Chapter VI

ASSESSMENT OF PROGRESS IN PROJECT EXECUTION

The assessment in this chapter will be carried out against the yardstick of the objectives of military research and development (R&D), as set out in Chapter Two. The first yardstick is the extent to which the projects have reduced India’s vulnerability in the security field. This objective is achieved by placing at the disposal of the armed forces weapon systems, equipment and technologies which have been or are going to be acquired or developed by countries which pose a threat to India’s security. Here time is of essence. If there is an undue delay in acquiring the relevant weapon systems, equipment and technologies, the country’s vulnerability gets accentuated. Unfortunately, as described in chapter four, there has been undue delay in the execution of all the three projects under study.

To be able to complete a project within the projected time-frame and deliver the weapon system or equipment for production is an important aspect of security in that it caters to the re-equipment plans of the services. If the project is not completed on time the concerned service has to look for alternatives. The Defence Research and Development Organisation (DRDO) has not been able to complete the projects and deliver the weapon system or equipment for production within the envisaged time, except in the case of the Prithvi missile system.

The Arjun MBT project was initiated to replace the Vajayanta tanks, whose performance in the 1971 India-Pakistan war not satisfactory. The Vajayanta continues to be in service. The Arjun MBT has not been able to meet the re-
equipment plans of the army. The Arjun should have entered service in 1984. The failure of the Arjun to enter service has upset the re-equipment plans of the army. Realising that the Arjun project was nowhere near completion, India signed an agreement with the erstwhile Soviet Union, in 1980, for the outright purchase of 500 T-72 MBTs and their subsequent manufacture under license. Recently proposals have been made for the procurement of T-90s, but the Defence Ministry is reluctant to grant approval.

The air force pinned its hopes on the Light Combat Aircraft (LCA) to replace the MiG series aircraft. As the LCA project is yet to be completed and the aircraft yet to be delivered for production, the air force is currently undertaking the modernisation of the MiG-21 bis aircraft, to be followed by the modernisation of the MiG-27 aircraft.

The Nag anti-tank guided missile (ATGM) has not yet been delivered for production. It was reported during the last week of December 1992 that an Indian defence delegation discussed with a visiting French delegation the prospects for renewing the contract to produce indigenously under license the Milan anti-tank missiles\(^1\). Later, in its Annual Report the Ministry of Defence has stated that it stepped up the production of Milan ATGMs\(^2\). While the DRDO is yet to deliver the latest generation Nag the government has stepped up the production of the earlier generation Milan ATGM. The Akash and Trishul Surface-to-Air Missiles (SAMs) are yet to be cleared for production. Presently a number of older generation SAMs are being employed.

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1. *The Hindu* (Madras), 31 December 1992, cited in Strategic Digest (New Delhi), Vol. 23, no. 3, March 1993, p. 506. The French delegation was led by Defence Minister Pierre Joxe while the Indian delegation was headed by Defence Minister Sharad Pawar and included the Defence Secretary, Secretary Defence Production and Abdul Kalam, Secretary Defence Research and Development.

6.1 REASONS FOR DELAY

The reasons for the delay in completing the defence R&D projects can be put broadly under three categories—financial constraints including poor budgeting of the projects, inefficient management of the projects and technology complications.

6.1.1 Financial Constraints

For sometime, both the Arjun MBT project and the LCA project encountered financial constraints. The LCA project faced financial constraints at the time that the Full Scale Engineering and Development (FSED) phase of the project commenced. Kalam’s predecessor was annoyed at this sorry state of affairs and said, in 1992, "The LCA project has been suffering terribly because of lack of funds. But we are still continuing with the project". When the project was in dire need of finance it was not funded. On the other hand, when money was available it was not made use of. This had, in fact, happened when the feasibility study for the LCA was being prepared. The Comptroller and Auditor General of India pointed out that “financial management [was] inadequate contributing to under-utilisation of funds”.

In the Arjun MBT project, the main reason for non-availability of funds at the earlier stage and exaggerated cost-overruns has been the practice of deliberately

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3 See the interview with V. S. Arunachalam, in The Hindu, 5 August 1992. The interview was held a few days after Arunachalam laid down office to proceed to the U. S. on a sabbatical. Replying to a question whether the LCA was suffering due to lack funds, Arunachalam said, “You had to see it to believe it”. A similar opinion was expressed by the present Director General of the DRDO, Abdul Kalam. Kalam informed the Standing Committee on Defence that the severe financial crisis faced during 1989-92 impeded the immediate commencement of FSED. See Standing Committee on Defence(1995-96), Fifth Report, Tenth Lok Sabha, Ministry of Defence, Defence Research and Development—Major Projects[New Delhi, 1995], p. 17.

underestimating the cost of the project in the beginning. Overtaken by an eagerness to indigenously design and develop a main battle tank and apprehending that the project would not be sanctioned if the cost of the project was high, the DRDO deliberately under-evaluated the project cost. In the words of a former Director General of the DRDO, for the Arjun project, "...[t]he amount we asked for (financial support) was trivially low. My sympathies are, however, with the scientists. In their eagerness to develop a tank indigenously they totally lost credibility with... time frames."5

The DRDO has not been able to run defence R&D projects within the budget allotted for a project. The allotment itself is based on the estimates provided by the DRDO. This implies that the DRDO has not been able to effectively visualise the amount that would be required for implementing defence R&D projects. While giving evidence to the Standing Committee on Defence, the Director General of DRDO said, in the context of the LCA project, "After technology upgradation, we went for full estimation and now we can estimate the overall cost better than previously."6 The Director General seems to be admitting that the DRDO is even now not in a position to make a precise estimate of the funds required for running a project, and it can be expected that the DRDO would seek additional funds for the LCA.

The DRDO has already invested or earmarked a total of Rs. 2898.61cr. for the development of the Integrated Guided Missile Development Programme (IGMDP), LCA and Arjun MBT. The details of the cost of these projects have been tabulated in table 6.1 below.

5 See the interview with V. S. Arunachalam, n. 3.

Table 6.1: Cost of IGMDP, LCA, Arjun Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Total cost (Rs. cr.)</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGMDP</td>
<td>388.83</td>
<td>13.41</td>
</tr>
<tr>
<td>LCA</td>
<td>2,188.00</td>
<td>75.48</td>
</tr>
<tr>
<td>Arjun</td>
<td>321.78</td>
<td>11.10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,898.61</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>


On comparison (see figure 6.1 below) it is noticed that the major portion of the investment is on the LCA project, which accounts for 75.48 per cent of the total investment on these three projects. The *Arjun* MBT project accounts for 11.1 per cent—incidentally the least—of the cost, while the IGMDP accounts for 13.41 per cent.

Figure 6.1: Comparative cost of IGMDP, LCA, Arjun Projects

![Pie chart showing the percentage costs of IGMDP, LCA, and Arjun projects](chart.png)

The cost of the *Arjun* project rose by nearly 21 times. The project was initially sanctioned at a cost of Rs. 15.5 cr. The cost estimate of the project after the second revision was Rs. 280.8 cr. Expenditure on the *Arjun* project has crossed even the second revised estimate. As of now, Rs. 322.78 cr. have already been spent on the project. At the time of commencing the project in 1974, it was estimated that the
foreign exchange (F. E.) component would be Rs. 3.7 cr. However, consequent to the second revision undertaken in May 1987 it was estimated that the F. E. component would be to the tune of Rs. 102.32 cr.—a whooping 27.65 times more than the original estimate. The estimated foreign exchange component as of now is Rs. 113.82 cr.

Table 6. 2: Cost Escalation of Arjun Project

<table>
<thead>
<tr>
<th></th>
<th>Original Cost</th>
<th>Revised Cost</th>
<th>Final Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total F.E. Component</td>
<td>Total F.E. Component</td>
<td>Total F.E. Component</td>
</tr>
<tr>
<td></td>
<td>15.50</td>
<td>3.70</td>
<td>56.55</td>
</tr>
<tr>
<td></td>
<td>12.96</td>
<td>322.78</td>
<td>113.82</td>
</tr>
</tbody>
</table>


As has already been stated, the amount sanctioned for the MBT project after revision in cost was 280.8 crores. The improvements suggested by the army were carried out after the project has been officially declared as concluded. By the time the project was declared as having been completed, the DRDO exhausted the amount sanctioned for the project. “The MBT project was closed... apparently to bring the cost of the project within the ambit of the sanctioned amount... in order to comply with... the recommendations of the PAC (Public Accounts Committee)”\(^7\). In its report, the PAC stated that “... a very strict watch should be kept by the Ministry to ensure that the expenditure is contained within the sanctioned estimate of Rs. 280.89 crores”\(^8\).

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In order to carry out improvements and for product support, two separate projects totalling Rs. 41.98 crores were sanctioned, which involved a foreign exchange component of Rs. 11.5 crores\(^9\). As has been already stated, the amount spent would come to Rs. 322.78 crores, including a foreign exchange component of Rs. 113.82 crores.

The DRDO had to resort to means other than approaching the Cabinet Committee on Political Affairs (CCPA) to secure the funds needed for carrying out improvements. The amount was provided from the budget of the Ordnance Factories.

The IGMDP began with an initial sanction of Rs. 388.83 cr., in 1983. When the cost–estimate was reviewed in June 1995 it was estimated that an additional Rs. 395.77 cr. would be required to complete the project. Thus, it is noticed that the cost of the project doubled from the initial estimate. The F. E. component increased by Rs. 137.1 cr.

<table>
<thead>
<tr>
<th>Original Cost (Rs. cr.)</th>
<th>Revised Cost (Rs. cr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>F. E. Component</td>
</tr>
<tr>
<td>388.83</td>
<td>154.07</td>
</tr>
<tr>
<td>Total</td>
<td>F. E. Component</td>
</tr>
<tr>
<td>784.06</td>
<td>291.17</td>
</tr>
</tbody>
</table>


The LCA project was begun with an initial estimate of Rs. 560 cr. Upon a revision of the cost estimation undertaken in June 1993, it was estimated that the total cost of the project would stand at Rs. 2,188 cr. Thus, it is noticed that the cost of the project doubled.

\(^9\) *CAG Report, Design and Development of main battle tank ARJUN*, n. 7, para 26.13.2
increased by almost four times (as can be seen from table 6.4 below). It was clear even before the project commenced that a significant amount of foreign exchange would be needed for running the project. But, unfortunately, there is a lack of information on this aspect. However, what is known is that after the June 1993 revision it was estimated that a sum of Rs. 873 cr. would constitute the F. E. component of the project cost.

**Table 6.4: Cost Escalation in LCA project**

<table>
<thead>
<tr>
<th>Original Cost (Rs. cr.)</th>
<th>Revised Cost (Rs. cr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>F.E. Component</td>
</tr>
<tr>
<td>560.0</td>
<td>n. a.</td>
</tr>
</tbody>
</table>

Source: Same as in table 6.3

Thus, from table 6.5 below, it can be noticed that while the cost of the IGMMDP doubled, the cost of the LCA project increased by four times and that of the *Arjun* project shot by twenty one times. This leads one to wonder whether the job of drawing up the cost-estimates of projects was carried out seriously.

The more a project gets delayed the more the cost of the project rises, especially for two reasons—one, when the F. E. component is involved the exchange rate varies and two, because of inflation. Also, as already pointed out, in its eagerness to indigenously design and develop weapon systems, the DRDO deliberately under-estimates the cost of a project, lest the government would not sanction one. Once the project is launched the DRDO begins to make fresh claims for more financial allocations, which may not be forthcoming. In the absence of funding, the project is

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10 These two reasons have been cited by the DRDO itself. Standing Committee on Defence(1995-96), *Fifth Report*, n. 3, p. 12.
delayed. Ultimately, the DRDO fails to keep its promise of delivering an equipment or a weapon system within the timeframe that it originally promised, thus seriously questioning the credibility of the DRDO. This is what seems to have happened in the case of the Arjun project.

Table 6. 5: Consolidated Table of Project Cost Escalation

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arjun</td>
<td>15.5</td>
<td>3.7</td>
<td>56.55</td>
<td>12.96</td>
<td>322.78</td>
<td>102.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(20.82)</td>
<td></td>
<td>(27.65)</td>
</tr>
<tr>
<td>IGMDP</td>
<td>388.83</td>
<td>154.07</td>
<td>784.06</td>
<td>291.17</td>
<td>784.06</td>
<td>291.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.02)</td>
<td></td>
<td>(1.89)</td>
</tr>
<tr>
<td>LCA</td>
<td>560</td>
<td>n. a.</td>
<td>2188</td>
<td>873</td>
<td>2188</td>
<td>873</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(3.91)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. O. C. = Original Total Cost; O. F. E. = Original Foreign Exchange Component; R. C. = Revised Total Cost; R. F. E. = Revised Foreign Exchange Component; F. C. = Final Total Cost; F. F. E. = Final Foreign Exchange Component.

2. All figures in Rupees Crores.

Figures in parenthesis refer to the escalation in final costs represented as the no. of times of the original cost.

Source: Compiled on the basis of Tables 6.2, 6.3 and 6.4 above

6.1.2 Project Management

Another reason for delay and consequent cost overruns has been the poor management of the projects. Arjun project was inadequately monitored for a very long period of time. The monitoring committees did not meet even for the mandatory number of times. Thus, in the absence of an effective monitoring mechanism the project lacked guidance and simply frittered away for a long time.
Preceding the sanctioning of the project, a 'high level working group' and a 'steering committee' were formed\textsuperscript{11}. The 'working group' was expected\textsuperscript{12}:

i. to progress the development of the [\textit{Arjun project}] in a coordinated manner

ii. to meet once [in every three months] or earlier if necessary; and

iii. to submit a progress report once in six months to [the] Steering Committee so as to bring such matter to its notice where... help and guidance was necessary.

It was, however, discovered in 1989 by the PAC that the 'working group met only 14 times, though it should have conducted at least 60 meetings between 1974 and 1989; the 'steering committee—which was formed to supervise the 'working group'—met 17 times, though it should have held 30 meetings, once every six months\textsuperscript{13}.

The LCA project ran into rough weather quite early on the issue of complex interface management problems between a number of expert establishments\textsuperscript{14}. "The Ministry [of Defence] stated that due to the complicated nature of the task, the matter (of establishing the Aeronautical Development Agency [ADA] ) was under the consideration of a committee of secretaries, whose deliberations took some time\textsuperscript{15}.

The LCA project suffered due to the inability to speedily establish a suitable management structure for running the project. It is, indeed, unfortunate that the project was first sanctioned and the mechanism to run the project was decided upon later. In contrast, the monitoring mechanism for the \textit{Arjun} project was decided almost a year in advance, though its functioning left a lot to be desired.

\textsuperscript{11} These were formed in April 1973. The \textit{Arjun} project was sanctioned in 1974.
\textsuperscript{13} Ibid.
\textsuperscript{14} See the reply by the then Minister of state for Defence, Raja Ramanna in the Rajya Sabha. India, \textit{Parliamentary Debates, Rajya Sabha, Official Report}(henceforth \textit{RSD}), Monsoon Session, 1990, Question No. 269.
\textsuperscript{15} CAG Report, Aeronautical Development Agency, \textit{Light Combat Aircraft Project}, n. 4, para 50.07.
The LCA did not have a whole-time project director for a very long time. The Director General of the DRDO officiated as the project director. This had to some extent had a negative impact on the progress of the project\textsuperscript{16}.

6.1.3 Technology Complications

The following are the various technology related problems that have delayed the progress of Arjun, the LCA and the IGMDP.

The scope of the Arjun project was altered while the project was in progress. This was not envisaged at the commencement of the project. This caused delay in the completion of the project.

Stating the reasons for the delay in the completion of the Arjun project, the then Defence Minister, Sharad Pawar, informed the Rajya Sabha that a combination of factors held up its early completion. They are\textsuperscript{17}:

i. Change in qualitative requirements (QR);
ii. Requirement of additional prototypes,
iii. Additional requirement of pre-production series (PPS) tanks; and
iv. More realistic assessment of technical and user trials.

A number of features of the tank had to be modified as a result of developments in tank technology and the experience gained during technical evaluation and user trials. While improvements of the features of the tank was in progress, the more the project was delayed the more rapidly were changes in technology taking shape. The demand

\textsuperscript{16} In its report the CAG refused to believe that the absence of a whole-time director did not have any adverse impact on the project. See \textit{Ibid.}, para 50.03.


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for enhanced firepower, mobility and protection—the three most important features of a tank—grew, necessitating alterations to the General Staff Qualitative Requirements (GSQR), whereby the Army demanded "a state-of-the-art tank, designed to take care of threats of 2000 and beyond"\(^{18}\). As protection, i.e., armour strength grew, the capability of the ammunition to defeat enemy armour had to be improved. To enhance the protection of the tank from contemporary tank ammunition, the armour had to be improved. The composite *Kanchan* armour was finally developed. Thus, improving every important feature of the tank became extremely vital, so as to ensure the overall reliability of the tank. While improvements of one feature were being validated another had to be improved.

The first prototype of the tank was subjected to user trials in 1983. Between 1983 and 1986, four prototypes of the tank were handed over to the Army for trials. Then, an additional six prototypes had to be developed and committed to trials. The initial plan was for testing 12 PPS tanks. Even after this, it was felt that additional number of PPS tanks, which included the modifications suggested by the Army, had to be tested, though the approval for the acceptance of *Arjun* was given. Finally, a total of 42 PPS tanks had to be made and sent for trials. All this required additional time.

When the LCA project was being conceived the objective was to develop a simple ground attack aircraft. However, by the time that the Air Staff Requirement (ASR) was issued the project metamorphosed into an all weather, air superiority, multi-role combat aircraft. In the absence of a combat aircraft development

\(^{18}\) *Ibid..*
programme for a period of twenty five years, there were ‘knowledge gaps’. This
required the development of complex, new technologies as well as obtaining
consultancy and technology from abroad in limited areas.

In preparing the feasibility study for the LCA project, consultancy was
obtained from two firms—Dassault of France and Marcell of Sweden. Problems
arose in ‘evaluating capabilities, finalising proposals of foreign consultants and
finally granting approvals for such proposals’. This involved deciding what
technologies would and could be developed indigenously and what needed to be
procured from abroad\(^\text{19}\). Time was also lost in procuring the technologies from
abroad and in their absorption.

The Pre Production Series (PPS) of the *Arjun* tank weighed 61.5 tonnes. This
caused frequent failures in the imported RENK transmission, which, according to the
army, performed at its ‘optimum’ when the tank weighed 58.5 tonnes. This points to
the difficulties that Indian defence R&D is faced with in integrating imported
technology with indigenously designed systems. The fire control system had also
been imported. In 1997, the army has asked for a better system. Hence, the
transmission and fire control system had to be improved.

At the time of commencing the LCA project, it was the considered opinion of those
involved with the project that either consultancy had to be obtained or some of the
technologies or sub-systems had to be imported ‘to fill in gaps in knowledge but that

\(^{19}\) The foreign collaboration in the project is discussed in the previous chapter.
these had to be kept to the minimum"\textsuperscript{20}. It was planned to import the radar, fly-by wire system and composite materials "to make the LCA [an] extremely agile and versatile aircraft..."\textsuperscript{21}. Later, the strategy was altered. Time was lost in finalising the strategy for the full scale engineering and development of the aircraft, and this involved consultations with all the concerned agencies, establishments and the air force.

Foreign participation is now limited to providing consultancy and not entire sub-systems contrary to the original plan\textsuperscript{22}. One of the reasons for the change in strategy was the huge cost involved in foreign collaboration. The project director of the LCA stated in an interview that it was decided that the carbon composite wings would be developed indigenously after it was realised that "making them (the Carbon Fibre Composite [CFC] wings) with a foreign partner would reach a high figure"\textsuperscript{23}.

The LCA makes extensive use of composite materials and is made of a number of other materials. There was a delay of five months in the development of the Carbon Fibre Composite (CFC) wing, which was originally intended to be integrated with the fuselage in December 1994\textsuperscript{24}.

The long time consumed in developing the fly-by-wire (FBW) System is one of the contributing factors for the delay in the completion of the LCA project.

\textsuperscript{20} S. R. Valluri, "Light Combat Aircraft", \textit{Mainstream}, 8 March 1996, p. 10 and p. 14. Valluri writes, "Seeking some of the technologies, equipment, etc. Is incidentally the price we have to pay for the past policy of no aircraft development and so no technology development".


\textsuperscript{22} Gopal Raj, "Many More Miles to Go", \textit{The Hindu}, 1 December 1995. Gopal Raj's observation is based on unnamed sources involved in the LCA project.

\textsuperscript{23} See "A Project With Promise", interview with the LCA project Director by Atul Aneja, \textit{The Hindu}, 28 January 1993.

\textsuperscript{24} \textit{The Hindu}, 6 April 1995.
Developing a FBW System for an aircraft is by no means an easy task. The technology is highly complex and the safety of the aircraft hinges on this system. Owing to a lack of competence in this field, the Aeronautical Development Establishment (ADE) sought to import the entire system. However, as no foreign company was willing to provide the same, some sub-systems had to be developed indigenously in consultation with Lockheed Martin and British Aerospace.

The assistance of Martin Marietta was also sought to jointly develop some of the modules of the FBW system in the LCA. This was adversely affected after the United States unilaterally imposed sanctions on India in the wake of the latter conducting nuclear tests in May 1998. Martin Marietta withdrew from the agreement. Therefore, the ADA had to complete the task on its own.

The IGMDP has been delayed due to denial of technologies under the Missile Technology Control Regime. Owing to its export control laws, the United States declined to sell the shell catalyst to India, which is used for triggering a propellant jet flame. The U. S. also refused to part with W-band 94 gigahertz antennas for the Nag missile, which were required for the seeker head in its guidance system.

6.2 ACHIEVEMENT OF SELF-RELIANCE

An important objective of defence R&D through these projects has been to achieve self-reliance in the production of some key weapon systems and equipment and in the

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26 This was disclosed by the Minister of State for Defence, N. V. N. Somu, while replying to a question by Akilesh Das. See RSD, 14 May 1997, Budget Session, Q. No. 4040.
27 This was disclosed to Chellaney by scientists associated with the IGMDP during the course of his personal interviews. Cited in Brahma Chellaney, The Challenge of Missile Proliferation: India and the United States [New Delhi, 1994], p. 21.
28 Ibid.
development of certain critical technologies. Self-reliance eliminates or reduces
dependence on foreign suppliers who can interrupt or stop supplies at the critical hour,
thus jeopardising national security. Self-reliance also helps in building the basis of
continuing stream of supplies in the medium and long term. And finally, self-reliance,
through increasing use of locally available material at relatively lower costs, can help in
reducing military expenditure and saving precious foreign exchange. It is therefore,
important to evaluate these projects in terms of their contribution to self-reliance.

At the time of launching the IGMDP, it was anticipated that some of the critical
technologies would be denied. With this in view, critical areas were identified for
development. They were “phase shifters for radars, impact diodes that act as high
frequency sources, carbon composites to withstand the heat of re-entry, key sensors
for guidance systems and computational fluid dynamics models29”.

A survey conducted in the U. S. in 1995 identified ten top critical technology
areas “with the highest military and commercial dual-use potential”30. These
included electronic and photonic materials, computer simulation and modelling,
high performance complex software, sensors and signal processing, high-
definition imaging and displays and micro/optoelectronics. It can be noticed that
India has an abiding interest in all these areas and is already working on these
technologies31. These technologies have found application in various projects
being undertaken by the DRDO.

30 These technologies have ‘aerospace roots’. Respondents of the survey stated that in their opinion high-
performance computing and telecommunication networks figured last among the ten technologies, the
American government and investment markets ‘gave them considerable visibility’. Aviation Week and
31 See chapter one for details.
The *Nag* uses active homing for its guidance. After the seeker head was successfully developed and tested in 1996, Abdul Kalam remarked that it was the third greatest achievement for India in its missile development efforts. Speaking to the media after the test, Kalam remarked that the seeker head is the eye of the missile as it enables it to see where it is going. These technologies have been developed indigenously.

The talents available at leading academic institutions in the country were effectively utilised in developing the software for the IGMDP. The following table presents a contribution of academic institutions to the IGMDP.

**Table 6.6: Contribution of Academic Institutions to the IGMDP**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jadavpur University</td>
<td>Guidance Algorithm for <em>Prithvi</em></td>
</tr>
<tr>
<td>IISc</td>
<td>Air Defence Software for Multi-target Acquisition for <em>Akash</em></td>
</tr>
<tr>
<td>IISc</td>
<td>Software for Computational Fluid Dynamics for <em>Agni</em></td>
</tr>
<tr>
<td>IISc</td>
<td>ANUKALPANA Simulation Software for evaluating <em>Akash</em>’s multi-target acquisition capability</td>
</tr>
<tr>
<td>IIT, Madras and DRDO</td>
<td>Design Methodology for Re-entry Vehicle System of <em>Agni</em></td>
</tr>
<tr>
<td>IIT, Delhi &amp; Solid Physics Laboratory (SPL) and Central Electronics Limited CEL</td>
<td>3-D Phase Shifters for the <em>Rajendra</em> radar for surveillance, tracking and guiding the <em>Akash</em></td>
</tr>
<tr>
<td>IIT, Kharagpur and Research Centre Imarat (RCI)</td>
<td>Millimetric Wave Antenna for the <em>Nag</em> Seeker-head</td>
</tr>
<tr>
<td>Osmania University</td>
<td>State-of-the-art Signal Processing Algorithm for <em>Nag</em></td>
</tr>
</tbody>
</table>


Note: This list may not be exhaustive.

Academic institutions have contributed to the LCA project too. The Indian Institutes of Technology (IITs) developed the software and other capabilities.

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32 *The Hindu*, 10 August 1996

33 See *RSD*, 14 May 1997, Budget Session, Q. No. 4140.

34 *A Project With Promise*, n. 23.
The various materials used in the missiles include aluminium alloys, titanium alloys, maraging steel, soft magnetic alloys, controlled expansion alloys, hard tungsten alloy spheres, nickel–based super alloys, beryllium copper and oxygen–free high conductivity copper, carbon–carbon composites, electronic materials and polymeric materials.

Aluminium alloys were type–certifed at Bharat Aluminium Company, Hyderabad, and magnesium alloy plates and maraging steel at Mishra Dhatu Nigam (MIDHANI.).

The Defence Research and Development Laboratory (DRDL) developed a number of materials for the missiles being developed under the IGMDP. This has not been an easy venture and, therefore, specific measures had to be adopted to meet the stringent quality requirements. Industries that had the ‘basic infrastructure and capabilities’ were identified to undertake the development of the materials. The result of these efforts has been unique. It helped in indigenously developing the materials required and also in saving foreign exchange\(^{35}\).

Indian private industry made a noteworthy contribution in enabling the Defence Metallurgical Research Laboratory (DMRL) to fabricate high precision metal components and composites required for the missiles. The ‘Diffusion Bonding Hot Press’ is a furnace used in joining and fabricating metal sheets to evolve complex shapes of high strength and fabricate the nosecone and other components of

missiles\textsuperscript{36}. Hind High Vacuum (HVV) had indigenously fabricated this ‘Diffusion Bonding Hot Press’—a high technology equipment—at a cost of Rs. seventy lakhs. It would have cost four to five times more if the same were imported; moreover, because of export control regulations on equipment that are used in the making of missiles it would not have been possible to procure this equipment from abroad\textsuperscript{37}.

In the LCA project, “[t]he participation of the private sector is in the areas of software development, materials development and supply, manufacturing of line replaceable units, manufacturing of precision components and simulators/simulation, apart from supplying some equipment and other items”\textsuperscript{38}. Most of the work was done by the DRDO laboratories, Hindustan Aeronautics Limited (HAL) and National Aerospace Laboratory (NAL). Besides, the Indian Space Research Organisation (ISRO) also joined the project.

One of the recent successes of the LCA project has been in the area of the fly-by-wire system. Some of the modules were being jointly developed with Martin Marietta of the United States until it withdrew owing to the imposition of sanctions on India. A national team was formed\textsuperscript{39} and it successfully completed the development of the fly-by-wire system well within a year after Martin Marietta withdrew. Announcing

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\textsuperscript{36} Prof. U. R. Rao congratulated the HVV for successfully fabricating this equipment and said that it would help in the making of the cryogenic engine that the ISRO is working on.

\textsuperscript{37} This was stated by the Managing Director of HVV on the occasion of the equipment being handed over to the DMRL. Reported in \textit{The Hindu}, 26 September 1992.

\textsuperscript{38} “The Great Indian Hope: Its Light Combat Aircraft (LCA) Programme”, \textit{Vayu Aerospace Review} (New Delhi), Vol. 25, no. 6, 1996, pp. 32-42.

\textsuperscript{39} Standing Committee on Defence(1998-99), Twelfth Lok Sabha, Second Report, Ministry of Defence, \textit{Demands for Grants, 1998-99} New Delhi, 1999, p. 16. The Committee was informed that a ‘national team has been formed to combat the situation.’ The Committee recommended that “all out efforts be made to meet the situation... [and] If necessary, the Ministry of Defence may make additional funds available to ensure timely completion of the project”.

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this recently, the Director General of the DRDO said that India has “beaten the technological sanctions imposed by the USA”. This stands as an illustration of defence R&D fulfilling the objective of being able to quickly mobilise national resources in the wake of technology denial.

The DRDL has developed the CFC material for use in the break pads of the LCA. Thus, the DRDL “successfully overcame the embargo regime”. These materials have a wide variety of application, including in missiles and aerospace. The Defence Metallurgical Research Laboratory (DMRL) developed the aluminium-lithium alloy, which comprises 30 per cent of the LCA structure. The airframe and the wing were designed by the ADE and NAL.

The Microwave Tube Research Centre (MTRC) was established to undertake R&D work in the field of microwave tubes. These tubes are required for the multi-mode radar of the LCA.

One of the significant contributions of indigenous efforts has been the Mission Computer for the LCA, the ‘brain of the aircraft around which avionics architecture is built’. The most significant contribution of the LCA project has been in the area of computer software. As a result, several CAD/CAM packages have been developed—the AUTOLAY package has been developed by the ADE for designing composite structures.

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41 The Hindu, 25 October 1997. The CCC materials can withstand very high temperatures ranging to 3000°C.
42 The Hindu, 5 June 1992. The microwave tubes also hold the prospect of being useful in generating solar energy. At the inauguration function of the MTRC, its Director vowed to establish a strong technology base in the field of microwave tubes. At the time the MTRC was set up it was proposed that Bharat Electronics would undertake the manufacturing of the microwave tubes.
43 Atul Aneja, “LCA—A Technological Leap”, a write-up on the LCA following an interview with the LCA Project Director, Kota Hatinarayana The Hindu, 28 January 1993.
laminates; GITA was developed by AID, Pune, to facilitate computer aided tool design; a package named as COMPAC was also developed which, together with sub-systems software provides for computer-based planning of processes; and a CAM package which provides the linkage to the shopfloor has also been developed44.

The Defence Electrical and Bio Engineering Laboratory (DEBEL) also contributed to the LCA and Arjun projects by designing and developing electro-medical and defence electronics equipment and engaging in research on human engineering projects45.

The DRDO established "various integration facilities wherein the dynamic behaviour of aircraft and its systems are simulated"46 in order to avoid complications during the 'flight test phase.' The infrastructure that was built includes the various rigs for testing and evaluating the various systems in the LCA. These are47:

- The dynamic avionics integration rig (DAIR)—a ground-based facility for integrated testing of LCA avionics.
- The mini bird and iron bird rigs—to test and evaluate the flight control system of the LCA. These function around an engineering test station, which caters to all interfacing needs for testing the digital flight control computer.

Thus, through the joint effort of the DRDO, national laboratories, public and private sector industries and academic institutions India achieved self-reliance in several critical technologies.

44 Ibid.
45 The Hindu, 5 June, 1992. Besides, DEBEL has also developed life-supporting systems for the navy.
46 <http://www.nic.in.desidoc/technologyfocus/dec98/avionics>
47 Ibid.
The then Minister of State for Defence admitted that India was being denied
electronic systems and devices. In order to combat this situation "[a] programme for
developing such critical technologies has been launched" 48, wherein materials,
components and sub-systems being denied to India are being developed indigenously,
in a consortium approach. The indigenous initiative in the development of critical
technologies/components resulted in the development of "75 types of critical
components and a number of materials have been developed" 49. Some of the
technologies which have been developed or are being developed include
microelectronics—including gallium arsenide and silicon technology, gyros, carbon
technology and critical fabrication and test equipment 50. Seventeen critical
technologies have already been identified and developed. Further, seventeen critical
technologies have been identified and some have already been funded.

Though the DRDO has been able to develop a number of technologies these have
as yet not resulted in delivering the LCA and some of the missiles for production.
Sanction has recently been accorded for the production of the Arjun tank. However,
information is as yet not available if production has commenced.

The Prithvi missile has been successfully developed and has entered service. In
contrast to past procedures adopted at DRDL, the IGMDP adopts a mission mode and

48 See reply by N. V. N. Somu to a question raised by Ajit Jogi et al. RSD, 17 July 1996, Budget Session,
Q. No. 380. Also see RSD, 27 November 1997, Winter Session, Q. No. 101. The Department of
Science and Technology is funding programmes in various areas. See chapter one for details.
49 Also see RSD, 27 November 1997, Winter Session, Q. No. 101.
50 This was disclosed by Abdul Kalam while delivering an a lecture in Bangalore at the Indian
consortium approach. In the "mission mode style of programme management the time schedules are fixed, targets clearly identified, work is carried out in an extremely intensive manner, funding is assured and all bureaucratic redtape is cut"\textsuperscript{51}. The success of the project can be attributed to the project management method and the leadership provided by Abdul Kalam. The earlier missile development efforts of the DRDL (when it undertook the development of anti-tank guided missile and the Devil Project) were characterised by 'poor interaction with the users, excessive emphasis on in-house R&D and lack of funds during critical stages\textsuperscript{52}. In the IGMDP "[t]he association of users at every stage greatly helped in increasing the effectiveness of the missile (Prithvi) and reduced the number of user trials\textsuperscript{53}".

The DRDO has initiated a Self-reliance Plan (discussed in chapter Two). The Plan hopes to meet the target of defence acquisitions through indigenous efforts accounting for seventy per cent of the total acquisitions largely through the production of the Arjun and the LCA and the missiles being developed under the IGMDP, besides other advanced technology projects that are under development. An early completion of these projects leading to the production of these weapon systems would determine the success of the Self-reliance Plan, which has already fallen behind targets.


\textsuperscript{52} Raj Chengappa, "The Missile Man", \textit{India Today}, 15 April 1994, p. 73. In an interview a former Director General of the DRDO stated that the then Defence Minister, R. Venkataraman, 'insisted that the user should be involved with the project right from the beginning. See interview with V. S. Arunachalam, \textit{The Hindu}, 5 August 1992.

6.3 CONSORTIUM APPROACH

Yet another objective of these projects has been to widen the research and development base in the country by associating in the execution of these projects, the Indian industry—both the private sector and the public sector, universities and national laboratories. One of the means of achieving this objective is the adoption of a consortium approach to the execution of the projects.

The consortium approach is an innovation brought to the DRDO by Kalam from the ISRO, where he had worked earlier on the SLV project. It is, in fact, a necessity to adopt such an approach, especially in high technology projects. For the success of high technology projects, vast amounts of varied and specialised resources are a prerequisite. By tapping and pooling together the resources available in any sector in the country, the DRDO has been able to ‘utilise the infrastructure and expertise in a participatory manner’. This approach was successfully implemented in the IGMDP and is now being replicated in all the defence R&D programmes of the DRDO. The LCA project reinforced the utility of the consortium approach.

In the ‘consortium approach’ DRDO laboratories, the academia, the public sector and the private industry—all come together to pool up their collective strengths and achieve the goals of the project. Through this innovative method several ‘cutting edge’ technologies were developed. “This was a conceptual breakthrough”54.

In the IGMDP, 12 academic institutions and 30 DRDO laboratories, Council for Scientific and Industrial Research (CSIR) laboratories—36 technology centres, and industry and professional societies—41 production centres55, have come together to develop the missiles.

The LCA project is being pursued as a ‘national effort’ involving “a core team of 300 in the ADA, engineers from HAL, NAL, DRDO [and] academic institutions”56. Elaborating on the national effort in the LCA project the then Defence Minister, Mulayam Singh Yadav, stated in the Parliament that57:

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Capability of design and infrastructure for fabrication/production and testing of various components/sub-systems and for integration of LCA have... been established in more than 100 work centres in laboratories of [the] Defence Research and Development Organisation, industry, research institutions in other sectors, academic institutions and universities.
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Through involving the industry and academic institutions, Indian defence R&D programmes have enabled the broadening of the R&D base in the country. Indian industry has contributed to defence R&D projects in a number of areas. Important among these are: development of exotic materials, fabrication of alloys, information technology, electronics, precision engineering, components, aircraft components and avionics. Thus, the Indian industry has gained technology empowerment.

Through undertaking these defence R&D programmes in a consortium approach, a lot of infrastructure—technology development centres, test facilities and production centres—has been built. This would provide a strong base for future defence R&D projects.

### 6.4 SPIN-OFF TO CIVILIAN SECTOR

Military technology provides spin-off to the civilian sector. It makes available for civilian application some of the technologies developed in defence R&D projects. Some of the technologies developed in the IGMDP have had the spin-off benefit in

56 See “Project With Promise”, n. 23.
57 See RSD, 12 March 1997, Budget Session, Question No. 243.
the health sector. The DRDO made necessary modifications to technology and developed a pace maker. This, and many more—angioplasty guide wire, cardiac catheters, 3D image processing through CT data processing, carbon disc heart valve, carbon–carbon bone transplants, etc—have been made possible through the efforts of the DRDO. The Dhristi laser equipment has been installed on an experimental basis for ophthalmic application. Similarly, a coronary stent has been developed for the first time in the country.

A number of materials—composites, high strength alloys, etc—have been developed for use in the LCA project and IGMDP. These can find application in the civilian sector of the country. The AUTOLAY software developed for the LCA programme is already being marketed through a company in the United States.

### 6.5 DELAY CORRECTION MEASURES

Many of the DRDO projects are in various stages of development and are yet to reach the production phase. Therefore, steps have been initiated for the speedy completion of ongoing projects as well as to prevent a recurrence of time-overruns for future projects. Replying to a question in the Lok Sabha, the then Defence Minister, Mulayam Singh Yadav, informed of the measures being adopted to avoid delays in prestigious, high technology–based defence R&D projects. They are:

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59 India, *Lok Sabha Debates*, 4 August 1997, Monsoon Session, Q. No. 169. The question was raised by Pramod Mahajan, earlier Defence Minister for less than a fortnight, and Lt. Gen. (Retd) Prakash Mani Tripathi. It is also understood that the same measures are already being applied in respect of other projects and shall be done in the case of future projects, too.
• Introduction of concurrent engineering practice.
• Development of technologies/competencies before taking up [a] project...
• Multi-tier project review system.
• Assured funding of higher priority projects.
• Accelerated indigenous development of critical technologies/ materials/ components/ sub-systems which have been denied or are likely to be denied under various export regimes of various developed nations.

In concurrent engineering soon after a sub-system is proved the technology for its manufacture is immediately transferred to the relevant production agency. This would, therefore, reduce the gestation period between a complete weapon system being accepted for induction and its production to commence.

Developing the relevant technologies/competence before commencing a project, remedial measure two cited above, needs closer examination. While it is desirable to be fully equipped before commencing a project, its feasibility is in doubt. Would the scientists not suggest that they would be able to develop some of the complex technologies by the time other elements of the project progressed/fructified? For instance, it was believed that the GTX (gas turbine engine) project underway was already an exercise in competence building. Nonetheless, the indigenous Kaveri engine is delayed by several years. On the other hand, if a project is not undertaken till the technology is fully developed, there might be a possibility where in a project would take a longer time to be initiated or ultimately would not be taken up. What is therefore required is making a judicious and realistic assessment of whether a required level of technological competence has been built.

A multi-tier review system would go a long way towards removing the hurdles faced by the projects. For, this would bring decision making closer to the project and
would facilitate better monitoring. However, its membership and the powers bestowed upon it are of far more crucial importance. At each level, the committee needs to have adequate powers in order to make decisions on the spot, without looking towards the higher authorities for decisions/approvals, with, of course, supervision by the higher levels. Its members should empathise with the project rather than working at cross-purposes. For any review to be meaningful, the committee would need to meet frequently and all members would be required to make themselves available at all meetings so as to provide continuity in review—decision making.

Whether or not funds would be provided would depend on the general economic conditions in the country and the priorities at a given point of time. It would, therefore, require a high level of commitment on the part of the government to assure that any DRDO project is not held up due to non-availability of finances.

The success of measures to develop critical technologies would depend upon the DRDO being able to correctly anticipate the technologies that would be denied and also the ability to develop such technologies/components within the country, importantly within the projected time schedule. Such a measure would go a long way towards making available the required technology/component at the time of commencing the project. As we have seen above, the development of several technologies/components—carbon composites in the LCA, the seeker head technology in the Nag missile, the software for the LCA, etc.—commenced only after the projects were initiated.