CHAPTER I

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Performance Audit on National Aerospace Laboratories, Bangalore

Highlights

Financial support for research activities

- **NAL's dependence on CSIR/Governmental funding increased during the last five years. Out of the total funds of Rs.602.70 crore received by NAL, only Rs.154.26 crore were generated through external sources during 2002-07 accounting for mere 26 *per cent* against the target of 50 *per cent* to be achieved by 2001.**

[Para 1.6.1]

Research Management

- **NAL's success in transferring and commercialising technologies developed was abysmally low. Of the 146 projects test checked, NAL developed knowledgebase in 75 projects of which only 25 knowledgebases (33 *per cent*) were transferred to the end users. Of the 25 knowledgebases transferred, NAL could commercialise only one knowledgebase for general industrial application in April 2007.**

[Para 1.6.2.2]

- **NAL earned only Rs.0.37 crore during 2002-07 from transfer and commercialisation of technologies, which was 98 *per cent* short of the target of Rs.15 crore set by its Performance Appraisal Board (PAB). NAL also failed to achieve the targets fixed by PAB in respect of filing of foreign patents and impact factor of research papers.**

[Para 1.6.2.3, 1.6.2.4 and 1.6.2.5]

Manpower Management

- **While there was shortage of 17 to 26 *per cent* staff in scientific cadre, NAL employed excess technical staff to the extent of 56 to 83 *per cent* incurring irregular expenditure of Rs.15.83 crore during 2002-07.**

[Para 1.6.3]

Project Management

- **NAL could not ensure timely completion of projects as per original approved schedule. 50 *per cent* of 163 projects test checked showed time overrun between one month to 83 months.**

[Para 1.7]

- **In respect of sponsored projects, NAL suffered a loss of Rs.5.17 crore due to undercharging on account of intellectual fee and service tax in violation of the norms fixed by CSIR.**

[Para 1.7.4.1]

- **NAL did not maintain a balanced portfolio of projects by laying adequate emphasis on in-house projects to develop general aerospace technology base for general industrial application.**

[Para 1.7.2.1]

- **The documentation in a large number of projects was deficient as project proposals, project expenditure, completion reports etc, were not maintained adequately to ensure transparency and facilitate subsequent review.**

[Para 1.7.2.3]

HANSA and SARAS Projects

- **Two-seater trainer aircraft, HANSA, developed by NAL after significant time and cost overruns did not find buyers in the market after the initial order for 10 aircrafts. NAL is also yet to develop its components indigenously.**

[Para 1.8.1]

- **Development of SARAS, a light transport 9-14 seater aircraft, also suffered from delays and deficient project management. Even after a lapse of eight years and cost overrun of Rs.22.53 crore, NAL is awaiting certification of airworthiness for SARAS aircraft from Director General of Civil Aviation (DGCA) as NAL failed to bring down its weight within the permissible limit and is yet to carry out various tests and generate documentation. As per DGCA, flight certification is expected only after 2010 and NAL may have to make a third prototype as well.**

[Para 1.8.2]

Summary of Recommendations

- *NAL may make greater efforts to reduce its dependence on the assistance provided by the Government/CSIR by effectively implementing various strategies as enunciated in 'CSIR 2001 Vision and Strategy'.*
- *NAL may formulate a clear cut business strategy and identify niche areas, partners, customers, competitors and markets to tap the opportunity in the growing aerospace sector.*
- *NAL may make greater efforts to transfer developed knowledgebases to the end users.*
- *NAL should strive to achieve the targets fixed by PAB for filing of patents, earnings from commercialisation of technologies and research publications.*
- *NAL may make adequate efforts to improve its manpower planning so that research and development activities are not hampered in future.*
- *NAL may accord higher priority to in-house projects to create new processes, products, applications and markets and make adequate efforts for transfer and commercialisation of technologies, wherever successfully developed.*
- *NAL may ensure that documentation in respect of in-house projects is maintained properly and Divisional Scientific Committees monitor them regularly to exercise effective control on execution of these projects.*
- *NAL may make efforts to assess the demand of the aircraft in the market in comparison with other similar aircrafts, make concerted efforts for marketing and find an industrial partner for large-scale production.*
- *In view of failure of NAL in obtaining DGCA certification on airworthiness, despite a lapse of ten years, CSIR may review the continuance of SARAS project.*
- *Keeping in view the problems faced by NAL in HANSA and SARAS projects relating to marketing of the aircrafts, difficulties in finding an industrial partner and lack of specialised manpower, NAL may review initiation of the new project for development of a 70 seater aircraft.*

1.1 Introduction

National Aeronautical Laboratory, the forerunner of the present day National Aerospace[1] Laboratories (NAL), Bangalore is a constituent unit of Council of Scientific and Industrial Research (CSIR). It was set up in 1959 to provide scientific support to the aeronautical industry. In recognition of its new role, NAL redefined its mandate in November 1997 to 'development of aerospace technologies with strong science content, with a view to their practical application to the design and construction of flight vehicles and to use this general aerospace technology base for general industrial applications'.

To achieve the above mandate, NAL undertakes various types of Research and Development (R&D)projects such as Mission Mode Programmes (MMP), in-house projects, grants-in-aid projects, sponsored and consultancy projects. While MMPs are undertaken with cost ceilings having definite deliverables, in-house projects are undertaken to conduct innovative research for development of aerospace technology. Grants-in-aid projects involve grants by way of financial inputs either in full or part and are undertaken in order to supplement laboratory's efforts in on-going and new R&D projects or for creating new capability/facility. Sponsored projects are projects wholly funded by the clients with specified objectives and defined outputs, which culminate in generation of intellectual property/knowledgebase. Consultancy projects are projects for rendering scientific and technical advice to the end users. Further, some important projects being executed by NAL include development of a two seater trainer aircraft (HANSA) and a 14 seater light transport aircraft (SARAS).

NAL is headed by a Director who is assisted by a Research Council (RC) and a Management Council (MC). It has 23 divisions, which undertake research activities in various disciplines and their work is monitored by Divisional Scientific Committees (DSCs). While RC and DSCs review the progress of research, MC looks after the day-to-day activities of NAL. NAL has two campuses at Kodihalli and Bellur in Bangalore, Karnataka.

1.2 Scope of Audit

The Performance Audit was undertaken covering the activities of NAL from 2002-03 to 2006-07. Project Management of various MMPs, in-house, grants-in-aid, sponsored, collaborative and consultancy projects including the projects on 'HANSA' and 'SARAS' aircrafts undertaken by NAL was studied with regard to their planning, implementation and monitoring. The output expected from these research projects in terms of research papers, knowledgebase (readily and commercialisable knowhow, process improvement, technology and technique or a new product) and intellectual property (patents, copyright, trademark/design and computer software) were also studied. Further, efforts made by NAL for commercialisation of

[1] Aerospace comprises the atmosphere of Earth and surrounding space.

technologies developed were also reviewed for arriving at audit conclusions in line with the defined audit objectives.

1.3 Audit Objectives

The Performance Audit seeks to examine:

(1) The extent to which NAL improved its cash flow by taking up externally funded projects to reduce its dependence on Government/CSIR funding;

(2) Whether NAL identified niche opportunity areas and implemented business strategies to emerge as a global leader in such areas;

(3) Whether Mission Mode Programmes, grants-in-aid projects, sponsored projects and other projects were managed efficiently and technologies developed were patented and commercialised as envisaged;

(4) Whether NAL maintained proper balance in project portfolio to give adequate priority to in-house projects to promote R&D activities for development of aerospace technologies for general industrial purposes;

(5) Whether scientific and technical manpower was efficiently deployed to achieve its mandate;

(6) Whether research findings with high impact factor were published in journals;

(7) Whether monitoring and documentation was adequate to ensure effective control over projects; and

(8) The extent to which NAL succeeded in indigenous development of light trainer and transport aircrafts ('HANSA' and 'SARAS') in an efficient and economical manner**.**

1.4 Audit criteria

The following criteria were used for assessing various aspects of the performance of NAL:

- Targets and milestones set by CSIR's vision and strategy statement;
- Milestones fixed for completion of important projects and actual achievements;
- Success in transfer of technologies and their commercialisation;
- Targets fixed by Performance Appraisal Board (PAB) and Research Council (RC) for generation of external cash flow (ECF), research papers and patents;

- CSIR's instructions regarding formulation and undertaking of projects, technology transfer and filing of patents; and

- Sanctioned vis-à-vis deployed manpower for R&D.

1.5 Audit methodology

Audit scope, objectives and criteria were discussed with NAL in the Entry conference held on 24 May 2007. As the R&D activities at NAL are conducted through various kinds of projects, 186 projects out of 456 projects (40 *per cent*) completed during 2002-07 and 62 (25 *per cent*) out of 246 ongoing projects as on 31 March 2007 were examined in Audit. Projects were selected from various categories on the basis of their money value. Audit was carried out between May and July 2007 and process of audit involved examination of project documents, progress reports, reports of various monitoring committees, interaction with scientists of various divisions etc,. The Exit conference was held on 29 January 2008. Audit findings were issued to NAL/CSIR and their comments have been considered while finalising this report.

1.5.1 Acknowledgement

The co-operation of NAL/CSIR during the entry conference, course of audit and exit conference was satisfactory and the same is acknowledged with thanks.

1.6 General audit findings

1.6.1 Financial support for research activities

The R&D activities of NAL are financed by CSIR and various government, non-government and private agencies. As CSIR laboratories are highly dependent on government funding, the 'CSIR 2001 Vision and Strategy' proposed to make an endeavor to decrease support from the Government to 50 *per cent* by 2001. This meant that the Laboratories/Institutes of CSIR were to make efforts to significantly increase non-CSIR resources, to increase their ECF.

Audit appraisal disclosed that even as of 2006-07, NAL was not able to achieve the above stated objective and the dependence on government funding continued to be high and in fact, increased during the last five years as shown in the table below:

(Rs. in crore)

TABLE I

Year	Funds released by CSIR to NAL	Projections made by NAL for generation of ECF	Funds received from sources other than CSIR							Total Funds received *(b+j)*	Percentage of CSIR's contribution to the total amount received
			Funds received for grants-in-aid projects	Funds received for sponsored projects	Funds received for Collaborative projects	Funds received for Consultancy projects	Testing and Analytical charges	Fees for transfer of technology	Total ECF earned *(d+ e+ f+ g+ h + i)*		
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*
2002-03	65.72	40	16.53	12.08	0.03	0.00	0.11	0.05	28.8	94.52	70
2003-04	70.83	30	9.92	23.42	0.00	0.03	0.06	0.02	33.45	104.28	68
2004-05	81.07	32	5.31	22.25	0.00	0.00	0.18	0.00	27.74	108.81	75
2005-06	107.19	28	4.73	25.54	0.10	0.07	0.09	0.05	30.58	137.77	78
2006-07	123.63	30	3.06	30.29	0.00	0.00	0.09	0.25	33.69	157.32	79
Total	**448.44**	**160**	**39.55**	**113.58**	**0.13**	**0.10**	**0.53**	**0.37**	**154.26**	**602.70**	**74**

Out of the total of Rs.602.70 crore received by NAL, only Rs.154.26 crore were generated through external sources during 2002-07, accounting for merely 26 *per cent* against the target of 50 *per cent*.

It was further seen that the projections (targets) made by NAL for generation of ECF during the period 2002-07 did not follow the spirit of CSIR directives. Instead of enhancing the targets for ECF, the projections made by NAL were reduced from Rs.40 crore in 2002-03 to Rs.30 crore in 2006-07.

Audit further observed that the generation of ECF was negligible from consultancy & collaborative projects and transfer of technologies.

NAL stated in December 2007 that its ECF has been the highest in the CSIR system, ever since the concept was introduced. NAL added that the reasons for continued dependence on CSIR grants was due to the fact that its technology programmes were for Government agencies mainly, Defence Research Development Organisation (DRDO), Defence Services and Indian Space Research Organisation (ISRO) and hence costing of the projects had been conservative, as per the considered decision of CSIR. The contention of NAL was not tenable as CSIR in its 'Vision and Strategy 2001' did not spell out any such consideration for conservative costing for government agencies, while suggesting strategies for improving the generation of ECF. Though audit recognises that the ECF generated by NAL is significant, however, compared to previous years, the percentage contribution of external funding has consistently declined during the last five years instead of showing any significant increase. Further, generation of resources from technology transfers, collaborative projects etc., is low. As such, NAL is far from achieving the above mentioned goal and continues to be largely dependent on CSIR funds.

Recommendation

NAL may make greater efforts to reduce its dependence on the assistance provided by the Government/CSIR by effectively implementing various strategies as enunciated in 'CSIR 2001 Vision and Strategy'.

1.6.2 Research Management

1.6.2.1 Strategy for linking R&D activities to market trends and demand

In January 1996, CSIR through its 'CSIR 2001 Vision and Strategy' document proposed a business strategy, which sought to link and relate R&D to market place by studying and analysing technology and market trends. In this connection, it proposed to identify niche opportunity areas, partners, customers, competitors and markets. Therefore, for preparation of business strategy, the Laboratories/Institutes were to assess the trend of current technologies, competitors, end users and potential markets to identify niche opportunity areas. Then they were required to assess their current capabilities and plan accordingly for the enhancement of capabilities to compete in the market.

The Performance Appraisal Board (PAB) of CSIR commented in 2001-02 that the Research Council (RC) of the laboratory was responsible for identifying niche opportunity areas, where the laboratory could emerge as a global ranking player. Narasimha Committee (June 2002) set up by CSIR for restructuring of NAL had also recommended that research projects should be taken up in selected areas based on technology forecasting and creative thinking and not confined only to NAL's testing facility, expertise and capabilities. It was seen that RC of NAL discussed the identification of niche opportunity areas only once (July 2005) and recommended that NAL should follow the suggestions of the Narasimha Committee. NAL did not furnish any document indicating that the recommendations of PAB, RC and Narasimha Committee were implemented by formulating a business strategy.

CSIR stated in December 2007 that NAL had taken into account many of these factors while selecting products like HANSA, SARAS etc,. The reply is to be viewed in the light of the fact that NAL is yet to commercialise HANSA aircraft and is still to find an industrial partner for developing SARAS aircraft (discussed in Para 1.8.1.2 and 1.8.2 respectively). Further, during 2002-07, NAL has not commercialised (2002-07) any technology for general industry (discussed in Para 1.6.2.2). This demonstrates NAL's inability to effectively link and relate R&D activities to market trends and demands.

1.6.2.2 Development and transfer of knowledgebase[2]

NAL had total of 282 projects ongoing as of 31 March 2002. During 2002-07, NAL undertook 487 and completed 456 projects. Of the completed projects, 186 projects were selected in audit. However, NAL could not furnish information on the status of

[2] Include readily and commercialisable knowhow, process improvement, technology and technique or a new product.

development of knowledgebase in 40 projects and therefore, audit analysis had to be restricted to 146 projects. The information furnished by NAL in respect of 146 projects indicated low success rate in transfer of knowledgebase developed, to end users. Of the 146 projects, NAL developed knowledgebase in 75 projects of which only 25 knowledgebases were transferred to the end users. Thus, the success rate in transfer of knowledgebase was only 33 *per cent*. Of the 25 knowledgebases transferred, only three[3] knowledgebases were for general industrial applications and NAL could commercialise only one knowledgebase viz. carbon fibre for general industrial application (April 2007).

Audit also observed that out of 25 cases of knowledgebase transfer, in 22 cases, NAL could not maintain the intellectual property (IP)[4] rights/ licensing rights of knowledgebases, as these projects were undertaken for various defence organisations, Department of Space, Department of Power and Department of Atomic Energy, which were considered 'strategic' in nature.

Of the remaining 71 projects, knowledgebases were proposed to be developed only in three projects, which NAL failed to develop. In other cases, either no technology was proposed to be developed or the project involved only testing, fabrication and supply of materials.

Thus, performance of NAL in transfer of knowledgebase to end users was weak.

Though CSIR stated in December 2007 that both knowledgebases and technologies developed by NAL have added asset value to the nation, it failed to give reasons for non-commercialisation of technologies in large number of projects.

1.6.2.3 Earnings from transfer/commercialisation of technologies

Earnings from transfer of technology came in the form of lump sum license fee. Besides, earnings from royalty on commercialisation of technologies was based either on a percentage of ex-factory sale/rate agreed to, or on the basis of actual usage/measurements. It was observed that despite having prescribed norms for realisation of royalty, there was no mechanism in place to check and verify the same and realise royalty from the parties on such basis. As a result, the possibility of loss on account of non-realisation of royalty/license fee could not be ruled out. NAL earned only Rs.0.37 crore during 2002-07 from transfer as well as commercialisation of technologies, which was 98 *per cent* short of the target of Rs.15 crore set by PAB for the said period.

CSIR did not offer any specific comments on the issue.

[3] Straight foil bearing, Embossing rollers and Carbon fibre (Para 1.7.3.1).
[4] Intellectual Property (IP) includes patents, copyright, trademark/design and computer software.

1.6.2.4 Filing of patents[5]

Performance Appraisal Board observed in 2001-02 that NAL had to its credit, several innovative developments, but these were not reflected in its IP portfolio. Therefore, PAB fixed a monitorable target of filing of 20 foreign patents per year for NAL.

The status of patents filed by NAL in India as well as abroad during 2002-07 was as follows:

TABLE II						
Number of patents	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**Total**
Filed in India	10	4	1	5	1	**21**
Filed abroad	2	1	1	1	4	**9**
Total	**12**	**5**	**2**	**6**	**5**	**30**

The above analysis indicates that against the target of filing 100 foreign patents in five years, NAL could actually file only nine patents, thus, indicating a significantly low performance.

In respect of patents filed in India, where no target was fixed by PAB, the performance of NAL had deteriorated during 2002-07.

Of 30 patents filed, 22 were filed from eight out of 456 completed projects during 2002-07 and the balance eight patents pertained to the projects completed prior to April 2002. Therefore, during 2002-07, only two *per cent* completed projects yielded patents.

CSIR in its reply (December 2007) stated that due to enhanced requirements of the national projects as well as reduction in the human resource position, priorities had to be shifted in favour of sponsored projects, which were generally not patentable due to security and IPR[6] reasons. However, the fact remains that the targets were fixed internally by PAB after taking into consideration the past performance of NAL and therefore all these factors would have been considered before prescribing the targets.

1.6.2.5 Research Publications

Performance Appraisal Board, in 2001-02, fixed a target of 50 papers to be published in Scientific Citation Index[7] (SCI) journals each year having average Impact Factor [8] of 1.5. In this context, a mention was made in Paragraph 3.6.1.2 of Audit Report No 2, Union Government (Performance Audit) of 2007 that NAL could not reach the targeted number of research publications and registered a shortfall of 61 *per cent* during the period 2002-05.

It was observed that during 2005-07, while NAL could achieve the target of 50

[5] A patent is a set of exclusive rights granted by a government to a person for a fixed period of time in exchange for the regulated, public disclosure of certain details of an invention.
[6] Intellectual property rights.
[7] A Citation Index is index of citation between publication, along with the user to easily establish which document cite with other document.
[8] Ratio of the citation received by a publication, to the number of publications in the journals.

research publications in a year, it was not able to achieve the desired impact factor. The average impact factor of the research publications ranged from 0.99 to 1.29, against an average target of 1.5.

Hence, NAL could not achieve the targets set by PAB for impact factor for research publications.

The strategic nature of the projects, restricting publishing of R & D results in open domain, was cited as the main reason for a lesser number of publications. CSIR stated in December 2007 that position of publications would improve as soon as R&D projects would get higher priority after satisfying the user needs.

Recommendations

- *NAL may formulate a clear cut business strategy and identify niche areas, partners, customers, competitors and markets to tap the opportunity in the growing aerospace sector.*
- *NAL may make greater efforts to transfer developed knowledgebases to the end users.*
- *NAL should strive to achieve the targets fixed by PAB for filing of patents, earnings from commercialisation of technologies and research publications.*

1.6.3 Manpower Management

CSIR appointed a committee (Narasimha Committee) in June 2002 for restructuring of NAL. The Committee recognised 'ageing workforce' as one of the weaknesses of NAL and recommended (December 2002) enhancing the sanctioned strength of the scientific as well as technical staff.

1.6.3.1 Scientific Manpower

As recommended by the Committee, CSIR enhanced the sanctioned strength of NAL in respect of scientific staff in November 2004 from 383 to 460. The year-wise position of sanctioned strength, men-in-position, recruitment/ retirement/transfer of scientific staff was as follows:

TABLE III

Year	Sanctioned strength of Scientific staff recommend by Narasimha Committee and approved by CSIR	Number of scientists available at the end of the year	Vacancy	
			Number	Percentage
2002-03	383	319	64	17
2003-04	383	315	68	18
2004-05	460	361	99	22
2005-06	460	340	120	26
2006-07	460	372	88	19

- It can be seen from the above that 17 to 26 *per cent* posts of scientific staff were lying vacant. Though recruitment exercises were undertaken, NAL failed to augment the strength of the scientific staff as per the revised sanctioned strength,

thereby defeating the purpose of increasing the sanctioned strength.

- During 2002-07, 48 scientists resigned besides retirement/superannuation of 66 scientists including 49 senior scientists in F and G levels. Though NAL recruited 138 fresh scientists at the lower levels (scientist EII and below) during this period, the retirement of large number of senior scientists in F and G level created a gap of experience. For example, in one of the most important technology centers i.e. Centre for Civil Aircraft Design and Development alone, 16 scientists resigned/retired (6 of whom were in the level of Scientist F and G). These were replaced by fresh scientists (15 Scientists in B, C and E II levels) who did not have adequate experience. This poses a threat to the successful implementation of important projects like HANSA and SARAS, which are already lagging behind their schedules.

1.6.3.2 Technical Manpower

The sanctioned strength of technical staff was enhanced in November 2004 from 285 to 300, based on the recommendations of the Narasimha Committee. Audit examination disclosed that NAL employed technical staff much in excess of the revised sanctioned strength as detailed below:

TABLE IV

Year	Revised Sanctioned strength	Persons -in- position	Vacancy	Contract technical staff	Total Technical staff (Regular + Contracted)	Excess staff	Excess expendi- ture (Rs. in crore)
2002-03	285	240	45	258	498	213	3.49
2003-04	285	223	62	239	462	177	2.99
2004-05	300	242	58	225	467	167	2.38
2005-06	300	247	53	301	548	248	3.12
2006-07	300	229	71	320	549	249	3.85
							15.83

Audit analysis revealed that while on one hand there were a large number of vacancies in the cadre of scientific staff, NAL recruited (on contract basis) technical staff, which was 56 to 83 *per cent* over and above the revised sanctioned strength approved by CSIR. NAL recruited, on an average, 268 technical staff on contract basis as against average vacancy of only 57.

CSIR stated in December 2007 NAL had hired large number of temporary manpower to manage heavy and peak loads of projects of short term duration, but did not furnish any approval of CSIR for hiring temporary manpower in excess of sanctioned strength.

Thus, NAL not only failed to fill up of vacancies of scientific staff, it hired technical manpower in excess of sanctioned strength involving excess expenditure of Rs.15.83 crore during 2002-07. This indicated deficiencies in manpower management which may have serious implications on the capability of NAL in successfully executing important projects for development of aerospace technologies.

Recommendation

NAL may make adequate efforts to improve its manpower planning so that research and development activities are not hampered in future.

1.7 Detailed Audit findings: Delays in completion of research projects, deficiencies in their management and non-achievement of objectives

Under the X Five Year Plan (2002-07), NAL proposed to fulfill its responsibilities towards development of aerospace technologies by undertaking projects under various categories.

During the period of review, NAL completed 456 projects, of which 97 were in-house, 84 grants-in-aid, 267 sponsored, five consultancy projects and three Mission Mode sub projects. NAL could not provide complete information regarding starting and completion dates for 130 completed projects. Of the remaining 326 projects, in 163 projects, (50 *per cent*) the original target dates for completion were not adhered to, which resulted in time overrun ranging from one month to eighty-three months as detailed below:

TABLE V

Time overrun	Number of projects
Up to six months	46
Exceeding six months to one year	38
Exceeding one year to two years	36
Exceeding two years to three years	20
More than three years	23

The delays in completion of the projects were on account of deficiencies in their planning and implementation including delay in commissioning pilot plant, delays in procurements etc,. NAL could not furnish information on revised costs. In the absence of data regarding revised costing of the projects, audit could not calculate the associated cost overrun.

This indicated deficiencies in project management in a large number of cases which is bound to have significant cost implications.

CSIR in its reply of December 2007 remained silent on the issue.

Some of the selected completed projects are discussed in the succeeding paragraphs, which highlight deficiencies in project management.

1.7.1 Mission Mode Programmes

During the X plan (2002-07), NAL proposed to achieve the objectives of the MMP by undertaking three sub-programmes viz.

(i) spearheading small civilian aircraft design, development and manufacture;

(ii) developing specialised aerospace materials; and

(iii) developing and sustaining high science and technology for national aerospace programmes.

Audit findings on above mentioned three sub-programmes are discussed below:

1.7.1.1 Spearheading small civilian aircraft design, development and manufacture

The mission of the sub-programme costing Rs.96 crore was to ensure return on investments of the IX plan by designing and fabricating stretch versions of the aircrafts (HANSA and SARAS) and to reduce imported components, particularly through development of sub-systems of the aircrafts, as the supply of the same was often uncertain. NAL set out the objectives of the mission as follows:

- HANSA-3: continue to make design and product improvements; support development of imported materials and instruments; and take up development of stretch version with four to six passengers' capacity (three prototypes);
- SARAS: fabricate two more prototypes for flight testing and certification and fabricate one more structural test specimen for weight optimisation and establishment of production standards and one more flying prototype;
- undertake indigenous development of selected subsystems of SARAS like propellers, starter generators, passenger seats etc;
- take up design of stretch version for 19-seater Light Transport Aircraft (LTA); and
- design, demonstrate and popularise micro air vehicles.

It was observed in July 2007 that NAL did not undertake any project on the last two areas. The reasons for the same were not made known. In the first three areas, NAL undertook two projects only in May 2005, three years after commencement of the X plan. CSIR extended the tenure of the projects till March 2009.

Audit findings on projects HANSA and SARAS have been discussed in detail in Para 1.8.

1.7.1.2 Development of specialised aerospace materials

Sub-programme costing Rs.16.87 crore was to be implemented during the X plan through the following research and development activities:

- set up comprehensive facility at pilot plant scale for carbon fibres[9], resins and

[9] It is a carbon filament thread, or felt or woven cloth made from those carbon filaments. By extension, the term is also used informally to mean any composite material made with carbon filament, such as carbon fiber reinforced plastic. Carbon fibers find many uses because of their strength and light weight.

prepregs[10] to enable the development of 'stitching' and repair technology for large composite components needed in national aerospace sector;

- develop and establish SiC-SiC matrix composites[11] technology and facilities to make high temperature components for gas turbine;
- develop ceramic – ceramic composites; and
- develop and fabricate ceramic radomes[12].

The above mentioned activities were proposed to be undertaken through 17 projects of which 11 were to be solely executed by NAL, two were to be executed by NAL jointly with NML[13] and the remaining by other CSIR laboratories. Of these 13 projects, technologies were to be developed in eight projects and five projects were purely for basic research. Up to March 2007, only three projects were completed. A review of three completed projects revealed that in two of these, NAL failed to achieve project objectives due to deficient planning, as discussed below:

(a) A project titled 'Failure analysis and accident investigation and evaluation of thermo-mechanical properties' costing Rs.3.24 crore was undertaken in January 2004. The objectives of the project were to set-up an independent laboratory for carrying out failure analysis and accident investigation work and to investigate, evaluate mechanical properties of materials up to 1500^{o}C and generate data on failure modes in composites etc,.

As per the project proposal, an equipment viz. Static Mechanical Testing Machine was required to be commissioned by March 2005 for evaluation of the mechanical properties of materials. It was seen that NAL invited quotation for the equipment in January 2005 i.e. just two months before the targeted date of commissioning of the equipment. NAL placed purchase order in August 2005 and the equipment was received by NAL in January 2007 after making a payment of Rs.1.64 crore. However, the same could not be installed as of December 2007 as it got damaged during transit. NAL declared the project as complete in March 2007 without installing/commissioning the equipment costing Rs.1.64 crore and without utilising the equipment for evaluating the mechanical properties of materials.

The final report of the project stated that sufficient data could not be generated on failure modes in composites due to inadequate time and resources. However, the fact remains that the project was treated as completed despite non-achievement of the project objectives. The expenditure of Rs.3.24 crore including equipment cost of Rs.1.64 crore was largely rendered unfruitful. Resources and extensions, if required,

[10] Resin prepregs for laminates, which overcome the difficulties, experienced with the wet lay-up process. These composites possess good heat and chemical resistance, excellent surface hardness and fire resistance.
[11] Silicon Carbide composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure.
[12] A bun-shaped cover placed over a radar scanner to prevent risk of fouling and to protect it from the weather.
[13] National Metallurgical Laboratory.

could have been requested for achievement of the objectives of the project.

CSIR did not offer any comments on this issue.

(b) A project titled 'Development of Shape Memory Alloys[14] (SMAs) for aerospace and biomedical applications' was undertaken in January 2004 at a cost of Rs.81 lakh with a target of completion in March 2007. The objectives of the project were to develop new alloys[15] of nickel and titanium (Ni-Ti[16]) base with hafnium[17] (Hf) for the actuators[18] of the Light Combat Aircraft (LCA) and for biomedical applications. NAL declared the project as complete in March 2007. The final report of the project showed that the alloys developed under the project were composed of Ni-Ti-Cu[19] instead of Ni-Ti-Hf[20], as strain hardening coefficient of Ni-Ti-Hf alloy was significantly higher as compared to Ni-Ti-Cu alloy and, for processing of Ni-Ti-Hf wire, hot rolling followed by hot drawing was required. However, due to the non-availability of facility for hot rolling followed by hot drawing, alloys of Ni-Ti-Hf could not be developed. As regards development of alloys for bio-medical application, the final report of the project was silent and NAL also failed to throw any light on this issue. Thus, the objectives of the project remained unachieved due to failure of NAL to consider the facility for hot rolling with hot drawing at the time of planning the project.

CSIR did not offer any comments on this issue.

Thus, out of the three completed projects, NAL failed to achieve the objectives as envisaged in respect of two projects costing Rs.4.05 crore, due to deficient planning and poor project management.

1.7.1.3 Developing and sustaining high science and technology for aerospace programme

NAL, under this sub-programme, proposed to undertake R&D activities at a cost of Rs.80.70 crore in the areas of:

- futuristic propulsion[21] concepts;
- CFD[22] to validate designs and optimise flight vehicle shapes and

[14] Shape memory alloys (SMA's) are metals, which exhibit two very unique properties, pseudo elasticity, and the shape memory effect.
[15] An alloy is a combination, either in solution or compound, of two or more elements, at least one of which is a metal, or where the resultant material has metallic properties.
[16] Nickel and Titanium.
[17] Hafnium is a chemical element in the periodic table that has the symbol Hf and atomic number 72. A lustrous, silvery gray tetravalent transition metal, hafnium resembles zirconium chemically and is found in zirconium minerals. Hafnium is used in tungsten alloys in filaments and electrodes and also acts as a neutron absorber in control rods in nuclear power plants.
[18] An actuator is a mechanical device for moving or controlling a mechanism or system.
[19] Nickel, Titanium and Copper.
[20] Nickel, Titanium and Hafnium.
[21] It is the study of how to design an engine that will provide the thrust that is needed for a plane to take off and fly through the air.
[22] Computational Fluid Dynamics.

performance;

- Engine-airframe interaction;
- Mathematical modeling and genetic algorithms applied to flight controls; and
- Artificial Neural Networks[23].

The areas of activities were divided into 48 projects. Of the 48 projects, NAL was to execute 43 and the remaining five were to be executed by other CSIR units. NAL undertook these 43 projects in February 2005 with the scheduled date of completion in March 2007. However, NAL could not complete these projects in time and these have been extended up to March 2008. As of March 2007, an expenditure of Rs.38.40 crore was incurred by NAL on these projects.

The completion of projects by end of the X plan was envisaged under these MMPs. As the work on most of the projects under the three sub-programmes started after delays, the time schedule for their completion had to be extended by six months to two years. In two of the three projects completed, the objectives remained unachieved. Thus, NAL failed to achieve the objectives laid down for the MMPs under the X plan due to poor project planning and management.

Recommendation

NAL may ensure that mission mode projects are planned effectively and executed efficiently, so as to achieve the objectives within the set time frame.

1.7.2 In-house projects

In-house R&D programmes/projects are undertaken to develop intellectual property and knowledgebase[24] with the funds provided by CSIR. During 2002-07, out of the available amount of Rs.159.92 crore (excluding Plan expenditure on MMP and non-plan expenditure), NAL undertook only 65 in-house projects involving Rs.10.47 crore.

1.7.2.1 Imbalance in project portfolio

CSIR, in January 1996, observed that each laboratory should evolve a balanced portfolio of projects i.e. some that were industrially led, cost shared and market driven, whilst others should be self propelled[25] to create new processes, products, applications and markets. Performance Appraisal Board (PAB) suggested in February 2002 that Research Council of the Laboratory should be accountable for maintaining an optimum balance in S&T activities. The meager investment of only Rs.10.47 crore on in-house projects indicated continued low priority being accorded to basic research

[23] An artificial neural network, also called a simulated neural network or just a neural network is an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation.
[24] Knowledgebase include readily and commercialisable know-how, process improvements, technology and technique or a new product.
[25] Projects taken up with funds released by CSIR.

and development activities. Further, an analysis of scientists engaged in these 65 in-house projects showed that out of the total numbers of scientists, an average of only five *per cent* scientists were engaged in in-house projects during the last five years.

Thus, NAL not only failed to maintain a balanced portfolio of projects, it also could not give due emphasis to in-house projects and could not utilise them effectively to create new processes, products, applications and markets as discussed in following paragraphs:

1.7.2.2 Failure to achieve project objectives resulting in non-commercialisation of technologies

Audit selected 38 completed in-house projects for analysis, which disclosed that though the success rate of NAL in developing knowledgebase was quite high, it failed to transfer knowledgebase to end users for commercialisation in all the projects. The detailed status of development and transfer of knowledgebase is discussed below:

- In respect of four projects, no knowledgebase was proposed to be developed;
- In respect of three projects, no knowledgebase was developed as the same were closed/merged;
- In respect of three projects, the status of achievement of objectives could not be ascertained as NAL was unable to furnish documents in support of project completion;
- Though knowledgebase was developed in 28 projects, the same could not be transferred/commercialised so far.

Thus, on one hand NAL did not take up adequate number of in-house projects and on the other hand, it failed to ensure transfer and commercialisation of technologies wherever successfully developed. NAL, therefore, failed to achieve it's objective of development of aerospace technology for general industrial application.

CSIR stated in December 2007 that NAL undertakes in-house projects as preparatory projects to major sponsored projects. It also stated that these preparatory projects, which are taken up in anticipation of sponsored projects, are discontinued whenever the sponsored projects are approved and work continued under the sponsored projects. The reply of CSIR indicated that development of intellectual property and knowledgebase was not given adequate priority and was linked only to sponsored projects. In the process, NAL not only created imbalance in project portfolio, but also was not able to utilise the opportunity of developing its own knowledgebase for further commercialisation and general industrial use.

1.7.2.3 Inadequate documentation of in-house projects

Maintenance of complete project documentation including project proposals, progress reports, completion reports and project evaluation reports is essential for efficient project management, monitoring and review. Audit observed that NAL had not maintained adequate documentation in respect of most of the in-house projects, thereby rendering the whole process non-transparent and not amenable to subsequent

review.

Audit requisitioned documents in respect of 16 of the 65 new projects and 38 of the 97 completed projects. It was seen that:

- Of 97 completed projects, the scheduled date of start/completion, actual date of start/completion, estimated cost and status of submission of final reports of the projects could not be furnished for 82 projects.
- NAL also failed to furnish the project proposals and the completion reports in respect of 32 out of the selected 38 cases.
- Of 16 new projects, NAL furnished project documents in respect of only four and the status of execution of balance 12 projects was not furnished.

This indicated absence of an institutional mechanism for ensuring adequate documentation and follow up on research projects.

CSIR replied in December 2007 that NAL would ensure maintenance of proper documentation of all the projects.

1.7.2.4 Deficient monitoring of in-house projects

The Divisional Scientific Committees (DSC) monitor in-house projects in NAL. Each DSC is comprised of the scientists of the concerned division, members from academic institutions and representatives from sponsors/interacting agencies and is required to meet once in a year. A review of the minutes of the various DSC meetings revealed that of the 38 completed in-house projects selected in audit, 18 projects (47 *per cent*) were never discussed by DSCs during 2002-07. This indicated deficient monitoring of in-house projects by the DSCs.

CSIR stated in December 2007 that NAL would convey to the DSCs to ensure a closer monitoring of projects in future.

Recommendations

- *NAL may accord higher priority to in-house projects to create new processes, products, applications and markets and make adequate efforts for transfer and commercialisation of technologies, wherever successfully developed.*
- *NAL may ensure that documentation in respect of in-house projects is maintained properly and DSCs monitor them regularly to exercise effective control on execution of these projects.*

1.7.3 Grants-in-aid projects[26]

During 2002-07, NAL undertook 74 new grants-in-aid projects costing Rs.24.81 crore

[26] Projects involving a grants-in-aid given by Government departments, international bodies etc, by way of financial inputs, either in full or in part, assistance in kind e.g. equipment, training etc,. to supplement laboratory's efforts in ongoing or new R&D projects or for creating new capabilities/facilities.

and completed 84 projects costing Rs.15.32 crore, including 56 projects started before April 2002.

Audit selected 40 *per cent* (34 projects) of 84 completed projects for review, of which NAL provided details of 26 projects. Though knowledgebase was developed from 20 out of these 26 projects, only one was transferred/ commercialised[27] so far.

CSIR did not offer any comments on the issue.

One completed project and one on-going project are discussed to highlight deficiencies in project management:

1.7.3.1 Non-achievement of objectives

NAL undertook a project titled 'Establishment of an Integrated Pilot Plant facility for Carbon Fibre and Prepregs (IFCAP)' in March 2000 at an estimated cost of Rs.14.63 crore for completion in 28 months. The project was funded by Aeronautical Development Authority (ADA), Bangalore. Under the project, NAL was responsible for establishing a pilot plant, developing process technology for spinning of SAF[28], producing SAF, converting the SAF to carbon fibres to produce standard modulus (SMF) equivalent to T300 grade and intermediate modulus (IMF) equivalent to T800 grade carbon fibre on the pilot plant facility. NAL was also to develop the process technology for prepregging and production of unidirectional prepregs of requisite quality for LCA in the pilot plant facility. NAL was also to arrange qualification and certification of the carbon fibres and prepregs. The pilot plant had been planned keeping in view the aircraft requirements and also requirements of the space sector.

It was observed that NAL could erect and commission the pilot plant only in June 2004, two years after the target date, due to delay in providing requisite infrastructure by the sponsors. Pilot plant was commissioned and the project was declared complete in April 2005 after incurring an expenditure of Rs.17.02 crore. It was observed that though NAL could develop the process technology for preparation of carbon fibres of SMF, the carbon fibres of IMF equivalent to T800 grade could not be developed. Also, the qualification and certification of carbon fibres and prepregs could not be obtained.

CSIR stated in December 2007 that development of SMF equivalent to T300 grade and only R&D on higher grade i.e. T800 suitable were envisaged in the scope of the work. The reply of CSIR is not tenable since the project objectives clearly laid down NAL's responsibility to produce SMF equivalent to T300 grade and IMF equivalent to T800 grade carbon fibre on the pilot plant facility.

Thus, NAL failed to develop advanced fibres of T800 grade and also could not obtain type approval for the T300 grade fibre.

[27] Transferred in April 2007.

[28] Set spinning of special acrylic fibres (SAF); Acrylic Fibres- Acrylic fibers are synthetic fibers made from a polymer (Polyacrylonitrile) with an average molecular weight of ~100,000.

1.7.3.2 Cost overrun due to delays

A project titled 'Development of SiC-SiC[29] by Chemical Vapor Infiltration (CVI) technology' costing Rs.5.15 crore was sanctioned in March 2001 to NAL by Defence Metallurgical Research Laboratory, (DMRL), Hyderabad for completion by August 2005. The project aimed at acquiring know-how and establishing a CVI based technology based facility at NAL for generation of SiC-SiC based Ceramic Matrix Composite[30] components for aero-engine and other applications in the country. The CVI reactor system consisted of many subsystems like graphite reactor, gas control system and vacuum pumping system. The reactor could be used for CVI reaction to obtain SiC, BN[31] and C[32] ceramics.

Audit observed significant delays in the procurement of CVI Reactor systems. Though the project was undertaken by NAL in May 2001, indent for procuring various components of the system were raised only between July 2002 and December 2003. The orders were placed between November 2003 and March 2004 and the components were finally received during December 2004 and February 2005. NAL could install the system during January 2005 to April 2006. It was observed that the cost of CVI Reactor system escalated by Rs.2.10 crore. Though the project was being financed by DMRL, NAL also had to bear an additional cost of Rs.40 lakh due to project delays. NAL stated (September 2007) that since CVI facility was being established for the first time in the country, it's cost estimate was inaccurate.

CSIR stated in December 2007 that the additional project cost was sanctioned after a review by an expert committee. However, the fact remains that NAL had to bear the extra cost of Rs.40 lakh due to inaccurate estimation of the cost at the first instance.

Thus, even in case of grants-in-aid projects, NAL had not been very successful in transferring/commercialising the technologies developed for general industrial application.

1.7.4 Sponsored projects[33]

As of April 2002, NAL had 146 sponsored projects. During 2002-07, NAL undertook 271 new projects costing Rs.92.86 crore and completed 267 projects costing Rs.59.65 crore, leaving a balance of 150 projects as of March 2007. Of 267 completed projects, Audit reviewed 106 projects costing Rs.43.02 crore. Of these 106 projects, only nine projects costing Rs.2 crore were undertaken for private parties and the rest were undertaken for various entities of the Government.

[29] Silicon carbide-silicon carbide matrix.
[30] For application in weight reduction and performance improvement of aircraft engine.
[31] Boron Nitride.
[32] Carbon.
[33] Projects wholly funded by the client having specified R&D objectives and well defined expected projects output/results, generally culminating in generation of intellectual property/knowledgebase are known as sponsored projects. Can also encompass process design, engineering process etc,.

It was seen that of the 106 completed sponsored projects, 102 did not yield any technology for general industrial application. In 42 projects, NAL carried out various tests by utilising laboratory facilities. NAL fabricated aerospace materials for various clients in 15 projects. In two projects, NAL supplied materials to the private parties, which were produced on the basis of the available technologies. Thus, these 59 sponsored projects did not yield NAL any deliverables in the form of technology. Audit also observed that more than 50 *per cent* of the sponsored projects could not be completed within the stipulated time schedule.

Further, in 10 cases, NAL designed and fabricated different items, but failed to secure IP rights/licensing rights of deliverables for the design developed from the projects as the projects pertained to various organisations under Ministries of Defence, Atomic Energy, Space etc. Besides, 12 projects were taken up for undertaking various experiments for these organisations, which were considered as 'strategic' in nature. In respect of six projects, NAL did not intimate the deliverables of the projects and in another 19 projects, NAL failed to intimate the status of development of technologies.

CSIR stated in December 2007 that sponsored projects were taken up by NAL to meet urgent and specific technology requirements of strategic programmes of national interests. They stated that these projects are application specific and exploit NAL's knowledgebase and hence they cannot be oriented towards development of IP, which is incidental. The reply of CSIR needs to be viewed in the light of the fact that NAL neither ensured timely completion of the sponsored projects to provide efficient services to the user departments nor could it achieve its objectives of generating aerospace technology for general industrial application from such projects.

1.7.4.1 Loss due to undercharging

As per the Guidelines for Technology Transfer issued by CSIR in February 2005, the total cost of a project should be arrived at after ascertaining (a) total expenses[34] of the project (b) the amount of intellectual fees[35] and (c) the amount of Service Tax[36]. While the intellectual fee of a project should be arrived on the amount of total expense of a project, service tax should be calculated after adding total expense and the intellectual fee of a project. Scrutiny of documents of 24 ongoing sponsored projects as on 31 March 2007 revealed that NAL did not follow the above provisions and undercharged the sponsors as detailed below:

- NAL charged intellectual fees of Rs.3.76 crore as against the amount of Rs.7.54 crore to be charged from the sponsors due to application of incorrect rates; and

- No service tax was realised from the sponsors against the realisable amount of Rs.1.39 crore.

[34] Total expense includes payments for staff engaged, cost of consumables/raw materials/components with 25 *per cent* overheads, cost of physical inputs/services/utilities with 25 *per cent* overheads, equipment usage cost/cost of equipment, TA/DA, contingencies, and others.
[35] It is 33 *per cent* up to Jan 2005 and 40 *per cent* from Feb 2005 onwards.
[36] As per the rates fixed by the Government from time to time on the services rendered.

CSIR stated in December 2007 that they had permitted NAL to charge less intellectual fees to certain agencies due to their large scale investment in NAL's infrastructure. However, details of the agencies/ lower rates of intellectual fees were not made available other than in the case of Aeronautical Development Agency. As regards service tax, while accepting the contention of audit, CSIR stated that all present proposals include the applicable service tax when these are sent to the sponsors.

Thus, NAL suffered a loss of Rs.5.17 crore due to undercharging on account of intellectual fee and service tax in violation of the norms fixed by CSIR.

Recommendations

- *NAL may ensure that sponsored projects are taken up with a clear objective of developing intellectual property/ knowledgebase.*
- *All efforts may be made to commercialise the technologies developed from sponsored projects, as there is more likelihood of having a demand for the same in the market.*

1.8 Projects on development of aircrafts: HANSA and SARAS

1.8.1 HANSA

In 1980s, the need for indigenous development of a basic trainer aircraft was felt in India. As NAL had fabricated a light aircraft using imported design and in this process, developed infrastructure to undertake design and development of a light aircraft, Research Council approved a proposal in June 1988 for developing two-seater trainer aircraft for training, remote sensing etc, at a cost of Rs.50 lakh for completion in two-three years. The objective was to build indigenously, a low cost and acceptable cruise efficient aircraft with an all-up-weight of about 500-600 kgs and power around 70-90 bhp[37]. The cost of each aircraft was expected to be less than Rs.5 lakh initially. In November 1993, NAL flew HANSA-2 on experimental basis.

NAL, then undertook the design and development of the aircraft which was to adhere to the requirements of FAR[38] 23 certification, as per which, the weight of the aircraft was restricted to 750 kg. As the weight of the HANSA-2 developed by NAL weighed 865 kg, NAL developed the HANSA-3 with a reduced weight which was flight tested

[37] Brake horse power-measurement for comparing engine power.
[38] Federal Aviation Regulations.

in May 1998. NAL incurred a total expenditure of Rs.5.50 crore on the development of HANSA-3. Review of this project revealed the following:

1.8.1.1 Failure to develop components of HANSA indigenously

While reviewing the progress on HANSA in March 2000, Research Council (RC) of NAL recommended that priority should be given to indigenous systems, provided there was no basic compromise on technical requirements. Otherwise, in high-technology areas like aircraft, indigenous design and development would collapse.

Scrutiny revealed that in the process of manufacturing of the aircrafts, NAL had imported all the components as the work of development of the aircraft was initiated without developing the components.

Thus, despite the first and foremost objective of 'indigenous development' of aircrafts as envisaged in 1980s, NAL continues to depend on imported components for design and development of HANSA. Though development of indigenous-systems was one of the main objectives of the MMP in the X plan, NAL was unable to achieve the same during this period.

CSIR stated in December 2007 that parallel efforts have been initiated by NAL under X plan under the project 'Spearheading small civilian aircraft design and manufacture' to indigenise the imported components to fulfill the long term needs. This indicated that though RC in 1980 felt the requirement of indigenous technology, the same is yet to materialise as the aforesaid project has been extended till March 2009 (discussed in Para 1.7.1.1).

1.8.1.2 Non-transfer of technology for manufacturing and non-assessment of commercial viability of HANSA

HANSA, a two seater trainer aircraft, was envisaged for use in training and remote sensing. Initially, NAL was to design the aircraft and then the technology was planned to be transferred to private parties for development and commercial production. NAL entered into an agreement in November 1991 with M/s Taneja Aerospace and Aviation Limited (TAAL), Bangalore as an industrial partner for the same. However, TAAL refused to participate as a risk sharing partner and chose to work as a contractor. Consequently in 1999, NAL on the advice of RC and the Director, decided to undertake certification, production and marketing of the aircraft. NAL took up manufacturing of these aircrafts, in order to supply 10 aircrafts to the Director General of Civil Aviation (DGCA) for distribution to the flying clubs, which was beyond its mandate of design and development of aircrafts. NAL incurred an average manufacturing cost of Rs.43.30 lakhs for each aircraft against an estimate of Rs.5 lakhs. Further, this cost was understated as NAL did not include manpower and overhead charges while working out the cost of an aircraft.

CSIR replied in December 2007 that HANSA technology did not find any buyer as the industries were not yet mature enough to manufacture and market aircrafts. Reply of CSIR indicates that neither there is demand for these aircrafts in the market, nor the

market is willing to take the risk of manufacturing the same. This also supports the audit observation in Para 1.6.2.1 that NAL failed to identify niche opportunity areas, competitors, partners and market and accordingly, formulate a business strategy.

1.8.1.3 Performance of the supplied aircrafts

Out of the order for 10 aircrafts, NAL supplied eight aircrafts to DGCA between May 2001 and March 2005. The remaining two aircrafts were not supplied as of June 2007.

It was observed that one aircraft (VT-HNT) which was delivered to Andhra Pradesh Flying Club in May 2001 met with an accident in December 2004 in which the pilot was killed and the aircraft suffered substantial damages. Another aircraft, (VT-XAL prepared for demonstration purpose) which was flown by the Centre for Air Borne System (CABS) in April 2005 was forced to land as the propeller got detached from the aircraft.

NAL stated in July 2007 that it did not have any documents on investigations on these accidents done by them or DGCA. This indicated that there was no mechanism in place to monitor the performance of the aircrafts supplied in the market for possible improvements/enhancements in the design of the subsequently manufactured aircrafts.

1.8.1.4 Deficiencies in management of HANSA project leading to unfruitful expenditure and blockage of funds

For manufacturing HANSA aircraft, NAL purchased engines, propellers and other components. It was seen that the requirement for these components were not assessed realistically by NAL, which resulted in these components lying unutilised for long periods. These cases are discussed below:

(a) Procurement of engines: In November 2003, NAL placed a purchase order for procurement of 11 Rotax 914F3 engines at a cost of Euro 161903 (Rs.99.93 lakh). The engines were procured for production of HANSA aircraft in next two years and for spare/product support. Subsequently, the order for one more engine was placed in July 2006. The engines were supplied between July 2004 and June 2007. It was observed that of the 12 engines, seven engines costing Rs.64 lakh received during March 2005 to June 2007 had not been used as of July 2007. The very fact that these engines were lying in the stores since March 2005 onwards and that NAL had no further orders for production of these aircrafts over and above the 10 originally ordered, indicated that there were no prospective buyers for HANSA aircraft in the market.

(b) Procurement of propellers: NAL also procured nine propellers between May 2004 and October 2004, at a cost of Euro 42545 (Rs.24.34 lakh) for production of HANSA aircraft as well as for product support. Though the life period of these propellers was only two years, NAL placed supply order for procurement of 11 propellers at a time, in December 2003. Of these 11 propellers, NAL could use six propellers within their life period and remaining five propellers worth Rs.11 lakh could not be used. As a result, the life period of these propellers expired leading to wasteful expenditure.

(c) Similarly, 29 items procured by NAL in March-May 2004 at a total cost of Rs.11 lakh for giving product support and for production of complete HANSA aircraft remained unutilised for three years.

CSIR did not offer any comments on these issues.

Thus, the objective of providing indigenous two-seater trainer aircraft remained unachieved as NAL is yet to develop components of HANSA indigenously. NAL also could not find a private partner for sharing the risk of development and commercial production for HANSA. NAL took up manufacturing of HANSA without assessing the future commercial viability of the aircraft. As a result, there are no further orders for the aircraft in the market.

Recommendation

NAL may make efforts to assess the demand of the aircraft in the market in comparison with other similar aircrafts, make concerted efforts for marketing and find an industrial partner for large-scale production.

1.8.2 SARAS

In mid 1980s, Research Council recommended that NAL should study the civil aviation requirements of India and recommended ways and means of establishing a viable civil aviation industry. It further recommended that NAL should carryout a formal techno economical feasibility study of a multi role Light Transport Aircraft (LTA – renamed SARAS in October 1993). The feasibility study (November 1989) showed that there was a significant demand for a 9-14 seat multi-role LTA in the country and estimated a market potential of about 250-350 aircrafts in the next 10 years. NAL submitted the feasibility study report to RC in November 1990 and started its search for an industrial partner. Though two organisations[39] expressed their interest to be the industrial partners, none of these risk-sharing partnerships materialised, as these organisations backed out. In August 1995, RC recommended to put up the proposal to the competent financial authority (CFA) after identifying the industrial partner and the project cost was estimated at Rs.126 crore.

A project titled 'Design, fabrication and air-worthiness[40] testing of a 9-14 seater light transport aircraft (LTA)' was sanctioned by CFA in June 1999 to design, build and certify a 14-passenger LTA suitable for sale at a good profit in the Indian market by

[39] Bharat Dynamics Limited, a Public Sector Undertaking in the Ministry of Defence and Myasishchev Design Bureau in Russia.
[40] Being in fit condition to fly.

bringing together various technologies perfected at NAL over the decades and to promote establishment of a civil aviation industry in India, by designing civil aircraft for the Indian market. Under the project, two prototypes were to be fabricated to obtain DGCA certificate. CFA approved Rs.131.38 crore for this project. Of this, Rs.65.31 crore was to be contributed by Technology Development Board, Rs.9 crore by Hindustan Aeronautical Limited and balance Rs.57.07 crore by CSIR. While Prototype-I was targeted to fly in January 2001, the Prototype-II was expected to fly in December 2001. Scrutiny of the project revealed the following:

1.8.2.1 Time and cost overrun

It was observed that though NAL had laid down a time schedule for both the prototypes giving details of phase-wise execution of the project, it failed to adhere to its laid down milestones due to deficiencies in project execution and delays in procurements. This resulted in time and cost overrun including wasteful expenditure and blockage of funds. As against the target of January 2001, the Prototype-I flew in May 2004, i.e. after a delay of more than three years. Prototype-II undertook its first flight in April 2007, after a delay of more than five years. Due to the above time overrun, the cost of the project increased by Rs.22.53 crore i.e. a cost escalation of almost 17 *per cent*.

While explaining the reasons for delay in completion of the project, NAL stated in June 2007 that due to the imposition of sanctions by the United States of America, the procurement and development of avionics[41] could not be made in time. Justification of NAL was not tenable because the Government sanctioned the project in June 1999, more than a year after the imposition sanction by United States of America in May 1998. Also, the target dates of flight for Prototype-I (January 2001) and II (December 2001) were also fixed after imposition of sanctions by US Government.

Scrutiny of project related records revealed that the delay in execution of the project was mainly on part of NAL rather than sanctions by the United States of America (which were effective between May 1998 and September 2001) as can be seen from the paragraphs discussed below:

(i) Delay in raising indents: Though the target dates for first flight for the two prototypes were January and December 2001, NAL raised indents for 13 out of 15 major items between July 2002 and August 2005. These items were received between March 2003 and February 2007. One of the items viz. Auto Pilot System was yet to be supplied. Delays in placing indents for these items contributed to delay in execution of the work.

(ii) Failure to procure critical system: One of the requirements for FAR 25 certification was provision of Auto Pilot/Stall[42] Warning System (SWS) in the

[41] All the electronic and electro-mechanical systems and subsystems (hardware and software) installed in an aircraft or attached to it. Avionics systems interact with the crew or other aircraft systems in these functional areas: communications, navigation, weapons delivery, identification, instrumentation, electronic warfare, reconnaissance, flight control, engine control, power distribution and support equipment.

[42] A stall in an aircraft is an event that causes the aircraft to drop suddenly.

Prototype-II. This system is helpful in reduction of workload of pilot in flights of longer duration. After failing to procure this system from the international market, two separate projects for indigenous development of the same were initiated in 2003. However, the projects were short closed in September 2005, as NAL was not in a position to provide all necessary input/output data to enable the Indian firm to continue the project. Therefore, the expenditure of Rs.1.80 crore incurred on the project proved infructuous. Subsequently, NAL placed a supply order in June 2006 on an Indian firm for co-development of Auto Pilot Systems at a cost of Rs.8.81 crore. The work was yet to be completed (July 2007).

(iii) Failure to place order for mechanical linkage: NAL decided in November 2003 to procure one Control Loader Unit and Mechanical Frame for arranging training simulator for SARAS aircraft. The Control Loader was to be mounted on the SARAS training simulator and mechanical linkage was to be used to attach the Control Loader. The laboratory decided to get the work of mechanical linkage done through an indigenous firm. However, NAL did not place the order for work on mechanical linkage. For procurement of Control Loader, supply order was issued in May 2004 and NAL received it in November 2004 at a cost of Rs.33 lakh. However, the same could not be used till date (July 2007), as the order was not placed for the mechanical linkage.

CSIR did not offer any comments on these issues.

1.8.2.2 Delay in obtaining certification for airworthiness by DGCA

A certificate from DGCA is required for airworthiness of the aircraft, certifying adherence to minimum acceptable international laid down standards. NAL applied for this certification i.e. FAR 23/ FAR 25 for SARAS in October 1997, which is yet to be granted by DGCA.

Audit observed that one of the most important reasons for delay in getting DGCA certification for airworthiness was the weight problem of the SARAS aircraft. As per the requirements of FAR 23/FAR 25 certification, initial design all-up-weight of SARAS was targeted to be 6100 kg. However, in October 2000, RC observed that the weight of the aircraft was anticipated to be 6600 kg and that the final weight would only be known in the production stage. Scrutiny of the minutes of meetings of RC during 1989 to 2006 revealed that from the very beginning of the SARAS project, right from the design stage itself, RC had suggested that NAL take utmost care in managing the weight. To reduce weight to the required level of 6100 kg, a weight optimisation exercise was initiated in August 2006. NAL stated in July 2007 that the weight of SARAS was significantly higher than the targeted weight. This was mainly due to conservative design of all the components, systems and sub systems as aircraft was designed for civil transport category for the first time in NAL with stringent safety requirements. The reply of NAL is not acceptable as the weight limit of 6100 kg was known to them while applying for Type Certification of Aircraft (FAR 25) in October 1997. DGCA stated in September 2007 that flight certification would be granted only after 2010 as NAL has to carry out various tests and generate a large

volume of documentation. It also stated that NAL may have to make a third prototype.

CSIR stated in December 2007 that time and cost estimates made at the time of proposal needed revision based on realistic assessment as the project progressed. The reply of CSIR needs to be viewed in the light of the fact that need for a Light Transport Aircraft was felt in 1989 with significant market potential, but even as of 2007, NAL has not been able to successfully develop such an aircraft to exploit the market potential.

1.8.2.3 Deficiencies in management of the project

It was seen that the project was not planned properly and instances of mismanagement in procurement as well as project execution were noticed. These cases, which contributed to cost overrun of the project, are discussed below:

(a) Injudicious procurement of engines led to avoidable expenditure of Rs.1.34 crore

NAL proposed to design and develop two prototypes viz. PT-I and PT-II of SARAS and targeted their first flights in January 2001 and December 2001 respectively. For this purpose, a certificate viz. FAR-25 was required to be taken by NAL from DGCA for SARAS aircraft. As per the requirements of FAR-25, the power of the engine should be 1200 shaft horsepower (SHP). Despite being aware of this requirement as early as in October 1997, NAL issued a supply order for procuring four engines of 850 SHP instead of 1200 SHP in September 1998 to a foreign firm for PT-I and II. This indicated deficient project management which overlooked basic aviation standards/requirements. This resulted in procurement of unsuitable engines which ultimately led to the PT-I being tested with lower specification engines and engines procured for PT-II had to be sold back to the firm incurring substantial losses as discussed below:

One set of LH (Turboprop Engine Reverse Rotation) and RH (Turboprop Engine Standard rotation) engines were required for PT-I and a similar set of engines was required for PT-II. NAL received two LH engines with 850 SHP costing US$ 4,48,698 and US$ 4,50,000 in 1999. Two RH engines with 850 SHP were supplied to NAL on loan basis by the supplier, free of cost up to March 2003.

It was observed that one LH and one RH engines were used for the PT-I. As the engine with 1200 SHP was required for the PT-II, one LH and one RH engine of 850 SHP became redundant. As such, NAL could not use the second set of one LH and one RH engine, before the expiry of loan period i.e. March 2003. It also failed to return the same to the firm before March 2003. As NAL expected a delay in the first flight of PT-II, it requested the firm in January 2003 to extend the loan period to March 2004. However, the firm refused to extend the loan period and NAL was forced to buy them at a cost of US$ 3,00,000 (US$ 1,50,000 each) in June 2003. It was inappropriate on the part of NAL to buy engines with lower SHP which did not conform to FAR-25 requirements.

It was only in February 2005 that NAL procured three high power engines of 1200 SHP at a total cost of US$ 7,50,000 (US$ 2,50,000 each) and sold one set of old LH and RH engines of 850 SHP for US$ 3,00,000 to the firm. The firm fixed the exchange price of the said old engines as US$ 3,00,000 (US$ 1,50,000 each) as against the cost price worth US$ 5,98,698 (US$ 4,48,698 + 1,50,000).

Thus, the injudicious decision of NAL to procure 850 SHP engines knowing very well the FAR 25 requirement of 1200 SHP engines resulted in a financial loss of US$ 2,98,698 (equivalent to Rs.1.34 crore), being the difference in the cost of the engines for PT-II.

(b) Blockage of fund due to advance procurement of passenger seats

NAL imported 28 seats for SARAS in July 2002 at a cost of Rs.80 lakh. These seats have not been fitted in the aircraft till date. The reasons for non-utilisation of seats even after expiry of five years from the date of receipt were not on record. NAL stated in July 2007 that the above materials would be installed after the aircraft was certified by DGCA. Thus, due to advanced procurement of these seats worth Rs.80 lakh, the amount remained blocked for more than five years. CSIR did not offer any comments on this issue.

Thus, even after a lapse of eight years, the project SARAS is still not complete. Meanwhile, the cost estimate so far has gone up by 17 *per cent*. Both the prototypes are still awaiting certification by DGCA for flying due to NAL's inability to bring the weight of the aircraft within the admissible limits. DGCA has not ruled out the necessity for NAL to build a third prototype before granting certification of air worthiness. This would further delay the process and increase the cost of the aircraft.

Further, as per the Report of the Working Group on CSIR for the XI plan, design and development of a 70 (+/- 20) seater regional transport aircraft has also been proposed for NAL. Keeping in view the poor market demand for HANSA, the tardy progress and cost overrun in development of SARAS, Ministry/CSIR may reconsider the proposed plan for development of a 70 seater regional transport aircraft.

Recommendations

- *In view of failure of NAL in obtaining DGCA certification on airworthiness, despite a lapse of ten years, CSIR may review the continuance of the SARAS project.*
- *Keeping in view the problems faced by NAL in HANSA and SARAS projects relating to marketing of the aircrafts, difficulties in finding an industrial partner and lack of specialised manpower, NAL may review initiation of the new project for development of a 70 seater aircraft.*

1.9 Conclusion

NAL is far from achieving the goal of improvement in External Cash Flow and continues to be largely dependent on CSIR funds. Research management was weak as it failed to identify niche areas for research and development and maintain a balance in its project portfolio. It's performance in transfer of knowledgebase to end users continues to be low as a result of which their earnings from transfer and commercialisation of technology is insignificant. Further, NAL could not achieve its targets for filing of patents and impact factor of research papers published. Many projects taken up by NAL also failed to fully achieve their objectives.

The two-seater trainer aircraft HANSA, though developed, is still being manufactured with imported components as NAL is yet to develop these sub-systems indigenously. After the initial order of 10 aircrafts, there is no further demand for it in the market. Similarly, the project on the 9-14 seater SARAS has suffered time and cost overrun. Further as per DGCA, NAL may have to build a third prototype before being granted the certificate for airworthiness thereby adding to time and cost overruns.