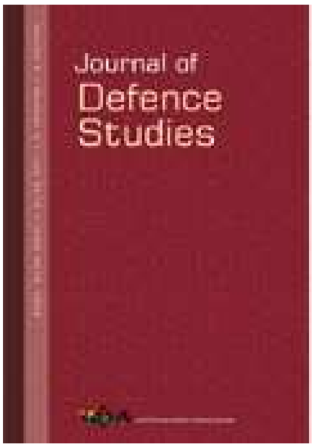

Journal of Defence Studies

Publication details, including instructions for authors and subscription information:
http://www.idsa.in/journalofdefencestudies

Transfer of Defence Technology: Exploring the Avenues for India

Kevin A. Desouza

To cite this article: Kevin A. Desouza (2017): Transfer of Defence Technology: Exploring the Avenues for India, Journal of Defence Studies, Vol. 11, No. 3, July-September 2017, pp. 69-98

URL http://idsa.in/jds/transfer-of-defence-technology

Transfer of Defence Technology
Exploring the Avenues for India

Kevin A. Desouza[*]

India has been the recipient of transfers of defence technology predominantly through the licensed manufacture mode which, while being cheap and easy to implement, has some major limitations. This article looks into alternate modes of technology transfer and explores additional possibilities through a broad perspective on technology development. It also attempts to assess the relative strengths of each mode, the challenges in implementation and indicate a way forward to meet suitable national goals.

India has a long-standing history of acquiring defence technology for the production of defence systems. From as far back as the 1950s, contracts with foreign firms have enabled the production of vehicles and guns, followed by main battle tanks and infantry combat vehicles, fighter and trainer aircraft, frigates and submarines, in the state-run production agencies comprising of ordnance factories (OFs) and defence public sector undertakings (DPSUs).[1] These contracts were executed in the licensed production mode where foreign firms provided a licence for locally manufacturing a specified number of systems.[2] Alongside, they also provided the design and production documents, special machinery,industrial training (know-how), as well as the systems themselves in a suitable proportion and sequentially delivered in fully formed state, semi-knocked down (SKD) kits and completely knocked

* The author is a Research Fellow in IDSA, New Delhi.

ISSN 0976-1004 print

Journal of Defence Studies, Vol. 11, No. 3, July–September 2017, pp. 69–98

down (CKD) kits. While the receipt of the fully formed systems enabled the understanding of their operation, maintenance and testing aspects, the SKD and CKD kits enabled the Indian workforce to absorb the assembly and integration of the various parts of the system to progressively greater depths.

The licensed production mode of the 1950s to the 1970s then appears to have evolved into a mode with an additional indigenous manufacture (IM) phase. This phase entailed the transfer of technology for local manufacture of a substantive portion of the assemblies/sub-assemblies and even discrete parts. The manufacturing technology of some critical parts of the systems termed 'proprietary' were, however, never shared and these were delivered in what are called IM kits. The kits along with the indigenously manufactured parts would then be put together to produce the whole system. Thus, licensed production came to be known as licensed production with IM or simply licensed manufacture (LM) or, as is noticeable from the early 2000s onwards, LM with transfer of technology (ToT) to simply ToT.[3]

The LM mode, currently being referred to as ToT in the Indian Defence Procurement Procedure (DPP),[4] essentially delivers the capability to manufacture or produce defence systems through the acquiring of necessary know-hows. However, for significantly upgrading the system or designing, developing and manufacturing new variants independently of the foreign technology seller firms, the know-whys are needed. These know-whys are never provided for established reasons and huge costs, leaving the recipient country considerably dependent on the seller firm for its futuristic needs.[5]

Though it has been established that ToT in the LM mode, or production ToT (PToT),[6] does not facilitate the acquiring of know-whys, is it possible that there are other modes, or in a wider sense, avenues, which can? Other avenues that do not explicitly mention technology but nevertheless involve the transfer of knowledge which could contain the know-whys? Can these avenues provide newer technologies as compared to PToT which invariably delivers those that are one or two generations old? How feasible are these avenues and what will they cost? This article attempts to answer these questions by analysing the other conventional modes of technology or knowledge transfer which are currently prevalent, and also searches for new avenues which hold a possibility of success. But first, there is a need to deliberate on the national goals that are to be pursued through these modes or avenues. A clear perspective of national goals will enable effective evaluation of each avenue for its contribution to them.

Suitable National Goals

Among the national goals, the acquisition of military systems with a superior edge over India's adversaries is an obvious overriding one, as stated in the Indian Defence Production Policy (DPrP) of 2011.[7] But that can be achieved by outright purchase of superior weapon systems instead of ToT that is tedious and costlier.[8] So, are there secondary goals? Some goals, such as increased economic/industrial growth, generation of employment and savings in foreign exchange, are of a general nature, common to all spheres. But to be more focused, is this secondary goal self-reliance, or going further in that direction, the unaffordable and unattainable self-sufficiency?[9] These goals emphasise, inter alia,[10] the need to indigenise all parts of the imported defence system, even if they are unsuited to manufacture in India, entail much higher costs due to low scales of production and ultimately may be produced at lower quality standards.[11] This particular aspect of indigenisation ultimately boils down to 'import substitution', which aims at replicating imported parts, and which has been a long-standing objective in the OFs and DPSUs.[12] Achievements in this area are reflected numerically in terms of indigenous content, possibly in keeping with the self-reliance index (SRI) concept propounded by the Dr A.P.J. Abdul Kalam Committee in 1992.[13] The Kelkar Committee subsequently recommended, in 2004, with respect to self-reliance that 'there is a need to go beyond import substitution to involve capability enhancement and development, increasing know-why, design and system integration.'[14] Though these appear to have been generally accepted by the environment as valid and commendable objectives, no method has apparently evolved to quantify them and replace the SRI.

Hence, the SRI continues to be used as a national objective of self-reliance and the focus on indigenisation or import substitution remains at the top of the agenda. Unfortunately, import substitution narrows the focus of the Indian defence industries to innovating, designing and developing alternates for specific imported modules or parts which have already been in use for a large portion of the life of their technology. In fact, many of these parts are close to obsolescence when it is realised that import substitution is imperative.[15] So, the focus devolves on developing parts for functions, and at specifications, which are outdated. This clearly means that the developed part will have no utility for newer systems employing newer technology which delivers smaller, lighter, more reliable and maintainable but less energy consuming parts, performing at higher speeds and delivering superior output. Is this beneficial to the country in terms of technological effort and output?

Also, in self-reliance, if the purpose is to ensure, in the words of K. Subrahmanyam,[16] that 'the operational exploitation and maintenance of the foreign equipment must not be held hostage under any circumstances', is it not cheaper and more effective to scientifically predict the exploitation and the number of likely failures in the systems in the future and then purchase and stock the needed fuels, material and spare parts in appropriate quantities including safety stocks,as is done in lifetime buys?[17] Calculating the optimal range and quantity of spare parts required for achieving a specified system availability is not an easy task, but there are proven techniques which are in use around the world for such applications.[18]

A factor which strongly goes against the goal of self-reliance is the 'global factory'. The Swedish firm, SAAB, offers its world-class Gripen fighter aircraft with a United States (US) engine, Italian radar and US or Israeli missiles.[19] The US F-35 Joint Strike Fighter aircraft was jointly developed with portions of the system contributed by no less than nine countries![20] One reason why such arrangements for multiple country-sourced sub-systems are found to be successful is that each country has focused on and perfected a specific area of technology and is among the world leaders in it.

So,instead of just self-reliance, can technology transfer also build world-class design, development and manufacture capability,thereby helping to achieve a more productive and profitable goal of 'technology leadership', albeit in a few select areas?[21] For example, leadership in a field such as nanotechnology or micro-electromechanical system (MEMS)-based sensors where the products of Indian firms compete internationally in performance and price for a dominant share of the world market. Or, coming down a notch, can technology transfer build these capabilities for producing technologies which can compete with the rest of the world, where international original equipment manufacturers (OEMs) look to out source some of the parts of their contemporary systems from Indian firms? Such technology competence, aside from helping meet the overriding objective of providing weapons systems with a superior edge, would bring in much-needed profits and build foreign country interdependence, thereby strengthening India's bargaining power for complementary technologies.

Some say that pursuing such a goal of technology competence could take India to bankruptcy and that even substantive self-reliance is difficult to achieve. However, this goal of technology competence is not entirely at variance with what is currently being targeted in India as 'international competitiveness' in manufacturing.[22] Also, achieving self reliance is not a pre-requisite for achieving technology competence in a few areas. Countries such as Israel, South Korea and China are close to achieving such capabilities in niche areas through significant external assistance accompanied by a substantial national effort as indicated by a recent study. Hence a look into other modes of technology transfer, both conventional and unconventional is useful.[23]

Other Conventional Modes of ToT

Licensed manufacture or PToT, as described in the beginning of this article, has been the predominant mode of technology transfer in the Indian defence sector over the past many decades. It has been mainly facilitated through government to government (G2G) agreements, with the ToT to the state-run OFs and DPSUs. In the last decade, however, many private firm to private firm (P2P) or private firm to state-run agencies (P2S) PToT contracts have been initiated and executed. Private firms are, understandably, cost conscious and are particular that they deliver only as much as has been paid for. Hence, agreements are possibly much more detailed to enable smooth execution.

After PToT, the most common of the conventional modes being linked to ToT is joint ventures (JVs) for co-development and co-production (JVs CD–CP). As the name suggests, JVs are independent entities formed from the contribution of two or more agencies or companies to achieve common goals. For such an arrangement to be successful, it is necessary that both partners contribute by bringing in complementary technologies, in addition to funding.[24] India has used this arrangement through collaborations with Russia for developing and producing the successful Brahmos missile;[25] and with Israel for the medium-range surface-to-air missile system (MRSAM), which has been recently announced as successful.[26] On the positive side, it has been reported that 70 per cent of the MRSAM system will be indigenous when productionised. However, there are also unverified and possibly biased reports that the Defence Research and Development Organisation

(DRDO) contribution was minimal, limited to making a few changes in the versions for the navy and the army.[27]

Irrespective of whether there was any contribution by Indian agencies, what is strange is that in both the Brahmos and MRSAM projects no mention has been made on what technology has actually been transferred. From working together, India should have gained the know-whys in system design as well as product development and production process development that Russia and Israel employ. Through working together, a fair amount of knowledge on the Russian and Israeli portions of the systems may have been gleaned. But have the know-whys or the know-hows of developing and manufacturing those portions been obtained through mutual agreement and consent? A significant aspect to note is that JVs actually allow the owner to maintain a tighter control on its technology. That is why owners are willing to use relatively newer technology in JVs as compared to that in LM.[28] Another aspect is that this arrangement leads to joint intellectual property rights (IPRs) as well as shared international market space and, therefore, the technology cannot be exploited and exported with the freedom that pure indigenous development facilitates, though it is comparable with LM that is limited by similar restrictions.[29]

From the self-reliance perspective, therefore, JVs CD–CP do not appear to be overly beneficial. The fact is that India or Indian firms will remain dependent on the foreign partners for their portion of the system until an indigenous version is developed. The development of the indigenous version too is very likely to be restricted by contractual clauses inserted by the foreign firm so as to protect its business interests. So, while the average LM would lead to dependence of say 30 per cent, which can be subsequently reduced through import substitution, a JV could involve a dependence of 50 per cent, which may be more difficult to reduce due to the relatively newer technology employed. For technology competence, however, it can offer some benefits in terms of exposure to world standards of design and development processes,as well as world standard products. But from the cost effectiveness angle, since development projects in general are prone to risks of delays and sometimes even failures, this arrangement will invariably turn out significantly more expensive than a PToT one.

JVs are also used for co-production only. One such example is Lockheed Martin's JV with the Turkish Air Industries (TAI), a state-owned company, for the production of F-16 aircraft in the 1980s, which resulted in successful production of a total of 308 aircraft over a period of around 12 years.[30] The share ownership was as follows: TAI had the major share with 49 per cent; Lockheed Martin had 42 per cent; General Electric (GE) had 7 per cent and the remaining was held by two other firms. A total investment of $137 million was made, with $70 million from Turkish partners and $67 million from the US partners, which was later supplemented by the latter with another $100 million. Lockheed Martin provided three experienced directors for five years and the general manager for 14 years. From the experience gained from building 80 per cent of the F-16 aircraft, TAI began branching out into other areas to include: parts of the transport aircraft CN-235 and A400M; modifications of Boeing 737s into an airborne early warning aircraft; and parts of helicopters Agusta Mangusta T-29 and Sikorsky T-70 Blackhawk. The TAI also developed a modification centre where they upgraded aircraft such as the C-130s, F-4s, T-38s and F-16s. Lockheed Martin claims that the company is now developing indigenously designed unmanned aerial vehicles, basic trainer aircraft and even a T-FX fifth-generation fighter aircraft. Whether these projects will be successful however, will have to be seen.

Interestingly, after 20 years, the Turkish government bought the shares of the US partners and TAI is now wholly held by government entities. Lockheed Martin claims that it remains closely associated with TAI and values its partnership as a major supplier for the next-generation platform.

Lockheed Martin also claims it has had similar success with other countries in the world, such as Belgium, the Netherlands and South Korea. With the latter, it has co-developed the new T-50 and F/A-50 aircraft for the global marketplace and is also helping develop Korea's KF-X next-generation fighter. The contract with the Korean companies is purported to have been a 'strategic alliance' or 'partnership/teaming model' with clearly defined workshare, rather than a JV. The partnership entailed a much higher investment by the Korean companies but included greater freedom, such as a clause allowing the Korean companies to buy out the IPR at a later stage.

Lockheed Martin, it appears, has also helped the Japanese with the development of the F-2 fighter programme. This was a case where the Japanese paid up front for the US firm to impart capabilities of designing, developing and manufacturing their own aircraft – an arrangement which appears to be very rare. Though the amount paid is not known, it is likely to have been exorbitantly high, clearly unaffordable for developing countries.

Though only Lockheed Martin's experience has been described here, there are probably numerous other such success stories in the defence world. Saab, Sweden has recently announced it's ToT project with Brazil for the Gripen fighter aircraft, covering the production, maintenance and development of additional features and a new variant for Brazil.[31] The arrangement appears to be following a similar pattern of first focussing on co-production, then development of customised features and finally veering towards full system development.

From the broad insights received on these JVs CP, it appears that the mode has potential to build the know-hows of manufacturing followed by some amount of know-whys, which are ordinarily not received in the LM mode. From the self-reliance perspective, the initial stages of generally undesired and apprehensively viewed majority control by the foreign partner seem to get well compensated by the long-term benefit of appreciable autonomy through buying off foreign shares or IPR. As for technology competence, partnering with global leaders ensures a respectable level.

The strategic alliance/teaming arrangement for workshare also appears useful especially if some amount of capability already exists within the country, as is the case with India. It is, however, unlikely that foreign partners will be open to eventually assigning/transferring the IPR of their part of the system, though they may be open to licensing them for manufacture. Here too, self-reliance and technology competence appear achievable on similar grounds as that of the JV CP, though the quantum of technology transfer is likely to be much lower.

Encouraging foreign direct investment (FDI) is a common policy used by governments to facilitate technology transfer into JVs with local firms. These JVs could be of the non-equity or equity form. The non-equity form is essentially a strategic alliance where the foreign investor offers the technology whose value makes up part or whole of his investment, while the local partner offers the infrastructure, workforce, management, etc. The foreign investor becomes the technology partner/supplier, while the local firm absorbs it. The technology could be transferred in a number of ways, such as the LM mode or through contract manufacturing/sub-contracting using documents for build to print (B2P), build to design (B2D) or build to specifications (B2S). The FDI and technology can also be channelled in a similar manner into JVs where the equity is shared.

In a B2P contract, the foreign firm provides the technical specifications, engineering documents and manufacturing process documents. The manufacturing process documents would include manufacturing drawings, detailed work instructions/manufacturing practices, quality requirements, detailed specifications of the product at intermediate stages, test methods and acceptance/rejection criteria, while the know-how would cover procedures taught through training sessions and tacit knowledge embodied in the technical consultants of the foreign firm.[32] The local firm executes the task strictly as per the above documents/instructions and using material or parts from sources recommended by the foreign firm. Unfortunately, a few proprietary components of the seller firm are invariably required, thus leading to a dependence. Another disadvantage is that the arrangement provides the know-hows of the manufacture process but not the know-whys. The B2P contracts are usually considered a ToT, so foreign firms need the approval of their government or even international export control agencies, if applicable.

In a B2D contract, the foreign firm provides the technical specifications and engineering documents. The engineering documents cover the drawings, acceptable tolerances, material compositions, surface finish required or, in the case of electronic modules, the circuit diagrams, net list showing connections between all components of printed circuit board (PCB) and Gerber diagram showing layout of components on PCB. The local firm is now required to develop or use its own process to manufacture the part. The advantage here is that an indigenously available manufacturing process technology is being utilised, thereby avoiding the cost of purchasing a licence for a new one or the royalties for using it repeatedly. The product design, however, is considered intellectual property (IP) and royalties will need to be paid for its use.

The B2S contract is, strictly speaking, not a ToT. However, it has been described here because these contracts are invariably combined with B2P and B2D ones to produce the different parts of a system under PToT. The foreign firm provides the specifications which may include the detailed dimensions, acceptable clearances, performance characteristics, reliability, etc., of the product. It is now left to the local firm to design, develop, manufacture and supply the product. For successfully achieving this, the phases of prototyping, user trials, evaluation, etc., may be required and will therefore take considerably more time, effort and money as compared to B2P or B2D.[33] However, since the B2S mode is not a ToT, it doesn't require export permissions of the foreign government or international export control regimes. Also, since the local firm has developed the product on its own, it holds the IP rights and the know-whys, and is therefore free, as well as capable, of exploiting them for producing product upgrades or variants, or for that matter, applying the technology for other purposes.

A prevalent view is that forming of JVs, whether for co-development and/or co-production or for sourcing technology through FDI, is a more complex, risky and time-consuming task than executing LM and is hence recommended only in cases where the complementary capacities, infrastructure, technology or capability available with the partners requires engagement for a longer term.[34] However, when such arrangements fit well with a mutual goal of profitability and acquiring a global market, the results can be extremely rewarding, as can be seen in the case of Lockheed Martin's JV with the TAI.

The level of investment and control of the partners in the running of the JV is a critical issue for foreign technology seller firms. Firms holding proprietary rights over cutting-edge and niche technologies, which have little or no competition in the world, may insist on a wholly owned subsidiary, while those offering a little older technology may be satisfied with a 51 per cent majority share of investment. The majority share enables the foreign firm to keep a tighter control on its technology and thereby prevent it from leaking out to competitors. A foreign firm representative has postulated an interesting rule—where firm and sufficiently high orders are assured by the host government for a period of 20 years, such as that for a strategic partner, a 49 per cent share or less will do. However, where these are not assured, and the firm needs to compete in a global market, a majority share is a must.[35]

Another facilitator that is being pursued in India for the acquisition of technology is 'defence offsets'. Here, a foreign OEM, to whom a large contract for the manufacture and supply of systems has been awarded, is obligated, in return, to use any of six avenues for benefiting India's defence and allied industry. Out of these six, four pertain to technology transfer in their different modes. This is in keeping with the worldwide trend of using offsets as a potential source of ToT.[36] The transfer could be by sub-contracting or PToT, through direct contracts or JVs with private firms (non-equity or equity), or PToT with government agencies and finally, acquisition of critical technologies by Indian DRDO. For enabling the last option (which has not been analysed so far), the DPP provides a list of 20 critical technologies, such as MEMS-based sensors, actuators, radio frequency (RF) devices, focal plane arrays, and nanotechnology-based sensors and displays.

Though the areas of critical technology have been specified, the DPP makes no mention of whether the technology desired is to be provided on licence or permanent assignment, for manufacturing or designing/developing a product or process. Going by inputs of reliable sources, it appears that the intention was and is to acquire the know-whys, in addition to the know-hows, of manufacturing products with that technology. It is also broadly known that though eight proposals under this avenue have been received, none of them have been accepted due to the exorbitant prices quoted, which are to the tune of a hundred times that of the manufacturing technology.[37] It may reasonably be concluded, therefore, that this avenue is not likely to enable useful transfers in the future, unless the DPP offers much higher offset credits for such proposals.

Widening the Scope

So far, we have identified and analysed the conventional forms of technology transfer. But are there possibilities for more avenues—avenues which can provide newer technology thereby enabling the closing of the gap with the advanced countries? Let us widen the ToT umbrella, where 'technology' does not merely cover the knowledge of use/operation, maintenance, repair, overhaul or production (or manufacture) of a defence system, as has been mentioned in numerous sources,[38] but all the knowledge that is generated and transferred in the path to realisation of the defence system.[39] Such a path can be broadly divided into six steps: (1) discovery of a new material or phenomena; (2) development of its application and prototyping; (3) development of the process for manufacturing the part; (4) mass manufacturing of the part; (5) designing systems and integrating the developed parts (and others)into them; and (6) productionising the system. A pictorial view is provided in Figure 1. The figure broadly reflects the environment in the US and most developed Western countries where fundamental research at universities is funded by government, corporates and non-profit organisations. Even though some research in universities and non-profit organisations are government funded, the creators in the universities can control the use of the invention by a one-time payment for a licence and committing themselves to certain conditions.[40] These licences can be used by R&D

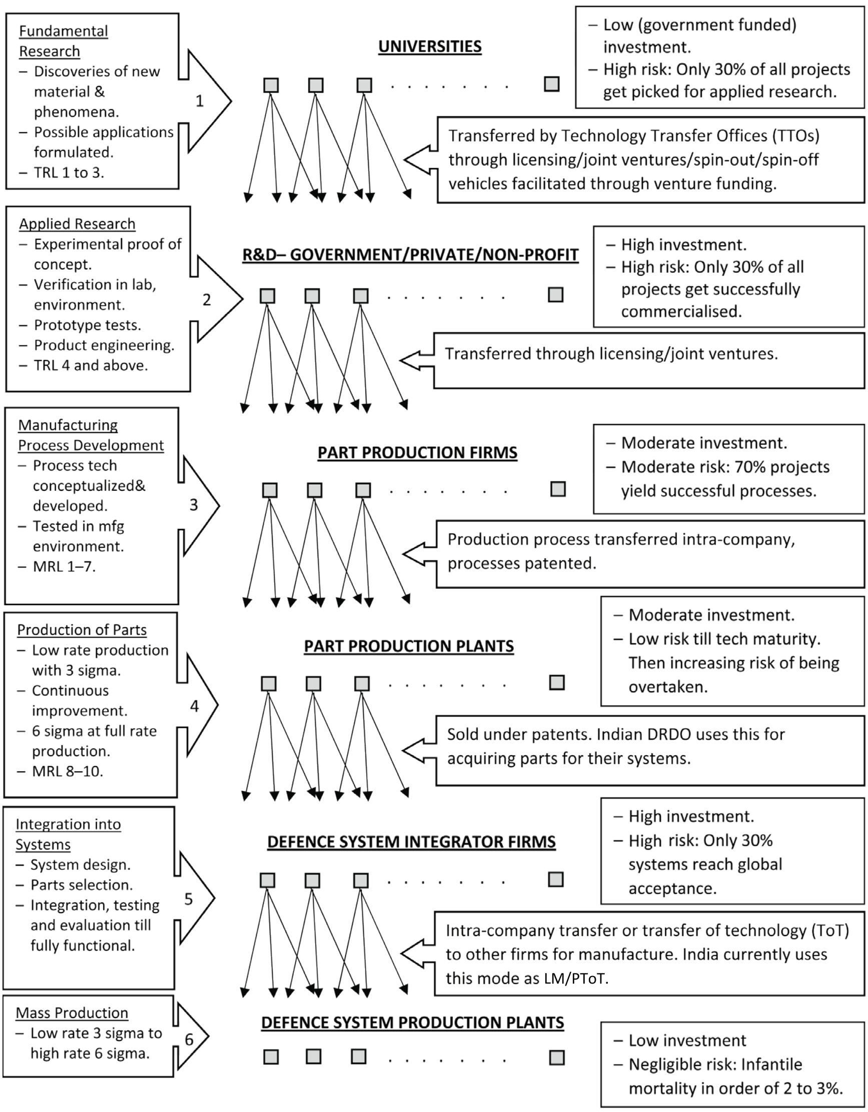

Figure 1 Technology Movement till System Manufacture

Source: Author's perspective

Notes: Figures quoted are broad indications only and not true representations. TRL: technology readiness level; MRL: manufacturing readiness level.

agencies to develop new, useful and non-obvious products which can be patented to prevent imitation and secure monetary returns.

Figure 1 depicts how 'technology' evolves and is vertically transferred downstream from one developer to one or many recipients.[41] Each transfer of new technology invariably comes with patents/licences to prevent imitation as well as to channel back income from royalties to the creators.[42] Some steps may use unpatented, established technology along with new ones to deliver its product.

Each step depicted, less steps 4 and 6, entails the use of know-hows to develop the product of that step, and in the process, learns to 'know why' the product needs to have, say, certain dimensions or compositions of material. To amplify this point, one can see that in step 1, one would need to know 'how' to conduct the research. During the research, an understanding of 'why' the phenomena will work only in certain conditions will develop. In step 2, one would need to know 'how' to develop the technology and design the product. In the process of doing so, it will be learnt 'why' specific dimensions or composition of material are necessary to achieve the performance desired. In step 3, one would need to know 'how' to develop the manufacturing technology, thereby generating know-whys on the processes, settings and specifications of each manufacturing activity. In step 5, one would need to know 'how' to design a system.[43] Thereby an insight into 'why' a particular dimension or composition or configuration is necessary to achieve a performance characteristic will be developed. However, in steps 4 and 6, only a limited amount of know-whys are generated, though these too have their significance, such as those generated while fine-tuning the production process to reduce the incidences of defects to a minimum level such as 6 sigma.

From the figure, it can also be seen that each step involves an investment and an uncertainty of success (or a risk of failure). Some steps, such as step 1, could require low funding (generally government funded) but entail high risk, while step 3 entails moderate funding with moderate risk.[44] In the R&D stage at step 2, due to the need for high investment and the presence of high risk, small and medium enterprises (SMEs) may turn to sharing the incipient technology in a quasi-licensing framework enabled through venture capitalists (VCs), while large corporates may opt for joint R&D through strategic alliances or partnerships.[45] After the R&D stage, when business gains of successful projects start to neutralise development costs, the ownership of the technology could change either to stockholders of an initial public offering (IPO) or one of the partners of a strategic alliance. These owners typically use strong patents to extend the life of the technology and do not share it till competing technologies start eating into its share of the market. Sharing could be either through licensing or participatory exploitation in a JV, especially with firms of developing countries where the technology is still unmatched. The latter option is considered superior due to the greater control of the technology owner and dual income through investments as well as royalties.[46]

At step 3, the development of the mass manufacturing process of a developed and patented part could be executed by intermediary firms or manufacturing firms with process development capabilities. These processes can also be patented to prevent illegal imitation and for obtaining monetary returns. Sometimes development of manufacturing processes can, however, take extremely long and necessitate large investments.

At step 4, production firms obtain a licence for use of the process to manufacture, paying either a fixed amount or a royalty on each product produced. These parts are then sold under legal agreements protecting the patents from violation by copying, reverse engineering, imitation, etc.

A similar framework for the system development exists at step 5 where the process of integrating the system as well as the developed system itself can be patented. At this stage, the integrator firm or OEM can either sell the finished system from its production plant or sell the production technology to other production plants. The latter is the activity we have defined as PToT.

The technology in PToT is clearly a finely finished product, with meticulous documentation for all aspects of integration, testing and quality assurance. When delivered to new firms, it is also invariably supplemented with the technology for operation, maintenance, repair and overhaul (if applicable). The manufacture processes are also matured with many contributory factors for failures being removed over a period of time. Little is left to be worked out by the recipient firm, which can employ technically less knowledgeable, less skilled and therefore cheaper labour. Hence, its suitability for less developed countries. In this arrangement, production can be executed with very little involvement of the transferor and with greater freedom to the recipient. However, in being so, it also holds a higher risk (to the seller) for the technology to be compromised, and is therefore used predominantly for older technology.

Opportunities for India?

Now that we have a broad understanding of the evolution and movement of technology, let us see if we can make use of it in our search for more avenues of ToT. A close look at Figure 1 shows that each step and the transfers after that are actually opportunities available for obtaining technology.

At step 1, cannot India partner with the advanced countries for fundamental research in select fields? True, fundamental research may throw up discoveries or inventions with a wide umbrella of applications from medicine to manufacturing and may not lead to military ones. In such an eventuality, the applications can be used by the respective industry in India. The India–US Science and Technology Forum, which evolved in the year 2000 after many decades of increasing cooperation in the science and technology fields, now has multiple programmes for interaction by students, researchers and entrepreneurs.[47] Such forums exist with other countries too. Can this area of activity not be enhanced to draw more benefits?

After step 1, can DRDO laboratories use transfers of the findings of fundamental research (through licences) to develop products which are patentable? It is very possible that of the competing technologies developed, only some are selected by the foreign government/agencies. Others which hold promise, but will not be utilised, can therefore be procured, possibly at a lower cost. Of course, this may require large investments and entail uncertainties in success. But couldn't this risk be mitigated by distributing the investment in a range of projects? If such transfers cannot be out rightly purchased, can India not fund some of the research projects at step 1 and maybe supplement them with Indian scientists deputed for specific durations for licensing rights? It is known that OEMs such as SAAB, Nexter and Lockheed Martin have sponsored research projects in very niche areas with numerous universities around the world. Then, why can't our DRDO and Indian private giants explore such opportunities in addition to the Indian research that they currently sponsor?

The Indian Department of Science and Technology's Global Innovation and Technology Alliance (GITA) is a potent arrangement where Indian researchers and developers avail opportunities for partnering in research with their counterparts in advanced countries such as the United Kingdom (UK), Canada and Israel.[48] The technologies covered are wide-ranging, from affordable healthcare to smart cities to the Internet of things, MEMS, and strategic electronics in areas such as power and telecommunication. Can similar arrangements not be made for defence or dual-use applications? A step in this direction was taken when the US named India a major defence partner (MDP) and communicated through a joint statement in June 2016: 'India would receive license-free access to a wide range of dual-use technologies in conjunction with steps that India has committed to take to advance its export control objectives'.[49] Cannot the same arrangement be replicated and utilised for obtaining dual-use technology from other advanced countries?

Or cannot scientists of Indian origin who create inventions in foreign universities assert that the benefits of their research be channelled to their parent country? There is a huge population of Indian scientists in the US and European universities who are probably willing to provide such technology to India. Cannot their work be legally harnessed through intergovernmental agreements providing appropriate clauses in research agreements with them?

Step 2 is actually a consolidation of numerous sub-steps where the technology is developed through technology readiness levels (TRLs)4 and above. Cannot Indian R&D agencies step in to take on such projects or at least a portion of the development such as product engineering for which a large Indian pool is available? The joint R&D and technology-sharing agreement with the US initiated as far back as 2006 and the later Defence Trade and Technology Initiative (DTTI) provide such an opportunity for the DRDO.[50] But these are on an extremely small scale. Can such arrangements not be explored in a larger way, and also with other countries? Cannot Indian private giants explore such research arrangements? Again, as in step 1, funding these projects will yield licences for product manufacturing, while co-opting our scientists will provide the know-hows of design and the know-whys of the product.

At step 3, cannot Indian agencies take on the design of the manufacturing process or developing the technology deployed in manufacturing? This step has been reported to provide the highest value addition in the chain.[51] If they are not competent enough as yet, cannot a team of engineers be associated with these projects to gain the know-hows of the development activity and the know-whys of the output? The advanced manufacturing research centres around the world today collaborate with universities, equipment suppliers, manufacturing technology providers, production companies and their supply chains to develop leading manufacturing systems and processes.[52] Cannot some of the DRDO specialists in manufacturing technology join these for improving Indian manufacturing technology and processes?

At step 4, cannot Indian production plants obtain a licence and mass manufacture the products to 6-sigma quality, though this arrangement may be limited to a defined quantity and period? Again, if they cannot, can select engineers not be associated to build capabilities in the field?

At step 5, parts can be purchased under patent protection agreements and integrated into systems. This is an activity which the DRDO, and now the private sector, has been doing for quite some time through JVs for co-development and co-production as covered earlier in this article. However, have the benefits of this arrangement in terms of obtaining world-class know-hows of system design and the know-whys of the developed systems been consolidated? There will always exist a large scope for further capability building in this area. Instead of co-development, can co-opting of brilliant Indian scientists into foreign projects not provide a win-win situation for India and the foreign partner?

All the above options would clearly increase self-reliance since a portion of the development or manufacturing activity is shifted to Indian soil. The latter steps of 5 and 6 are relatively cheaper and easier to achieve especially when a strong base of fundamental and applied research is not available. This is probably the reason why it has been somewhat prevalent in India. For technology leadership, however, it is clear that one would have to move upstream, that is, instead of limiting ourselves to steps 6 and 5, we would need to target the earlier steps. And the higher upstream we go, the higher the possibility of technological superiority, ultimately achieving leadership through pioneering breakthroughs at step 1 or step 2.

It is very likely that many of these options have been attempted by the Ministry of Science and Technology or the DRDO. But if so, what were their outcomes and what were the reasons for their failures? For there are apparently no success stories being reported in the area. These need to be made public, because India's defence industry today includes numerous private giants and over 6,000 micro, small and medium enterprises (MSMEs). All these stand to gain by past experience so as to build ways to tap the development chain of the advanced world.

Unconventional Technology Transfers

With the wider perspective, we realise that all forms of knowledge related to prospective technological products or their evolution can contribute in some way to a country's technological capabilities. The propagation of this knowledge (or technology), which falls outside the conventional forms discussed earlier, can take place through various media and methods. Among these, a significant group of activities come under the category of 'technology diffusion'.

Technology diffusion has been defined as activity which creates an awareness of that technology in the country/region.[53] This could be with or without deliberate intent by the government or the foreign supplier firm. Activity without deliberate intent would include coverage in media such as the Internet, television, newspapers, periodicals, movies and even chat groups. Deliberately intended activities by the foreign supplier firm could be purchase of inputs, components and services from local firms, requiring the latter to become familiar with the technology. Deliberately intended activities by the host government would include training requirements for local personnel or the compulsory licensing of technology to local firms.

Then there are activities which go beyond technology diffusion and are more focused, deliberate and expensive. These, which we can term as 'technology acquaintance', cover foreign visits by selected persons, technical seminars, journals, published papers, study groups, technology monitors/intelligence, trials and most significantly in respect of defence systems, joint exercises with foreign military forces.

Technology diffusion and acquaintance are significant methods to build awareness of the capabilities of different competing technologies. As such, they contribute effectively to selection in the acquisition process and provide a relatively inexpensive and easily accessible means to initiate activity to acquire and incorporate the technology into own systems. However, whether these activities alone can generate enough knowledge to develop new systems is highly questionable. Many young DRDO scientists have stated that the inputs to their work were the papers published in the public domain as well as seminars in India and abroad.[54] However, if this were the case, there would be no need for technology transfers and the effort and cost for executing them.

Another avenue for transfers is the one enabled through 'flight of human capital'. Scientists and engineers defecting or migrating to new countries, the attracting of scientists back to their home country and the export and re-importing of students are the major ones. This form of technology transfer is not new. In the late nineteenth century, a large number of American students were 'exported to' and 're-imported from'

Germany to gain experience in the fast-growing technical fields.[55] A recovering Japan sent its scholars to British universities for obtaining technological experience.[56] China sent large numbers of students abroad after 1978 to gain skills necessary for the country's economic and social development.[57] Then there is the possibility of hiring foreign engineers. Around 2002, the Chinese automotive firm Chery hired the services of an Austrian engineering specialist to transfer the technology of engine design and the know-how to build one. Chery opened its new plant in 2005 with a plan to manufacture 1,50,000 engines to start with. The cost, however, was a huge $370 million, which Chery planned to recover through the economies of scale in the Chinese market.[58]

So, if China can use a foreign engineering specialist and the US and European countries can use Indian scientists for their R&D, what is to stop India using foreign scientists? The exorbitant cost of the background IP (know-hows) that the scientist will bring and that of the IP that he will generate (know-whys and design)is one obstacle.[59] By delivering both these, he, however, terminates his own market value, at least as far as that product is concerned. Hence, though he will deliver the final product, it is unlikely that he will share his complete spectrum of know-hows and know-whys. The second is that it will most probably require the foreign government's approval under its export control regulations. These regulations are invariably in line with the Wassenaar Arrangement (WA) where even the briefing of a foreign visitor is judged as an intangible ToT, requiring an explicit authorisation.[60] And lastly, in today's collaborative R&D environment, it may take not one but many scientists, possibly networked in alliances, to deliver the goods. Notwithstanding these obstacles, intergovernmental agreements can possibly facilitate such 'scientist exchanges' for mutual benefits.

'Acquiring of foreign factories' and design houses by Indian firms have been reported in the recent past, giving the impression that it will automatically transfer technology to India.[61] However, factories or their machines, by themselves, do not provide technology. As mentioned earlier, they need to be accompanied by technical literature as well as the critical know-how which resides as tacit knowledge in the developers and engineers. Both these are considered IP and need to be purchased through legal agreements. Unfortunately, IP can be exorbitantly expensive especially if it pertains to design and development. Also, since governments in countries such as the US fund many of the fundamental research programmes that lead to design and development of products, transfers to foreign persons or agencies are not permitted without authorisation. Employees of these factories who hold the know-how will also need to be sufficiently motivated to transfer it to workers in a foreign country who will eat up their own jobs!

'Special machinery' or 'software' which enable cutting-edge R&D or production do have significant technology transfer gains, especially if they are accompanied with training and technical consultants. China has been known to procure special machines in excess to their requirement for sub-contracts, so as to learn to use them for their development work. How well this strategy worked is not certain, especially since the machine would have required maintenance and product support. Nevertheless, a trained worker from the sub-contract factory would probably be able to make good use of it for duplicating products.

Lastly, there is a category which uses unethical means such as 'illegal imitation', 'reverse engineering' or 'technology espionage'. PToT contracts invariably prohibit reverse engineering and use of the transferred technology for other purposes, for a specified duration of say 15 years.[62] Beyond the period, reverse engineering can be used for bona fide reasons of modifications for local conditions or indigenisation/import substitution of parts nearing obsolescence. The Chinese method of 'indigenous innovation', as covered earlier, provides a quasi-legal arrangement which involves a way to promote original innovation by reassembling existing (foreign) technologies in different ways to produce new breakthroughs.[63] The Dong Feng-21B anti-ship ballistic missile, which the US strategists have dubbed the 'aircraft carrier killer', is one such example where China reportedly rearranged existing technologies to build the system.[64]

Reverse engineering, however, is a little deeper, in that it aims at decoding and replicating the product or system, which is a clear violation of IP laws prevalent in the world. It is also getting more difficult as an increasing proportion of the composition of defence systems is in the form of software, making it well-nigh impossible to reverse engineer through studying and replicating the hardware, as has been the approach in the past. Overall, though there have been a few incidences of successful reverse engineering, a general and substantive opinion of the engineering community, other than the fact that it is illegal and not to be encouraged, is that efforts through these modes cannot be relied on and this strategy is fraught with the risk of alienation from dependable sources and friendly countries. And of course, reverse engineering does not provide know-hows and know-whys and therefore will not enable the development of indigenous innovation, design and development capability.

Technology espionage is undoubtedly illegal, but not unheard of. In the technology acquisition/introduction/pre-concept stage, the Chinese defence science and technology system employs open-source information collection and espionage activities to overcome the restrictions imposed on transfer of defence-related technology due to the various arms control regimes.[65] Technology espionage has also been reported in other parts of the world and was probably even state driven during the Cold War period.[66] In the current age of networking and cyber warfare, continuous attempts are made to hack into the systems of adversaries, with the acquisition of their technology being the significant objective. However, the aim here would possibly be to acquire knowledge on their weaknesses and not the entire design and manufacturing process.

Challenges

The article has covered the numerous avenues of ToT and dwelt a bit on their strengths and weaknesses as well as obstacles that they may face. There are, however, a few challenges of a general nature and relevant to India, which have not been covered so far and need a look.

The US International Traffic in Arms Regulation (ITAR) and similar regulations in other advanced countries place strong controls on the export of technology to other countries. These also are in line with the WA, which is a multilateral export control regulation to which most advanced countries are signatories. The stringent nature of these regulations can be gauged from the fact that even briefings to foreign visitors are to be controlled and specifically authorised under its best practices on intangible transfers of technology.

Since successful technology transfer requires willing and whole-hearted delivery (especially for the component of tacit knowledge residing in the developers) from one party to another in return for commensurate returns, it is imperative that the relationship between the two is initiated and then sustained as a win-win one.[67] Advanced countries will need to trust that Indian scientists, agencies and private firms will abide by agreements to protect their IPR. Unfortunately, India has a dismal rating on IPR protection. In February 2017, India was ranked 43rd out of 45 countries, according to a report by the US Chamber of Commerce's Global Intellectual Property Center (GIPC). The report stated India's key areas of weakness as the National IPR Policy, which does not address fundamental weaknesses in India's IP framework, the limited framework for protection of life sciences IP, and patentability requirements being outside international standards, among others. The GIPC also recently re-emphasised how India would have to build twice the standards required by TRIPS to enable large scale innovation and investment in India.[68] Clearly, a lot needs to be done for India to build the trust and confidence of foreign OEMs that is necessary for successful R&D collaborations as well as for attracting ToT through FDI.

Besides the two above-mentioned major challenges, there are a few others which deserve a thought. One is the work culture of 'jugaad', which encourages quick innovations for short-term and cheap solutions, thereby assigning a lower priority to delivering quality and long-term capability building. An aspect that many of the foreign OEMs have stressed is that long-term relationships deliver better products and help build solid capabilities. Also, foreign OEMs have perfected their work systems and practices over decades to deliver complex weapons such as fighter aircraft and missiles which have a high degree of reliability. The Indian defence industry, on the other hand, is much less developed and will need to assimilate the work cultures of the foreign OEMs to successfully deliver products of world-class standards. How these work cultures can be assimilated, especially by the state-run OFs and DPSUs, is something their leadership will need to deliberate upon.

Yet another challenge is the risk-averse attitude in the Indian government and public sector environment, especially in defence matters. A spate of scandals in defence purchases over the past three decades has taken a toll, leading to a state of almost decision paralysis in the earlier government. The technology development fund initiative of the DRDO to bring the private sector into R&D by funding them has taken over eight years to materialise probably because of the apprehension on how proposals would be selected and the risk involved. Investments in steps 1, 2, 3 and 5, as described in Figure 1, all entail significant risks. How these risks will be absorbed in the Indian defence system of accounting, which is founded on 'making every rupee pay', is a question which will need to be answered by the top leadership in the Finance Ministry. Fortunately, the current political leadership has been encouraging risk-taking of late, and a way ahead might soon appear.

And finally, there is the challenge of the quantum of investment needed. Being the largest buyer of defence equipment in the world, in a buyer's market, may enable the leveraging of orders for benefits upto 10–20 per cent of their value. But the investment needed for pursuing many of the avenues listed in this article will exceed this value many times over. Building up a strong and sound business case will hence be required, and it may be worthwhile employing the most competent, experienced and dependable agencies for this. These too may not be available in India and there may be no recourse but to turn to those abroad for this vital task.

Conclusion

Along with the conventional modes and the potential technology transfer opportunities, there exist numerous other unconventional avenues to gain technology or useful knowledge related to and required for the evolution of a technological product. Every avenue varies in focus, depth of application, effectiveness, investment, and the risk involved, and each also pertains to different steps in the path to evolution of the defence system. An aligning of the different modes with each step is attempted in Table 1. An additional step has been added to those in Figure 1, indicating the exploitation of the system and its technology. This step is home to many lighter, unconventional forms which precede serious ToT activity.

Current efforts in the Indian defence technology environment essentially focus on the latter steps, with the production agencies using PToT at step 6 and the DRDO targeting systems design and integration at step 5. The DRDO's valid emphasis on acquiring the know-whys[69] of

Table 1 Step-wise Categorisation of Different Modes/Avenues of ToT

Step	*Technology Transfer Modes and Avenues*	
	Modes and Avenues Available in the Step	*Opportunities for Acquisition After Step*
1. Fundamental Research: Wide focus, low investment, high risk.	Sponsored research, co-research, collaboration in international research networks, sponsored Indian student and researchers, hiring of foreign scientists.	Import of fundamental research output.
2. Applied Research: More focused, high investment, high risk.	Co-development, sponsored Indian scientists, hiring of foreign scientists, import of special machinery for R&D, sub-contracting (B2S).	Import of product designs.

Step	*Technology Transfer Modes and Avenues*	
	Modes and Avenues Available in the Step	*Opportunities for Acquisition After Step*
3. Development of Manufacturing Process: Focused, moderate investment, moderate risk.	Co-development of process, hiring of foreign engineers, turnkey projects by foreign firms for building of an industrial plant and transfer of process technology, sub-contracting (B2D).	Import of process technology.
4. Mass Production of Parts: Focused, moderate investment, low risk.	Sub-contracting (B2P), training on production and maintenance, co-production, technical collaboration in production, acquisition of factories,import of special machinery for production and testing.	Import of parts.
5. Integration into systems: Moderate focus, high investment, high risk.	JVs for co-development of systems, hiring of foreign scientists/engineers through consultancy, outright purchase of design and development capability.	Import of system designs.
6. Mass Production of Systems: Focused, low investment, negligible risk.	Licensed production, Licensed manufacture (foreign aided/G2G/P2S/P2P), JVs for co-production, strategic alliance/teaming for co-production/workshare, use of foreign technicians for guiding production, acquisition of factories/special machinery.	Import of systems.
7. Exploitation of Systems.	Use of foreign engineering consultancy for sourcing, outright purchase of defence systems, their use and maintenance, technology diffusion, technology acquaintance.	

Source: Author's perspective.

design instead of just know-hows of production, from foreign technology sellers, is an effort to move upstream into step 5. Such an acquisition of know-whys will indeed serve to build more self-reliance through design and development of indigenous systems. However, pursuing the design know-whys of step 6 PToT delivered systems is akin to 'tail chasing', with India forever trying to catch up but inevitably staying a generation or two behind the leaders.[70]

If India desires to achieve technology leadership, or at least technology competence, it needs to move upstream and build world-class capabilities in the earlier steps of technology evolution. If indigenous efforts to build such capabilities are not fruitful, then avenues to import it could be explored. This import is not a simple purchase from a seller. Neither is it free of risks. It can only be achieved through painstaking effort and meticulous planning over a considerable period of 10–20 years, maybe more. To reduce the risks, specific fields of technology could be targeted where India possesses some indigenous resources and is placed at an advantageous or at least even footing with others. And finally, investments in these areas will need to exceed the 'critical mass' necessary to bring results.

Notes

1. Ron Matthews, *Defence Production in India*, New Delhi: ABC Publishing House, 1989, pp. 35–37. Also see Laxman Kumar Behera, *Indian Defence Industry: Issues of Self Reliance*, New Delhi: Institute for Defence Studies and Analysis (IDSA), 2013, pp. 9–21.
2. Though the word 'licence' may not have been used in the contracts, the number of systems which were to be produced under each contract was specified. The work was executed as per typical licensed production programmes.
3. See Ministry of Defence, Government of India, 'Defence Procurement Procedure 2008', 29 July 2008, p. 67, available at http://mod.nic.in/dod/sites/default/files/DPP2008.pdf, last accessed on 5 July 2017 where the phrase 'licensed production under ToT' is used.
4. See the Ministry of Defence, Government of India, 'Defence Procurement Procedure 2016', p. 128, available at http://www.mod.nic.in/defence-procurement-procedure, last accessed on 5 July 2017, the framework described as ToT resembles that of LM.
5. K.A. Desouza, 'Transfer of Defence Technology to India: Prevalence, Significance and Insights', *Journal of Defence Studies*, October 2016, available at http://www.idsa.in/jds/jds_10_4_2016_transfer-of-defence-technology-

to-india, last accessed on 5 July 2017. The article describes know-hows and know-whys and postulates reasons why know-whys are never provided. Also, in a discussion with a senior official of the Indian Defence Research and Development Organization (DRDO), it was revealed that foreign firms charge huge, unaffordable amounts for the know-whys.

6. Ibid. The term PToT was introduced in this article to signify that it delivers only manufacture or production technology.
7. See Ministry of Defence, Government of India, 'Defence Production Policy 2011', 1 January 2011, p. 2, para 2, available as http://mod.nic.in/sites/default/files/DPP-POL.pdf, last accessed on 5 July 2017.
8. See K.A. Desouza, 'Examining the Case for Complete Transfer of Technology', 21 March 2017, available at http://idsa.in/idsacomments/examining-the-case-for-complete-transfer-of-technology_kadesouza_210317, last accessed on 5 July 2017. Here, the complexity of ToT has been detailed; especially see note 5 on high cost.
9. Matthews, *Defence Production in India*, n. 1, p. 17.
10. See Ajai Shukla, 'Indigenisation: A False Debate', *Business Standard*, 10 September 2013, available at http://www.business-standard.com/article/economy-policy/indigenisation-a-false-debate-113091001027_1.html, last accessed on 5 July 2017.
11. Many foreign parts use raw material which is unavailable in India. Even import substitution needs some amount of the unavailable know-whys to understand which specifications/tolerances are important and cannot be compromised (OF board senior officer, 15 July 2016). The lack of these leads to expensive reverse engineering efforts which are not entirely successful in delivering quality products.
12. Laxman Kumar Behera, *Indian Defence Industry: An Agenda for Making in India*, New Delhi: IDSA, 2016, pp. 46, 59, 72.
13. Standing Committee on Defence 2006–07 (14th Lok Sabha), 'Defence Research and Development Organisation (DRDO)', New Delhi: Lok Sabha Secretariat, 2007, p. 3.
14. Ajai Shukla, 'Indigenisation: A False Debate', n. 10.
15. Obsolescence is the latter stage of a component's life when no new replacements are likely to be received due to the phasing out of its production.
16. K. Subrahmanyam, 'Self-reliant Defence and Indian Industry', 2 October 2000, available at http://www.idsaindia.org/an-oct-00-2.html, accessed on 1 October 2016.
17. In the Indian military services, lifetime buys of spares are executed with the foreign original equipment manufacturer (OEM) when his production plant is within two years of closing down.

18. See techniques used by software Opus10, developed by Systecon, Sweden, and VMetric, developed by TFD Group, the United States (US), which can be viewed on the websites of the developing firms: www.systecon.se/defense/our-tools and www.tfdg.com/products/so.html. These depend on acurate prediction of reliability, which, in turn, requires stringent procedures during design, development and manufacturing, and these are slowly being adopted by the Indian defence industry.
19. Available at http://www.airforce-technology.com/projects/gripen-e-multirole-fighter-aircraft/, last accessed on 5 July 2017.
20. Available at https://www.f35.com/global, last accessed on 5 July 2017.
21. Technology leadership in select areas is aspired for by many countries, including South Korea and China. As mentioned by an established defence economist, in the early 2000s, Britain chose such a goal for achieving strategic assurance/influence.
22. See Ministry of Defence, Government of India, 'Defence Production Policy 2011', n. 7, p. 2, para 5, where addressing of issues impacting the competitiveness of Indian firms with foreign ones is mentioned. Also see DPP 2016, p. 63, where it states that the offset policy aims at fostering the development of internationally competitive enterprises.
23. Ranjit Ghosh, *Indigenisation: Key to Self-sufficiency and Strategic Capability,* Monograph, New Delhi: IDSA, pp. 46, 48, 51, 53, 61, 65, 70, 72, 78.
24. Nalin Jain, Chief Executive Officer (CEO) General Electric (GE), in an interview by *Defence and Technology magazine*, published in their January–February 2014 edition, p. 19. The proportion of technology contributed may not necessarily have to be equal.
25. Available at https://en.wikipedia.org/wiki/BrahMos, last accessed on 5 July 2017.
26. Available at https://en.wikipedia.org/wiki/Barak_8, last accessed on 5 July 2017.
27. Available at http://www.indiandefensenews.in/2016/06/barak-8-lrsam-israel-and-india-fight.html, accessed on 8 March 2017.
28. Available at https://en.wikipedia.org/wiki/Technology_life_cycle, last accessed on 5 July 2017.
29. S.P. Ravindran, 'Technology Inflows: Issues, Challenges and Methodology', *Journal of Defence Studies*, Vol. 3, No. 1, January 2009, p. 136.
30. Information received during presentation by Lockheed Martin representatives in IDSA on 19 May 2017.
31. See http://www.brazilmonitor.com/index.php/2017/04/09/to-brazil-transfer-of-technology-is-a-key-issue-of-saab-gripen-fighter/, last accessed on 15 June 2017.

32. Ravindran, 'Technology Inflows: Issues, Challenges and Methodology', n. 29, p. 137. Also refer http://www.elitetecheng.com/blog/build-to-print-vs-build-to-specification/ last accessed on 15 May 2015.
33. Ibid.
34. See Mrinal Suman, 'Handbook for JVs', *Force*, October 2012, available at http://www.forceindia.net/dpp_Handbook_For_JVs.aspx, last accessed on 5 July 2017.
35. As presented by a Swedish firm representative in a seminar on Indo-Swedish defence cooperation on August 31, 2016.
36. As mentioned by a well-established, foreign defence economist in IDSA in December 2016.
37. As obtained from an interview with a senior DRDO official.
38. Desouza, 'Transfer of Defence Technology to India: Prevalence, Significance and Insights', n. 5, lists out definitions of ToT from various sources, all converging to the delivering of the knowledge of operation, maintenance and production of a product or service.
39. 'Technology' is closely related to 'knowledge transfer', as mentioned in https://en.wikipedia.org/wiki/Technology_transfer, last accessed on 5 July 2017.
40. Available at https://en.wikipedia.org/wiki/Bayh%E2%80%93Dole_Act, last accessed on 5 July 2017.
41. See descriptions of vertical and horizontal transfer at https://en.wikipedia.org/wiki/Technology_transfer last accessed on 5 July 2017.
42. See University of Rochester, UR Ventures, 'What are Technology Transfers?', available at http://www.rochester.edu/ventures/about/what-is-technology-transfer/, last accessed on 5 July 2017.
43. Former DRDO Chief, V.K. Saraswat, in an interview by *Defence and Technology*, published in their November–December 2013 issue, p. 26 speaks of the need for know-hows for designing.
44. See https://en.wikipedia.org/wiki/Technology_transfer, last accessed on 5 July 2017.
45. See licensing options in https://en.wikipedia.org/wiki/Technology_life_cycle, last accessed on 5 July 2017.
46. See ibid.
47. See India–US Science and Technology Forum, *Annual Report 2013–14*, available at http://www.iusstf.org/cms/gall_content/2015/3/2015_3$PDF131_Mar_2015_112522687.pdf, last accessed on 6 July 2017.
48. See GITA's website: https://www.gita.org.in/, last accessed on 5 July 2017.
49. 'US Names India as a "Major Defence partner"', *The Wire*, 8 June 2016,

available at https://thewire.in/41534/us-names-india-as-a-major-defence-partner/, last accessed on 5 July 2017.

50. 'Defence Trade and Technology Initiative: India, US Agree on 2 New "Pathfinder" Projects', *The Economic Times*, 12 April 2016, available at http://economictimes.indiatimes.com/news/defence/defence-trade-and-technology-initiative-india-us-agree-on-2-new-pathfinder-projects/articleshow/51800651.cms, last accessed on 5 July 2017.
51. 'Design as Integral Part of Make in India', *The Economic Times*, 17 January 2017, available at http://blogs.economictimes.indiatimes.com/et-editorials/hi-tech-design-must-be-an-integral-part-of-make-in-india/, last accessed on 15 May 2017.
52. Ric Parker, 'From the Trent XWB…, to Composite Titanium Fanblades', *Defence and Technology*, Vol. XIII, No. 99, January–February 2014, Gravitas Publishers, p. 13.
53. United Nations, *Transfer of Technology*, New York and Geneva: United Nations, 2001, p. 7.
54. As obtained by the author during seminars and interactions.
55. Committee on Science, Engineering, and Public Policy, *Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States (2005)*, National Academies Press, pp. 92–93, available at https://www.nap.edu, last accessed on 5 July 2017.
56. From an established defence economist.
57. Committee on Science, Engineering, and Public Policy, *Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States (2005)*, n. 55.
58. James Kynge, *China Shakes the World: The Rise of a Hungry Nation*, UK: Hachette, 30 December 2010, p. 81.
59. Background IP is defined at https://en.wikipedia.org/wiki/Background,_foreground,_sideground_and_postground_intellectual_property, last accessed on 5 July 2017.
60. Available at http://www.wassenaar.org/wp-content/uploads/2015/06/ITT_Best_Practices_for_public_statement_2006.pdf, last accessed on 5 July 2017.
61. For example, the Kalyani Group acquired the Ruag factory in Switzerland and Mahindra Aerospace bought majority stake in the general aircraft manufacturer, Gippsland Aeronautics, in Australia. See 'Bharat Forge Offers Local Solution to Armys Needs', *The Financial Express*, 10 December 2013, available at http://www.financialexpress.com/archive/bharat-forge-offers-local-solution-to-armys-needs/1205541/; and 'Mahindra buys Major Stake in Australian Firms', *The Hindu*, 16 December 2009, available at http://

www.thehindu.com/business/companies/Mahindra-buys-major-stake-in-Australian-firms/article16853553.ece, respectively, both last accessed on 5 July 2017.

62. Desouza, 'Transfer of Defence Technology to India: Prevalence, Significance and Insights', n. 5, pp. 45, 46.
63. Ghosh, *Indigenisation: Key to Self-sufficiency and Strategic Capability*, n. 22, p. 78.
64. Shukla, 'Indigenisation: A False Debate', n. 10.
65. Ghosh, *Indigenisation: Key to Self-sufficiency and Strategic Capability*, n. 22, p. 78.
66. See Amit Gupta, *Building an Arsenal – The Evolution of Regional Power Force Structures*, Praeger Publishers, 1997, p. 19, where he writes of Israel stealing the blueprints of Mirage III from Switzerland and reverse-engineered them to make the Kfir.
67. See European Parliament, 'Dual Use Export Control', 2015, p. 31, available at http://www.europarl.europa.eu/RegData/etudes/STUD/2015/535000/EXPO_STU(2015)535000_EN.pdf, last accessed on 5 July 2017, where it mentions that the key barrier to indigenous production of controlled goods is often tacit knowledge.
68. See http://blogs.timesofindia.indiatimes.com/cash-flow/india-is-trips-compliant-our-response-is-who-cares-this-government-has-not-been-as-ambitious-as-we-hoped/, last accessed on 5 July 2017.
69. Interview of former DRDO Chief, V.K. Saraswat, n. 43, p. 25.
70. The very appropriate phrase 'tail chasing' is courtesy Commodore Sujeet Samaddar (Retd.) who was one of the external discussants in the seminar in which this article was presented.