily an indicator of fundamental flaws in technology. It is clear, however, that the sources of such resistance must be identified and understood if technology in capable hands is to attract greater confidence and acceptance. Resistance to technology can be characterized as a measure of the variance between science and technologies assessment of and response to societal needs; and human perceptions of the validity and value of that response (UNESCO, 1981).

Inertia and Momentum Bodies at rest tend to stay at rest - Inertia. Bodies in motion tend to remain in motion - Momentum. Both of these concepts of physics provide useful analogies for the human and organizational reaction to change. At both levels, change can threaten relationships and methods of operation which appear from the inside to be stable and successful. The old adage "If it isn't broken, don't fix it" is often the principle of choice. This is so, even though that this choice may breed complacency and false confidence, particularly in a rapidly evolving and increasingly demanding environment of change. We are now moving from an era when product failure was of more concern than obsolescence, to one in which obsolescence is much more likely to precede product failure. This has understandably presented individuals and organizations with fundamental challenges to traditional decision making with regard to technological change and innovation.

Inertia and momentum remain the most persistent sources of resistance to new technology. There is little that the technology transfer program can do in isolation from a broader awareness of this problem at the national level. Nonetheless, identification and quantification of inertia and momentum as sources of resistance to change can provide specific, valuable information relevant to all aspects of program planning from technology development to technology transfer.

Authority Acquiring or developing the authority to implement or encourage technology change in organizations is influenced by factors such as policy, mandate and management support. These are outlined above as elements of a technology transfer program. Without clear evidence of empowerment, authority over remote sensing will either be in dispute or will be exercised with severely constrained vigour.

Elitism From its inception in the 1960s remote sensing has suffered to varying degrees from charges of elitism. It must be acknowledged as well that elitism has been promoted from within as well as being a product of biased perception from outside the technology. Perhaps the most visible and most widely recognized result of elitism in the technological establishment has come to be termed "technology push". Faced with frustration over what is seen as resistance to innovation, the technology establishment has often resorted to promotion of technology as a benefit in its own right quite apart from application. The reasoning being that in the presence of high technology, applications will be encouraged to evolve more quickly than they would in a more technology-limited environment. While there is some empirical justification for this view, the simple presence of ever more sophisticated technology has not generally been rewarded with equivalent growth in applications or technology transfer. Indeed, in some cases, it has fostered an anti-technology reaction from the user.

Assessing and Managing Risk Research in such varied areas as theories of innovation and negotiation (Neirenberg, 1968) have long recognized that real CHANGE takes place only as a response to recognition of NEED. The assessment of need is influenced at least as much in terms of RISK as it is in terms of benefit. If risk can be equated with resistance to change or innovation, then assessment of risk must be a fundamental strategy of any technology transfer program or effort.

A strategy to manage risk must consider the following basic elements:

-Identifying the sources of risk
-Understanding the risks from the adopter's perspective
-Taking action to control and reduce risk, both real and perceived.

Many of the risks associated with the adoption of new technology can be controlled if their sources and implications are understood. In remote sensing, understanding of risks has lagged behind technology expansion. The level of effort devoted to understanding the sources of risk has been comparatively weak and uneven. Consequently, the risks associated with remote sensing are often much more fully accounted for from the technology perspective than they are from the applications perspective.

4.2.1 Sources of Risk Feasibility.... "Can it be done?" This element of risk - technical feasibility - has traditionally received the most attention in remote sensing programs. Correspondingly, sources of information, expertise, advice and support in this area are plentiful. The risk due to technical feasibility can be assessed for a given application from low to high. Risk would be considered to be low, for example, when successful transfer requires only replication of published, proven methods demonstrated under identical conditions (environmental, infrastructure, human resources). In practice, however, this is an unrealistic expectation.

Moderate risk would be associated with applications for which demonstrated methods would require adaptation to local conditions, needs and constraints. As acceptance of the technology expands, so to do the opportunities to carry out such applied research and so to does the relevant information and expertise. Much work of this type is now being reported in the literature and much expertise exists in the consulting or value-added industry in Canada and elsewhere. (Anon., 1992)

High risk of technical feasibility is associated with applications requiring original basic research with little directly applicable guidance. Basic research is directed at long term goals. The capability to implement and sustain such research is a requirement for self-sustaining adoption of remote sensing. Establishing this capability must itself be considered a long term objective, lower in priority to the more immediate requirement for low or moderate risk applications demonstration. In most cases such work is done by groups such as the author's agency. (Teillet et al, 1992)

Availability...."Can we do it in practice?" Much potentially valuable remote sensing research has never been extended to the real-world conditions and constraints under which the application would be implemented or transferred operationally. To do so requires consideration of the factors identified in Figure 2.

These factors include; cost, human resources, geography, infrastructure, supply and support. To answer many of the questions associated with availability of technology requires knowledge and a perspective which the technology providers rarely can be expected to have had the opportunity or orientation to develop. Such questions might concern the implication of cultural, geographic or religious tradition on the perception of the role and appropriateness of technology. Evaluation of availability must, however, go beyond any paternalistic or protectionist assessment of what is appropriate. It must consider the full range of factors which will determine whether or not technology will germinate, take root and grow at a stable and productive rate.

Acceptability...."The Bottom Line" In the final assessment of risk, it is not the performance or availability of technology which often really matters. What really matters is the perception of acceptability of the technology's contribution to the body of information which will serve as a basis for decision making. Figure 3 outlines several of the most common challenges to acceptability. It also identifies strategies which can be implemented to address these challenges.

Our experience suggests that for successful technology transfer the cultivation of positive attitudes with respect to the technology and its acceptability is as vital as is its implementation and associated applications research programs. The effort involved in changing attitudes with respect to acceptability, has in most cases, been grossly underestimated. The reasons for this are still not yet fully appreciated in remote sensing. They are, however, well documented in the literature on technology transfer, innovation and human resources development. (Rogers, 1962; McCarthy and Shapiro, 1983) Thus, while comparatively little assistance may be expected from the technology establishment; this final element of technology transfer risk is the subject of intensive research and study in other fields of research and expertise.

Success in assessing risks due to acceptability will come only through a balanced program of investigation. Such a program will have to extend beyond what has become the traditional bounds of remote sensing research to include the socio-cultural and political contexts. These have a profound and fundamental affect on the processes and outcome of technology transfer efforts. Figure 5 illustrates a strategy which encourages the full recognition of all of the identified sources of risk in project and program planning. The simple model facilitates recognition of imbalances in the consideration given to the three primary sources of risk identified here. Through regular, structured and conscious assessment of balance of effort, the overall technology transfer risks can be reduced and minimized as the program advances. As has been indicated, successful risk management requires the acknowledgement and integration of a range of skills and experience. It is highly unlikely that any single organization or individual can provide all of the experience required at the outset of a technology integration program. Innovative approaches to partnership and teamwork are likely to be an operational requirement for successful risk assessment, and program management.

In the Canadian context, experience (encouraged and supported by high level government policy) has demonstrated that partnerships between government and industry have much to offer as a mechanism for the development of innovative teams and effective technology transfer. Government-industry cooperation has lead to many important advances in the development, integration and application of remote sensing technologies in Canada. The role played by industry in the Canadian remote sensing community is outlined below.

5. THE ROLE OF THE PRIVATE SECTOR

The roles of the various sectors in remote sensing in Canada have been reviewed elsewhere. (Ryerson, 1991) In that context, it is sufficient to note that government agencies have typically been responsible for international agreements to receive and archive imagery; they carry out research and systems development; they develop applications; and they co-ordinate activities within their own jurisdictions. Early private sector activities concentrated on providing goods and services to the government. As a direct result of a favourable technology transfer policy at the national level, industry has been able to capitalize on the experience gained to develop and aggressively market derived products and services to a domestic clientele and to a rapidly expanding international market.

In Canada, the private sector has been particularly important in the technology transfer process. The growth of an industrial capability in remote sensing in Canada has been aided by a Canadian government policy which strongly encourages contracting out of government technology requirements to industrial suppliers. This has provided industry with opportunities for direct exposure to government R&D programs and results, as well as to participate in the development and supply of prototype and production systems. When these advantages of partnership with government are combined with the industry's ability to respond quickly to user's needs in terms of both technology and services, the potential for effective technology transfer is increased significantly.

The Canadian experience demonstrates that the most effective role of government in the process of technology transfer has, for the most part, been that of close cooperator, rather than that of direct or intentional competitor. This does not and must not exclude the qualities of excellence which breed innovation in government programs and services. Canada's single greatest undertaking in remote sensing, the RADARSAT Program, provides the latest indication of the synergy which can evolve through government-industry cooperation. In RADARSAT there is cooperation in technology development, needs assessment, and technology transfer.

While government competition with industry is considered by the authors to be detrimental to the long term effective use of remote sensing, there are and have been useful roles which can be played by government/industry partnerships in Canada. Many of the institutional barriers to remote sensing adoption have been overcome through such mutually supportive partnerships. The industry's closeness to the domestic and international marketplace can provide it with a unique and useful perspective on what applied research must be done. Governments, on the other hand, have a useful perspective on the international research scene, the technology frontiers being crossed and access to the information provided by the Embassy network throughout the world.

In closing on the issue of government/industry relations, it should be noted that the two largest remote sensing oriented companies in Canada (and the world) did not face competition with their governments. They instead formed strategic partnerships with governments which saw them provide products and services, while the governments did some basic research and provided an environment in which the industry could grow and reach into international markets with high quality products and services. Increasingly these products and services are based on sound research and development done in partnership between government and industry. Recently, the larger players in industry have taken on more self-funded research of a strategic nature to meet their own long term needs.

6. CONCLUSIONS

This paper has discussed the major impediments to the adoption of remote sensing and has presented a technology transfer model based on the authors' experience as well as on work done in other fields. While other models and approaches have been and will be successful, they will share the basic elements of the model suggested here. The key common factor in successful programs is the willingness for the technology proponent to be sensitive to both the real and perceived needs and capabilities of the user.

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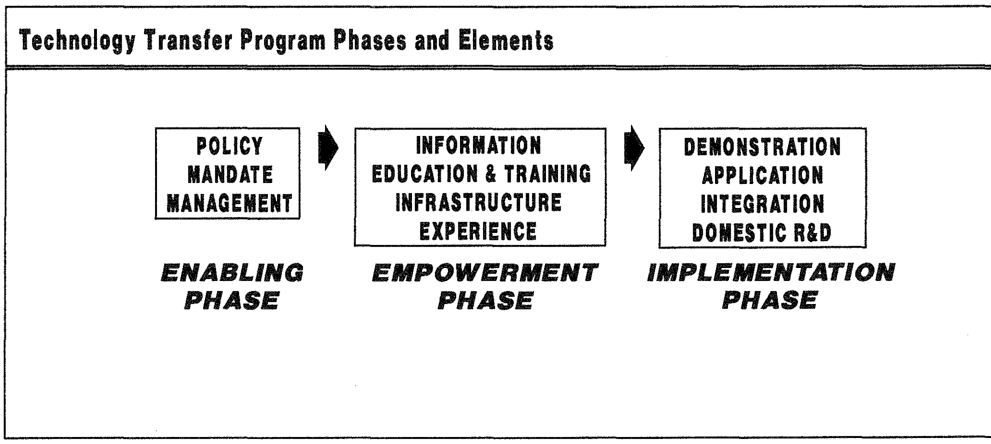

Figure 1

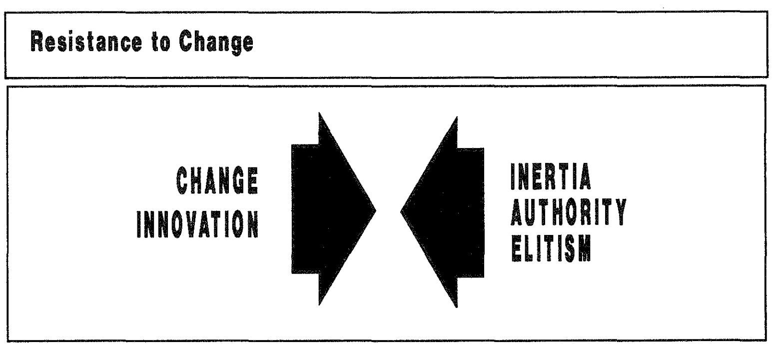

Figure 2

AVAILABILITY OF TECHNOLOGY: Factors to Consider

COSTS	- the REAL costs (purchase, O&M, replacement, training)
HUMAN FACTORS	- workforce size, depth, culture and traditions, performance gaps and training needs.
GEOGRAPHY	- where is the PROBLEM?...the TECHNOLOGY? - where are the DECISIONS MADE?
INFRASTRUCTURE	- adequacy of existing FACILITIES & CONDITIONS. - level of available SUPPORT. - availability of TRAINING.
RS/GIS DATA	- data availability, reliability, consistency, security.

Figure 3

ACCEPTABILITY: Challenges / Strategies	
CHALLENGE	**STRATEGY**
Awareness	Promote
Confidence	Demonstrate
Resistance to Change	Train & Reward
Organizational Inertia	Stimulate & Challenge
Traditional Standards	Evaluate standards vs needs

Figure 4

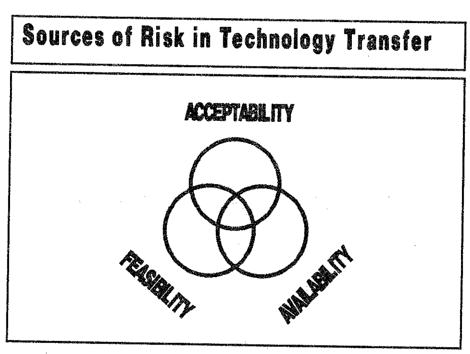

Figure 5