Defence Science Journal, Vol. 55, No. 2, April 2005, pp. 141–148

REVIEW PAPER

Technology Transfer and Technology Management in Strategic Systems

Prashant Salwan

Indian Institute of Management, Indore

ABSTRACT

In a knowledge-based economy, the issues of technology transfer and management of technology, especially in sensitive strategic industries, are of major concern. The transfer of technology is a complex multidisciplinary area of technology management involving technology transfers from overseas developing agencies and internal technology transfers. Technology is a combination of four basic components–facilities, abilities, facts, and frameworks. Economics of scale and complexities in technologies, especially in major weapon systems, would increasingly render the concepts of self sufficiency and even self-reliance impossible ideals to achieve, even by the developed countries. In such a scenario, transfer of technology will continue to be used as a powerful tool of global geopolitical power projection by the developed countries as an extension of their foreign policies. For nations like India, there is no option but to invest in the indigenous R&D and S&T base in sensitive/strategic industries. Experience in transfer of technology with those of space, defence research, atomic energy, scientific and industrial research must be pooled into knowledge bank to achieve synergy.

Keywords: Transfer of technology, knowledge-based economy, technology management, national security, technology-transfer agent, product-development, technology-transfer strategy, manufacturing plan

1. INTRODUCTION

The venerable doyen of management gurus, Peter F. Drucker, was the first, prescient observer to comment on the emergence of knowledge as the prime source of an industrialised nation's competitive advantage, and the power of knowledge workers, in the post-industrial, borderless, global economy that is evolving since mid-1980s. The second industrial revolution, as some observers have termed the current, knowledge-based rapid advances in information technology, genetic engineering/biotechnology and allied fields, would be dominated by those nations that possess the highest quality workforce of knowledge workers: Peter F. Drucker goes to the extent of insisting that the only competitive advantage of the developed countries is the supply of knowledge workers, as the knowledge constantly makes itself obsolete, with the result that today's advanced knowledge is tomorrow's ignorance, a stand supported by other experts in the field like Prof Michael E. Porter.

2. TECHNOLOGY TRANSFER

In such a scenario of a knowledge-based[1] economy, the issues of technology transfer and management of technology, especially in sensitive strategic industries,

Revised 16 August 2004

are of major concern, not only in the context of national competitiveness but also in the context of national sovereignty and security interests. The field of transfer of technology is a complex multi-disciplinary area of technology management involving technology transfers from overseas developing agencies and internal technology transfers of indigenous to local, and (in some rare cases in the Indian context), to foreign clients.

It must be recognised that the technology transfer agent is no longer merely feeding information as in the semi-active mode. The technology transfer agent is a technologist who is actively searching for the solution to the problem. The agent must have a clear understanding of what it takes to satisfy the needs of the user. It is with this solution that the entrepreneur can proceed to fabricate a prototype, test it, manufacture the product, and sell it. This is the general statement of technology transfer. Although, successful technology transfer can be accomplished when the entire market demand is for a single manufactured unit, it is more usually the case that successful technology transfer is marked by the steady entrance of a manufactured product into the marketplace.

2.1 Elements of Technology Transfer Cycle

Experience has shown that certain elements in the demonstration process must, at a minimum, be present during the transfer cycle[2]. These are:

- A firm statement of user need
- A clearly stated and understood boundary of solutions (acceptable solutions)
- A firm commitment by the user to remain actively associated during and after the technology transfer
- Participation of representatives of influential interest organisations
- Market analysis
- Manufacturer
- A champion and an entrepreneur (who may also be the champion) are the most important elements.

2.2 Transition from Research to Product Development

2.2.1 *IBM Case Studies*

Cohen[1], *et al.*, focusing on the transfer of technology from research to a profitable commercial enterprise, describe a study of 18 IBM projects; some of these were successful, while the other failed. They prepared valuable guidelines for moving technology from research to product development. This study can form an archetype for the improvement of guidelines helping in the technology transfer that are responsive to the unique requirements of a given organisation.

As a result of this study, those factors that affect technology transfer have been identified and are discussed in the order of their relative importance:

(a) *Technical Understanding*[3]

- It is necessary that research personnel fully understand the main technology before passing it on. Though this may seem obvious, it is not always the case.
- It is necessary to evaluate the benefits of new technology in comparison to what is already available and to other competitive advancements.
- One must identify where it will fit in the product line and what requirements must be met to reach the fit.
- One possible means of manufacturing needs to be exhibited.

(b) *Feasibility*

- A good estimate of user need is essential for the success of any technology management and transfer venture.
- Some estimate of cost effectiveness should be made.
- In some cases, feasibility implies acceptability by the end user. This would recognise some kind of joint study with actual users to establish feasibility.

(c) *Advanced Development Overlap*

- For projects being transferred out, some overlap of research activities may be needed, either to support development or to explore advanced or related technologies. For systems work (computer software), creation of special advanced development effort is often the answer to problems of scaling-up or to answer questions of economic feasibility.

(d) *Growth Potential*

- When projects are narrowly focused on a specific need and do not have paths to technical growth and product applicability, the technology transfer may suffer. This is because existing technologies stretch themselves and the limited advantage offered by the new technology may not be sufficient to warrant a change.

(e) *Existence of an Advocate*[4]

- A strong proponent activity is needed to help overcome the hurdles during the technology transfer process.

(f) *Advanced Technology Activities in a Development Laboratory*

- In moving technology from research to manufacturing, the advanced technology programs in the development laboratories are often necessary. (For some research organisations, research and advanced development units may work in the same group).

(g) *External Pressures*

- In some cases, parallel activity by a competitor may help provide the push for technology transfer; in others, regulatory requirements may necessitate adoption of new technologies, for example, advanced waste treatment technologies.

(h) *Joint Programmes*

- It was concluded that joint programmes with the receiver groups are beneficial, but these do not ensure success.

2.3 Technology Transfer Strategy for Large/ Complex Products/Systems

A generalised technology transfer strategy development plan is depicted in Fig. 1 and a description of major activities of this plan follows. To understand this approach clearly and to operationalise the concept, real research project execution and actual organisational experiences are needed. Hypothetical examples cannot easily convey the organisational and individual behaviour context that affects technology transfer. The example for successful technology transfer strategy for a large complex system, is the integrated guided missile development programme (IGMDP). The IGMDP was taken up for the development and production of five types of missiles required by the Indian Armed Forces, viz, *Agni, Prithvi, Akash, Tirshul*, and *Nag*.

The IGMDP comprised a broad spectrum of activities including critical technology development, product development, manufacturing process development, identification of production agencies, establishment of critical production agencies, establishment of critical production facilities, technology transfer and production, etc. The technological goal of the programme was to ensure that the missiles developed are contemporary in performance at the time of their deployment. To realise this goal under the threat of technology obsolescence and also to realise the missiles at the earliest possible time, the IGMDP adopted concurrent development and production as the key competitive strategy.

Based on a critically analysed technology scenario for the next two decades, new technology and product development efforts were launched through collaborative effort and consortia. A coherent management system was developed for coordination of all the efforts and to harness the best talents. Such efforts over a decade were found extremely fruitful and the first milestone was achieved by completing all the developmental trials, user trial tests, and entering into the phase or production or the first indigenous missile for the Indian Armed Forces.

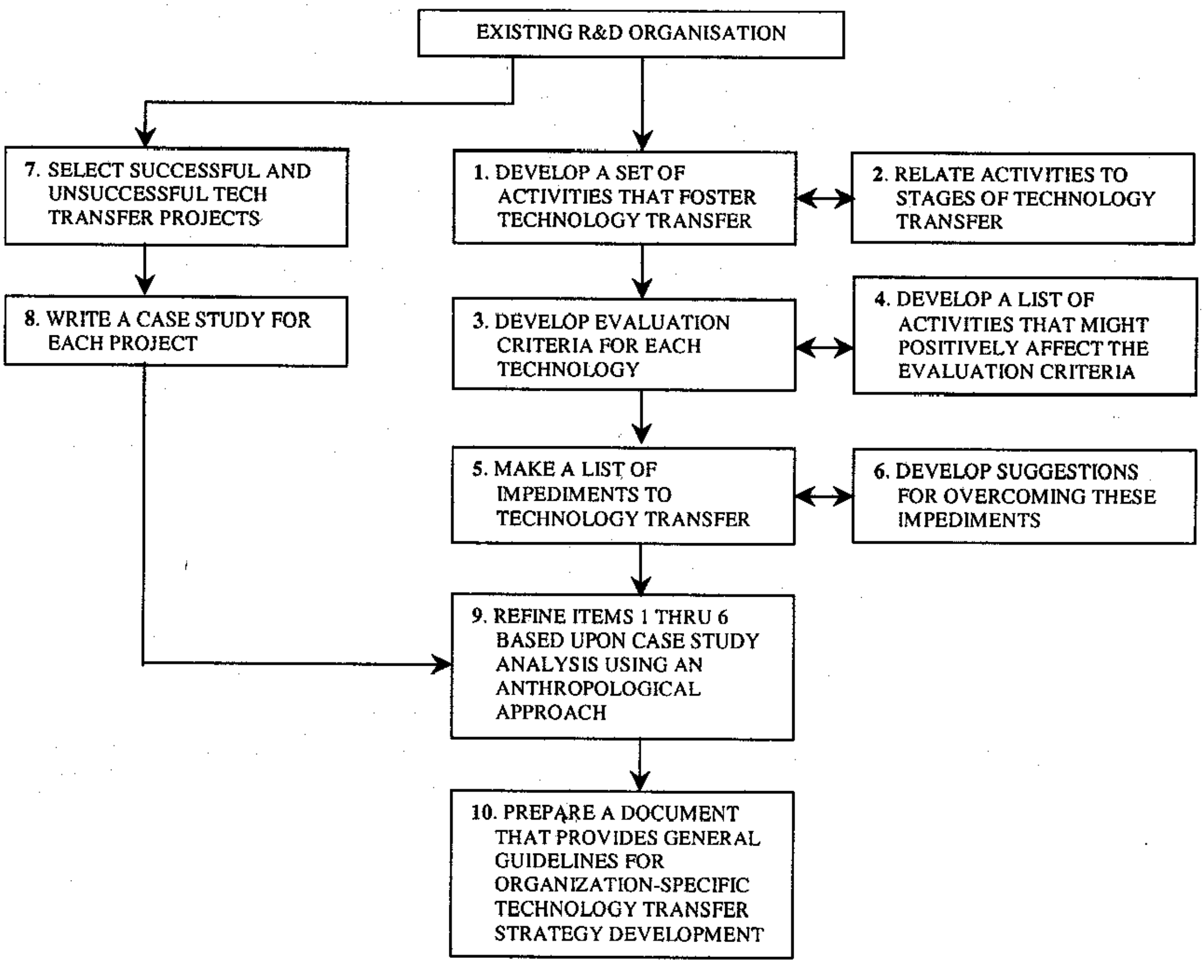

Figure 1. Technology transfer strategy development plan

3. TECHNOLOGY & DEVELOPMENT

Technology and warfare are closely related. On one hand, the industrialised nations have used technology for maintaining their lead in the developed world, developing countries mostly depend upon imported technologies for their growth. The threat to real life exerts a strong push on the higher-level technology for military hardware. Thus, the development of new and advanced level of technology becomes a continuous process for military weapon systems development and acquisition. Ultimately, it is the technology that becomes the force-multiplier. But technology cannot remain any more a black box.

Technology is a combination of four basic components[5-8]–facilities, abilities, facts, and frameworks. Facilities or technoware includes all physical entities necessary for transformation such as equipment, machinery, plants, and factories. Abilities or humanware includes creativity, skills, perseverance, and ingenuity. Facts or inforware includes specifications, designs, theories, and observations. Framework for orgaware includes systematisation, networks, management, and marketing. Out of these basic elements, humanware is the ultimate source of technology, while inforware is designed to evolve as a new type of capital–knowledge.

Technology cannot be created or transformed without proper technology climate. Such a climate cannot be restricted to only a research and development organisation; but should envelope the entire matrix, including the industry and the users.

4. MANAGEMENT OF MAJOR WEAPON SYSTEMS

Cardinal Newman quoted that, "Nothing would be done at all if a man waited until he could do it so well, no one could find fault with it". Much of the rapid progress made by the early developers of radar in Britain during the second world war can be attributed to Sir Robert Watsoin–Watt's doctrine of using the third best–the best being unattainable and the second best unavailable, until too late. Fortunately for him and for the Royal Air Force and Britain, his programme review groups did not have access to today's procedures and techniques for ensuring optimal solutions to each problem.

The challenge of programme management[9] is to find the practical middle ground between producing underdeveloped systems and extended development and testing to the n^{th} degree of a few high-cost systems that never reached rate production. The key guidelines to be followed are:

- Select an acquisition strategy and risk management plan in context with the unique aspects of the programme.
- Avoid planning a development-to-production gap into the program.
- Enter full-scale development only with a solid technology base and a management commitment for timely support and continuity of effort, provided that the need still exists and satisfactory progress is maintained.
- Plan for transition-to-production, starting at programme initiation.

Management of a major weapon system, from development through production, requires effective administration and coordination of many activities. At the production phase, large financial commitments are made based on the detailed planning of previous phases. The transition is a highly visible, highly reactive time which lays emphasis on preparation for production and change management. A programme manager[7] should recognise the fundamental principle that systems acquisition is an industrial process which demands both, an understanding of that process and the implementation of basic engineering disciplines and their control mechanisms. Transition from full-scale development into production places particular demands on engineering design, test and manufacturing, in both application and timing, and emphasises assurance of design stability and certification of the manufacturing process. The problems with the acquisition process are not administrative, but instead technical and techno-political. The technical process focuses on three critical activities–design, test, and production.

5. OVERVIEW OF TRANSITION PROCESS

Transition from development-to-production is not an event with a readily identifiable starting point in the acquisition process. The transition process incorporates many activities. It is a continuum of interrelated and interdependent activities. Military acquisition has time and again extended the product development efforts well into the production phase. As a consequence, numerous product changes are introduced, planning essential for manufacturing is delayed, and the burden on manufacturing to make up time for engineering delays is a monumental task for what could otherwise be a successful acquisition programme. Fast tracking is a high-risk venture. The transition process is very broad and it is impacted by activities that are not done in the early design and testing.

Planning for production and manufacturing engineering, following the design process[5], is a major transition process risk. Documented early producibility, engineering and planning integrated with advanced development, offers benefits of increased end-item compatibility with the process and procedures necessary to produce the item, and reduces the number of changes in the product configuration introduced on the factory floor. Acquisition costs and schedule delays could be reduced when the programme is structured to accommodate the transition to production.

Documented early planning focusing on the specifics of the manufacturing practices and processes required to build the end-item should be initiated while the design is fluid, and completed before the start of rate production. A manufacturing plan should be a comprehensive document, to provide guidelines for action, to identify and give visibility of high-risk factors, and then provide direction by which the risk can be minimised. The essential elements of a manufacturing plan, which will significantly reduce the risk of transitioning a programme from development to production are:

- Master delivery schedule which identifies by each major sub-assembly, the time spans, need dates, and the person responsible.
- Hard tooling requirements to meet increased production rates as the programme progresses.
- Special tools
- Special test equipment
- Assembly flow charts
- Receiving inspection requirements and yield thresholds
- Production yield thresholds
- Productibility Studies.

6. EMERGING PARADIGMS IN TECHNOLOGY TRANSFER IN STRATEGIC INDUSTRIES

For client nations in the developing world, more transfer of technology to assemble/licence manufacture components/subsystems of major systems, is no longer acceptable. Access to real[10,11] technology is being insisted upon, as exemplified by the insistence of United Arab Emirates (UAE) on access to source codes of the advance capability F-16 D Block 60 fighter aircraft's advanced avionics/electronic warfare suites, the development of which was being funded by UAE as part of its order worth US$ 7 billion plus for the supply of 80 fighter aircraft. UAE's demand for the access to sensitive source codes–an unprecedented demand by a tiny, third world (but oil-rich) country, is now threatening to scuttle the whole contract, since US DoD is unlikely to permit such access. This episode is a good example of the kind of hard bargaining and political-cum-technological issues involved in transfer of technology in strategic systems.

In addition to access to sensitive technologies, client nations insist on extensive technological offsets of varying degrees, in terms of contract value and also technological content. In one notorious, extreme example of offsets being used to win contracts, Boeing offered offsets worth 140 per cent of the value of contract, when it offered its E-3 Sentry[12] airborne warning and control system (AWACS), in a contract worth US $1 billion, to UK's Royal Air Force, ie, Boeing agreed to buy-back goods/services worth US $ 1.4 billion from UK, for obtaining a contract worth US $ 1 billion! However, in most recent contracts, offsets range from 30-50 per cent, with the seller obliged to transfer and set up a whole range of manufacturing/service operations in the client nation. The most recent example of the kind of technology offsets being offered can be seen in Australia's Wedgetail airborne early warning and control aircraft (AEW&C) system program, valued at US $ 824 million. All the three bidders for this contract, ie, Lockheed Martin, Raytheon, and Boeing, are offering to set up centres of excellence in Australia to support the system, manufacture substantial portion of the system through Australian contractors, and generate additional revenues for Australian companies in future by re-export to other clients. Similar campaign is being waged for UK's requirement for airborne stand-off radar (ASTOR) programme[13-15] valued at US $ 1.2 billion. In this programme, too, the three bidders–Northrop Grumman, Lockheed Martin, and Raytheon (all American) offered extensive offsets to UK companies as partners and the prospects for re-exports to other clients for similar systems. To sum up, in an intensively competitive field, the sellers have to offer extensive carrots–technological offsets in the form of partnerships to the client countries and also a share in future sales of such systems to other countries. The days of simple barter deals, involving, say, crude oil for combat aircraft or ships or tanks, are essentially over. However, this particular scenario may not apply to a group of third-world nations, who are not in the most-favoured nation status with the developed countries–eg India.

Where the seller agrees to substantial offsets, it still does not automatically mean that the client country has full control over the technology transferred.

For instance, US DoD/ Dept of Commerce, exercise strict control over all the technologies of US origin sold/transferred to third-world nations and at any point of time, can veto re-export of systems incorporating US technologies. A case in point is the Swedish JAS-39 Gripen fighter, which has extensive systems and technologies of US origin, including the engine. For export of the JAS-39 Gripen fighter to South Africa, Sweden had enormous trouble to obtain the necessary re-export licence clearnces from the various US Govt agencies. The obvious implication is that even if some technology is transferred, it does not automatically bestow ownership to the client company/nation.

7. CONCLUSIONS

Transfer of technology will continue to be used as a powerful tool of global geopolitical power projection by the developed countries as an extension of their foreign policies, either through overt or covert measures. In exercising control over transfer of technology in sensitive/strategic industries and technologies, the developed countries will continue to act in concert, through such measures like Missile Technology Control Regime (MTCR), European Union Dual-use Regulation 1994, US Dept of Commerce Munitions List, etc.

For nations like India, there is no option but to invest in the indigenous R&D and S&T base in sensitive/strategic industries.

The technology transfers involve mostly transfer of know-how, not know-why. In many high-tech, complex technologies like main battle tanks, fighter aircraft, submarines, etc, nations which were recipients of transfer of technology, did not/could not transit themselves into fully capable players in these fields on their own, inspite of decades of licence production of such systems, eg, India (Hindustan Aeronautics Limited), which licence produced western combat aircraft like Foland Gnat, Sepecat Jaguar, Alloutte helicopters, and Soviet fighters like MiG 21M and MiG 27M, for over 20 years yet is finding the development of light combat aircraft (LCA) and ALH an uphill task. Even where only modernisation/ upgradation of MiG 21M aircraft for the Indian Air Force was involved, the order for 125 kits, each valued at US $3 million plus, went to the MiG-MAPO Bureau, Russia, with Hindustan Aeronautics Limited performing only the assembly of the kits in India: this, after manufacturing the MiG 21M in India for almost 20 years. In fact, Sweden[16,17] for its JAS-39 Gripen fighter has to rely on American technology partners in the development and production of its F-2 fighter, which is essentially an F-16D derivative, with more than 50 per cent US technology input: however, despite more than 15 year development cycle, the F-2 fighter aircraft is arguably the costliest fighter is its class at a unit price of US $80 million plus, with only marginal improvements in performance over the latest F-16D Block 60 advanced capability model, being developed for UAE by Lockheed Martin, which costs approx. US $60 million. If an industrial superpower like Japan with its vast high-tech industry and R&D base, who has vast experience in transfer of technology, that too after licence production of F-15 fighter, which is even more powerful than F-16, is so disappointing, that difficulties experienced by India can be imagined.

Economics of scale and complexities is technologies, especially in major weapon systems, would increasingly render the concepts of self sufficiency and even self reliance, impossible ideals to achieve, even by the developed countries. In the 21st Century, with the exception of the US and possibly, Russia, probably no nation would venture to undertake development of major weapon systems on its own: even Americans are actively soliciting international partners in its Joint Strike Fighter (JSF) programme, which would arguably be the largest Combat Aircraft program in the world, for the next 40 years, with over US $50 Billion in sales projected.

Judicious transfer of technology/technology master plans at national level, balancing resources versus national security interests, are the only answers to the challenges of the emerging new technological imperialism. One has to augment the indigenous S&T/R&D base, with trustworthy international alliances and partnerships in critical technology areas.

Experience in transfer of technology with those of Indian Space Research Organisation (ISRO), Dept of Atomic Energy (DAE), Council for Scientific and Industrial Research (CSIR) and Defence Research and Development Organisation (DRDO) must be pooled into a knowledge bank to derive the benefits of synergy of the programs of these organisations.

REFERENCES

1. Cohen, H.; Keller, S. & Streeter, D. The transfer of technology from research and development. *Research Management*, 1998. **22**(3).

2. Ebata, Kensuke. US and Japan in technology transfer Ju-Jitsu. *Inter. Def. Rev.*, 1993, **6**, 461-62.

3. Elliot, James. Military Aircrafts Program: Domestic projects for military aircrafts in the developing world. *Military Technology,* 1998, **7**, pp.54-61.

4. Elliot, James & Bonsignor, Ezio. Asia's new aerospace industry: At the tuning point? *Military Technology*, 1998, **2**, 24-32.

5. Mogavero, Louis N. Shane, Robert S. What every engineer should know about technology transfer and innovation. Marcell Docker Inc, New York, 1982.

6. Jain, R.K. & Triandis, H.C. Management of research and development organisation, Managing the unmanageable. John Wiley & Sons, New York, 1990.

7. Abdul Kalam, APJ & Rajan, Y.S. Strategic industries. *In* India in 2020: A vision for new millennium. Viking/Penguins Books India, 1998. pp. 187-16.

8. Arnett, Eric. Military technology: The case of India. *In* SIPRI Year book, 1994. Stockholm International Peace Research Institute. Oxford University Press, 1994. pp.343-65.

9. Indiresan, P.V. Vision 2020: What should India DO? *In* Presidential address on the 10th anniversary of Indian National Academy of Engineering, 20th December 1997. Indian National Academy of Engineering, New Delhi, 1997.

10. Bonsignore, Ezio. The UAE fighter choice and its implications. *Military Technology*, 1978, **7**, 51-53.

11. Warwick, Graham. Export attention. *Flight International*, 10-16 March 1999, 32-33.

12. Jeziorski, Andrej. Comrades in Arms. *Flight International*. 10-16 March 1999, 48.

13. Kemp, Daian. Last wedgetail bids received. *Janes Def. Weekly*, 24 Feb 1999, 6.

14. Anselmo, Joseph C. Satellite builders fear export nightmare. *Aviation Week & Space Tech.*, 22 February 1999. 24-25.

15. Anselmo, Joseph C. US denial of china satcoms echos round the world. *Aviation Week & Space Tech.* 01 March 1999, 6-27.

16. Arnett, Eric. Military technology: The case of China, *In* SIPRI Year book, 1995. Stockholm International Peace Research Institute. Oxford University Press, 1995. pp. 359-86.

17. Anthony, Ian. Multilateral weapon-related export control measures. *In* SIPRI Year book 1995. Stockholm International Peace Research Institute. Oxford University Press. 1995. pp. 598-633