Chapter -4
BENCHMARKING OF THE MODELS/METHODOLOGIES IN USE

This chapter benchmarks some of the models & methodologies in use with the help of a sample set of DRDO projects and a detailed case study based on the experience of the researcher in the Indian guided missile development programme. Based on this analysis the inferences for the integrated model are drawn and are incorporated in the new model.

4.1 NEED FOR BENCHMARKING

As brought out by the literature survey, hundreds of models have been evolved in the literature but surprisingly very few have found acceptance by the real life managers. As a result of this, each project found its own way of dealing with the problems faced during the selection & execution phases. The parallel body of knowledge thus developed, is not available through the literature. This led to limited utility of the existing models. Hence there is a need to study and benchmark the various models/methodologies in use.

4.2 ANALYSIS OF SAMPLE SET OF DRDO PROJECTS

Defence Research and Development Organisation (DRDO) has been created in the Defence Ministry primarily to design, develop and lead to production of various Weapon systems as well as to develop the state-of-the-art technology required for advanced systems, in order to equip the armed forces. The requirements of the weapon systems are generated by the Services based on their needs and the threat perspective, which they anticipate in advance. Technology trends elsewhere and the need for modernisation of the existing systems dictate the specifications of the systems required for the three Services to counter the threats posed in and around the borders. DRDO with its 50 R&D Laboratories has contributed significantly to this venture. Many projects and programmes have been undertaken by the organisation and a tremendous support has been provided to the Defence through technology excellence.

As explained in chapter-3, a survey has been carried out to obtain the information and suggestions from all the DRDO laboratories and major
Project/Programmes with a view to understand real life problems faced by various projects of DRDO with the help of a questionnaire.

A total of 30 DRDO laboratories responded with information on more than 62 sample projects and subprojects. This includes 15 technology build-up projects and 47 staff projects with a distribution of 24 Army projects, 9 Airforce projects, 4 Naval projects and 10 projects for more than one services.

In terms of the cost of the projects the projects are distributed as follows:

- (i) project cost < 25 lakhs - 12 projects
- (ii) Project cost < 1.0 crore - 12 projects
- (iii) Project cost < 5.0 crore - 16 projects
- (iv) Project cost < 20.0 crore - 11 projects
- (v) Project cost < 100.0 crore - 5 projects
- (vi) Project cost > 100.0 crore - 6 projects

Valuable feedbacks has been obtained from the above sample projects and a brief summary of various sources of project origination, evaluation and selection methodologies, project management systems/tools used, problems experienced and suggestion for improvement are given in the following paragraphs.

4.2.1 ORIGINATION OF PROJECTS

The survey indicates the origination of the projects may occur due to diverse sources. The various sources of origination for the projects in the sample set includes:

a) Requirements from user, which includes:
- Requests for simple study/analysis (only knowledge generation)
- Requests for product development as per given specifications (projection based on perceived future requirements)
- Requests combined with partial funding of the development projects (participation)
- Requests followed by placement of production orders (financial commitment)
- Requests for product development that are required for integration/replacement of new/existing systems. (financial as well as schedule commitment)

b) Technology forecasting, future projects, happenings, elsewhere in the world, perceived need for core-competence development, need for technology demonstration etc.

c) Subprojects for major programmes

d) Results of study projects/recommendations of seminars/brainstorming sessions/working group discussions

e) Problems faced during the previous/existing projects, recommendations of the trial teams/review teams.

f) Extensions of the project completed successfully, variants, derivatives and technology spin-offs.

4.2.2 INITIATION, EVALUATION AND SELECTION

As soon as a project requirement originated from any of the above source, the initiation is carried out through a project proposal. The proposal is evaluated and if found suitable, the project is selected.

The various evaluation mechanisms followed for the sample set of projects include:

a) technical feasibility study based on the previous experience on similar projects, literature survey etc.

b) Peer review

c) Pilot study projects

d) Iterative improvement of project requirements through a cycle of feasibility study & user interaction.
If a project is found suitable by any of the above methods, it is selected and sanctioned. The sanction is carried out at multiple levels, depending up on the origination of the project and its cost.

4.2.3 EXECUTION MECHANISMS

The survey indicates the existence of a large variety of project execution mechanisms for the sample set of projects. This includes:

a) small projects executed by a group of scientists belong to a particular department of a lab

b) laboratory level projects with lab Director being the chief of the project. This includes:

- projects where a complete lab is dedicated for a single project
- multiple projects sharing the common resources of a lab with matrix structure

c) large projects spanning across many laboratories, managed by dedicated project management teams and programme management groups.

The projects are progressed with the help of a large variety of management structure which include 3 tier & 2 tier management boards, steering committees, advisory councils, working groups, task forces, etc.

4.2.4 PROJECT MANAGEMENT SYSTEMS/TOOLS USED

a) Most of the labs/projects reported that they are using

- Bar charts/Gantt charts and PERT charts for planning
- Periodic reviews and progress reports (weekly, monthly, quarterly, half yearly and annually) for monitoring and control.

Assessment of progress is invariably being made through periodic review meetings and physical progress assessment by visit of project personnel to the work centres.
The controlling and problem solving mechanisms again reported to be mainly through periodic review meetings, peer reviews, specialist committees and interactions.

It has been observed that each project is having its own unique setup with a particular organization structure, review and monitoring as well as controlling mechanisms. Also there has been wide disparities on the level of monitoring and review as well as reporting mechanisms.

b) Further to this use of specialized management systems/tools has been reported for planning and monitoring purposes by some of the labs/projects as given below:

- A centralised programme management information system linking all the projects and work centres, works with the help of a centralised database updated every month based on the feedbacks received from all the work centres and projects and generates fresh reports at the beginning of every month for various levels of the programme management. The main purpose of this tool is to monitor the progress at various work centres with a view to surface the problems well in advance and also to improve the communication between the projects and the work centres.

- A tool based on a centralised control centre called PACE chamber, used mainly for resolving inter-project and intra-project resources/priority clashes and to progress critical activities by ensuring that necessary resources and priorities are available for all the critical activities.

- A computer based tool for keeping track of programme funds right from the sanction phase to the commitment and expenditure including FE, such as PULSE.

- The work package definition document (WPDD), a tailored version of MIL standard 1521 B, for planning.

- Weekly progress reporting from each work centre for the purpose of progress monitoring.
4.2.5 PROBLEMS EXPERIENCED

The following are some of the problems experienced by the sample set of projects as reported during the survey:

a) User related problems

- User not clear about their requirements at the time of project formulation
- Projected user requirements are incoherent and incomplete with number of technical gaps
- Continuous change in the user perceptions, project scope and specifications during the execution of the project
- Very long user evaluation time resulting in the delayed induction

b) Planning related problems

- Difficulties in the assessment of technology requirements/availability of skills at labs/PSUs/Other institutions at the time of project planning has resulted in underestimation of efforts required in terms of time, cost & resources.

- Facilities for hardware realization in the required quantities could not be planned in advance and hence to make available large number of hardware for user trials, facilities were required to be augmented at a later stage. This resulted in time & cost overrun.

- Fixing up of responsibilities, allocation of funds and time frames were not seriously worked out at the time of sanction of project. This resulted in major structural changes during the execution phase.

- Technological and hardware inputs are assumed to arrive at a particular point in time, but this did not happen.

- Handling of some of the technologies for the first time has posed problems in making correct estimates of time frames, development cost, fixing of responsibilities and make/buy decisions resulting in need for parallel/multiple approaches.
- There is a wide gap in the perception about the technical requirement of the system between the users and the planners (user need to be enlightened).

c) Problems during execution

- During the course of development work some difficulties/system failures were observed which necessitated major design modifications and use of materials/processes not envisaged in the planning stage. These have led to additional design cycles and development of new technologies, thus requiring additional resources and funds.

- Delay in the make/buy decisions and decision on the choice of development partners resulted in late starting of certain work packages.

- Rapid obsolescence of some of the electronic devices triggers multiple design iterations

- Embargo on the import of certain components from advanced countries

- Shortage of specialist manpower in certain areas, requires time sharing.

- Loss of trained manpower in the middle of the project and new manpower was inducted but need for their training delays the projects.

- Difficulty in assessment of problems of the partner/subcontracting agencies, dependence on sub-subcontractors by the subcontracting agencies.

- Delay due to change of work priorities at partner agencies. Realistic estimates with respect to the work assigned to public sector units is not possible due to changing priorities accorded by them to our work.

- Production agencies do not take the orders seriously as the value of our orders are small hence planning made by the projects completely gets upset. There is a need for continuous presence of project personnel at work centres.
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- Continuous stream of unforeseen technical problems experienced in some projects/systems

- Lack of enthusiasm and changing of priorities & resources at some of the partners.

4.2.6 SUGGESTED IMPROVEMENTS FOR DRDO PROJECTS

The following are some of the improvements suggested by various project leaders during the survey.

a) Classification

- Apart from classifying the projects on cost basis, they should be grouped based on technological areas and other important parameters, including nature of the project.

b) Project feasibility & sanction phase

- A detailed feasibility study to ascertain the availability of the relevant technology or the capability to develop the required project is essential and should be made compulsory for all major projects. If more than one laboratory is involved in project implementation phase, preparation of a detailed document covering all the aspects of the project work, specific work responsibility of each of the participating laboratories, manpower and fund allocation, etc., helps in visualising the actual magnitude of the work at each work centre. This will also help to identify the critical systems of the project which require close monitoring for the successful completion of the project.

- The Competent Project Sanctioning Authority should insist that labs/departments proposing projects should take the utmost care and exercise maximum planning in putting up new proposal. Especially in case of the product development projects, authorities should make it mandatory for constant interaction with the users through the proposal phase of the project. Concretisation of goals and specificity in project output and its ultimate goal namely delivering the product to the users.

- Draft project proposal should be exhaustively planned, taking into consideration all the factors for its successful output. Any major project
c) Project Execution

- The project team should have a judicious mix of scientists, user officers and engineers from production agency, so that when the product is ready for production, the team can peel off to the production centre to ensure smooth transition from development to production and when the product is ready for operational induction, the user team can peel off to the user base to ensure continuity of training, operational utilization of the product and sustained product support.

- Joint funding by Lab/User/Production Agency is essential to ensure adequate involvement on the part of all the participating agencies.

- A clearly defined Task Directive issued to all the participating scientists upto the level of scientists, will definitely help in getting the best out of each scientist.

- A weekly activity chart - may be even daily activity chart if the task priority so demands - and its vigorous follow up at all levels of project implementation is essential.

- Team build up and sustaining its enthusiasm over the full project cycle is very difficult, but essential. This may necessitate introduction of motivation features and re-organisations at appropriate events.

- Check and control mechanisms need periodic updating based on the experience gained during project execution.

- The projects are multi disciplinary in nature and hence a heterogeneous group is required to progress it, achieving as far a level of homogeneity as possible keeping the overall objective in mind.

- For certain smaller projects the efforts in the review mechanism some times may exceed the efforts in the actual development. Effective
review mechanism would be more useful in the Mega projects involving multiple agencies with long lead times.

- Incentives for early completion of assigned tasks should be incorporated in the contractual obligations, which should be substantial to motivate the partner.

- A look ahead group for each project to work on next generation of the current product under development will ensure timely availability of the upgraded system to the user; thus enhancing the credibility of the development team in the eyes of the user.

d) Portfolio Management

- There should be a System Engg. & Monitoring group in each lab which should plan and monitor all projects equally well. Managerial problems can always be overcome. But technical problems are given less importance and hence do not get solved adequately. A strong system Engg. group in each laboratory can solve such problems.

- A programme monitoring group with a representative from the user is desirable for overseeing the project.

- There is a need to develop an integrated MIS on projects centrally at HQrs. The decision making authorities can seek information from this database interactively online. Though the creation & maintenance of such a voluminous database is labour intensive but will serve useful purpose in the long run. Such a system will also help in avoiding duplication of scientific research and make the expertise generated at one laboratory accessible to other labs.

- Use of matrix management with a common programme group is found most suitable for management of a portfolio mix of projects

- Use of special tools such as CASMS & PACE of IGMDP are very useful
e) Networking & interactions

- LAN/WAN facility within organisation, between research laboratories, academic institutions and public and private organisations for optimum utilization of resources for timely realization of set goals. Interconnecting of the work centres and working groups on a LAN would immensely help in free flow of up-dated information in respect of project progress and procurement status. A dedicated procurement cell for a project will greatly enhance material management.

- Organisation should evolve certain hardware/software modules, components, subsystems etc. which can be adopted by all labs, like power supply modules, signal processing subsystems, application specific integrated circuits (ASICS), Hybrids, display systems, etc.

4.2.7 SUMMARY OF OBSERVATIONS FOR CASE STUDY ON SAMPLE SET OF PROJECTS

The above case study reflects the various methodologies in use, typical problems & concerns of the real life projects. Among many issues, the following important observations can be derived, that are directly relevant to the present study.

a) Origination of projects:

- Projects originate from a very wide spectrum of sources ranging from user requirements to the technology forecasting.

- The origination can occur at any point in time. Hence the project evaluation & selection process should be viewed as a continuous process rather than an once-in-a-year process.

- The type of projects may range from a pure theoretical study to a complete product development cycle. Hence the project selection model should be able to handle all types of projects.
b) Initiation, evaluation & selection

- Considerable difficulty is experienced in the assessment of technological requirements, time, cost & resource requirement, make/buy decisions, and partnership decisions.

- In reality, the estimates made at the beginning undergo drastic changes during the execution. Number of unforeseen internal and external factors may change the direction of the project.

- Evaluation of projects in real life is very complex and involves multidisciplinary teams and detailed analysis and iterations.

- Peer review, stands out as the single most useful method for evaluation of projects in the face of technological uncertainty.

- All the above indicates that project evaluation cannot be an one time exercise. Projects must be continuously evaluated throughout their life cycle.

c) Project execution

- Real life projects use a variety of tools for planning and monitoring. However most of existing tools are inadequate to reflect the actual status of the R&D projects.

- Projects face a large number of problems during their execution. These problems range from ambiguous/changing user requirements, unforeseen technical problems during R&D, problems in productionisation, delayed/stretched user evaluation etc. The problems also originate due to constraints on the availability of specialist manpower, funds, facilities, raw materials, components & devices etc.

- The above problems show that a successful project requires good user participation & commitment right from the beginning, production preparedness as a part of the development and effective management system that ensures solutions to all the problems and availability of resources required for project progress.
The management systems need to be tuned based on the type of project. However, the existing classification schemes are inadequate to handle large types of R&D projects and hence there is a need for suitable classification models for this purpose.

There is a need to make use of the latest developments in the information technology such as the computer networking to progress the projects that spread over a large number of organisations.

4.2.8 The above case study broadly indicates various models/methodologies in use and provides inferences for the new model. However, in order to gain further insight into the complexities and factors responsible for the success of the projects, it is necessary to study some of the successful projects in detail. Keeping this in view, a detailed case study of the Indian guided missile development programme is undertaken, the details of which are given below.

4.3 CASE STUDY OF IGMDP

4.3.1 BACKGROUND

Integrated Guided Missile Development is one of the major thrust programmes of the DRDO. The Defence Research and Development Laboratory (DRDL) of the DRDO has been identified as the Lead Centre for the Design and Development of Guided Missile Systems and thus leading them to Production. During the period from 1970 to 1982 the Laboratory established the System Engineering and Technology for the development of Surface to Air and Anti-tank Missile systems. Though these missiles underwent multiple flight trials, they could not be finally inducted into the Services due to the change in user's requirements. This had happened because of a high rate of obsolescence in the missile technology and the necessity to use the best possible weapons as and when they are demanded. Hence in 1982, the Government appointed a Committee for the Missile Technology Policy with Dr. APJ Abdul Kalam, as Chairman, to forecast the technology requirements for the next 15 years, so that the systems developed would be contemporary at the time of their induction into the services.
Based on the emerging technology scenario and DRDL’s expertise, the Government approved 5 projects, 4 of them directly for User Services and one technology demonstrator. Thanks to the foresight of DRDO and political leaderships, government launched the Integrated Guided Missile Development Programme (IGMDP), simultaneously taking up all 5 Projects together and also funding for a Limited Series Production Facilities at the time of its sanction. The Management Structure also was evolved for a continuous commitment from the Developing Groups, Production agencies and the Defence Forces.

4.3.2 BRIEF DESCRIPTION OF THE GUIDED MISSILE PROGRAMME.

The five projects of the Guided Missile Programme are:

i) Prithvi:- It is a Surface to Surface Battlefield Missile. It uses a single stage, twin engine liquid propulsion system and strap-down inertial guidance with real time software incorporated in the on-board computer to achieve the desired accuracy during impact. Prithvi has unique features such as the multiple, field interchangeable warheads, manoeuvering trajectory and higher lethality compared to any equivalent class of missiles.

ii) Trishul:- It is a highly mobile, low level Quick Reaction Surface to Air Missile. It can also be used as an anti-sea skimmer from a ship against low flying attacking missiles. It employs a dual propulsion mode, high energy, solid propellant rocket motor, and is operated on command guidance. It has necessary ECCM features built into it as counter measures, wide operating range and higher quantity of warhead. The multirole capability provides Trishul an edge over other comparable missiles.

iii) Akash:- It is a Medium Range Surface to Air Missile and uses high energy propellant for the booster and ram-rocket propulsion for the sustainer phase. It has a dual mode guidance, initially on command mode from a phased array radar and later homing guidance. The radar provides capability for multiple target tracking and simultaneous deployment of missiles to attack those targets at the same time.

iv) Nag:- It is a Third Generation Anti-tank Missile system with ‘fire-and-forget’ and top attack capability. It predominantly uses composite materials for the airframe, and employs a smokeless solid propellant for the propulsion. Imaging infrared guidance and Millimetric wave radar operat-
ing at the W-band are being developed parallelly to provide the fire and forget capability and to eliminate the need for Man in the system loop. The HMX based tandem warhead in the missile helps to penetrate the latest armour. India will be the first to deploy such a class of missile in the world.

v) Agni: It is a Re-entry Test Vehicle intended for Technology Demonstration. It used a solid propulsion booster and liquid propulsion upper stage derived from the Prithvi. The strap-down inertial navigation system possesses explicit guidance, which was attempted for the first time in the world. Agni employs an all-carbon composites structure for protecting payload during its re-entry.

It can be seen from the above technical description that IGMDP has attempted for the best technologies to give competitive edge.

4.3.3 MANAGEMENT THRUST

All the five missiles provide technology and management challenges. Hence, the thrust for management evolution was:

i) The missile systems when provided to the User Services are contemporary or excellent in performance compared to the world class missiles available for use. Also they need to be reliable, cost effective, maintainable and easy for operation during deployment.

ii) It is all the more important to cut short the total duration of the design, development and production-to-deployment period. Hence it was decided to adopt a concurrent development-production philosophy.

iii) The Management system should ensure effective participation from the user, production agencies, academic institutions and R&D Organisations, to harness the best talents available in the country.

4.3.4 INITIAL CONSTRAINTS

In 1983, at the time of obtaining the programme sanction, the technological base prevalent at DRDO and in other research establishments in the country, was not adequate accomplish the desired milestones in a short stipulated span of time. This had been mainly because of the fact that a
number of high technology packages were to be undertaken simultaneously and this type of handling had never been tried in the past. However, the availability of limited timely information on various technical aspects of missile technology, in adequate availability of a trained manpower and, meagre resources forced for an active participation of multiple work centres and desired to have a continuous inflow of dedicated and quality personnel. Indeed, the programme took a tough challenge through its multiproject environment by developing at the same time, five sophisticated missile systems. Therefore, judicious sharing of the available resources within the country, reallocation of different priorities as the situation demanded, and a progressive induction of skilled manpower as and when needed, had been forming part of the broad strategy evolved for the purpose. The compressed time frame for the entire development plan was necessitated by the fast obsolescence of the technology, on one hand, and a pressure to demonstrate the reliability of the missiles on the other side. It was achieved by undertaking a number of flight tests, for the users before their deployment into the Services. Thus, the scenario in 1983, posed to the management, was manifested with a demand for a high technology, larger trained personnel and resources in a limited allowed time schedule.

4.3.5 IMPLEMENTATION STRATEGY

In order to achieve the preset goals, and taking into account the constraints enumerated above, an effective strategy had been adopted by utilising the expertise developed within DRDO during the previous three decades in different laboratories, from other R&D Organisations, from various industries who had built in infrastructures for fabrication of the relevant hardware and, from certain academic institutions who, would be in a position to contribute to the successful design and development of various software packages required from time to time. The partnership as it emerged through their involvement, consortium and, concurrent technology transfer is explained as given below.

4.3.6 PARTICIPATIVE MANAGEMENT

The user, a most vital link in the participation of the programme, always demands the best possible weapons with high reliable performance. Time schedule control and cost effectiveness are the other prime considerations for him. DRDO laboratories scattered in various parts of India, harnessed the entire expertise at their command, for the promotion of the programme.
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Academic institutions selected for their cooperation, make available the peer review in establishing confidence in the State-of-the-art technology. In the same way, a number of R&D establishments participate in various technical consultancies, and also help in the programme by providing subsystems, developed for the purpose. All these measures result in greatly reducing the development time for the programme in its totality, and also relieve the management from inducting more work force of the technical manpower. They also ensure in non-repeating of the technical skills so obtained and infrastructure so developed over a continuous research for a long time, elsewhere. Industries both public and Private controlled, absorb the new technology produced in the DRDO laboratories and establish the required production set up for the quality items to the desired quantity. All these five agencies are linked together in the programme, from design to development with specified role in the participation.

4.3.7 MANAGEMENT STRUCTURE

IGMDP adopted a 3 tier Management Structure. Guided Missile Board (GMB) is the apex forum for the management of the IGMDP. Its members are drawn from Government representing the Ministry of Defence and Finance, User Services, Production, and other experts to provide decisions on the mission objectives, technological options setting up of targets, inter-departmental priorities, and allocation of the funds. The Board meets once in every six months time.

The Programme Management Board (PMB), which is the second tier management structure, integrates the Chief Executives of various R&D Labs., Production Units, Finance and User Services who are directly involved in assigning priorities for performing different tasks towards the goals set up by the Guided Missile Board. This Board meets once in four months to review critical activities and work around plans.

Each of the 5 projects, under the IGMDP, has its project Management Board (PJB) with the project Director as its Chairman. This Board meets once in two months and reviews the monthly progress of tasks with participation of System Managers.

The Public Sector Industries which are directly contributing to the programme towards establishment of Limited Series Production Facilities
and technology transfer from R&D, provide their performance details to
the Production Management Committee (PMC), which is responsible for
gearing up the PSUs towards productionisation.

The Programme Directorate and the Directorate of Planning & Resources
exclusively set up for IGMDP, are the vital links between various Manage­
ment Boards, different Technology Centres, the PSUs, Industries, Institu­
tions, User and the Government machinery towards task progress and
financial management.

This unique management structure evolved, for first time in the country,
and consisting of integrated R&D, Production, User and the Government
agencies, in three levels is to ensure commitment and adherence to deci­
sions of the Management Boards, and thus bringing a synergetic ap­
proach.

4.3.8 MATRIX MANAGEMENT

The Guided Missile Programme with five Projects involving research,
design, development and productionisation, needs to share a number of
test facilities, equipment and specialised manpower. The management of
such a system with limited resources is rather complex. At each stage
separate strategy has to be adopted for obtaining better results.

Each project is headed by a Project Director, who reports to the Chair­
man, PMB, who provides the guidance, monitors the progress, gives
financial sanctions and solve the inter project priorities whenever sharing
of common facilities are involved. The Project Director is assisted by a
Deputy Project Director, and Project Managers in the projects. Each
manager is identified with the responsibility of realizing the subsystems
from the various technology directorates and/or from production centres.
For realising the ground systems pertaining to the three users, separate
Project Managers are selected. At the technology directorates of the
DRDL/RCI and at any other DRDO laboratories, System Managers are
identified for realising a particular subsystems from their directorates or
laboratories, as the case may be.

Public sector undertakings, ordnance factories, joint sectors, private in­
dustries and consultants all have a unique focal point, each identified for a
proper coordination and faster realisation of various subsystems. The
user gets first hand information on the developmental activities taking place regularly, and understands the complexities of the technology, as he is attached to a project.

The process of a dual role for the experts in Technology and Project not only helps in the progress of the projects but is also beneficial to the scientists to upgrade themselves in both technical and management areas due to the job rotation, which takes place regularly, resulting in their job satisfactions.

4.4 MANAGEMENT METHODOLOGIES

4.4.1 REVIEW SYSTEM

In the life cycle of a project, it goes through various phases, before it is declared operational. From the concept level onwards, a detailed feasibility study is undertaken and is reviewed regularly. Once the system concept is finalised in the review, clearance is given for the preliminary design of the system, its subsystems, and the design documents are reviewed through a duly constituted Preliminary Design Review (PDR) teams. PDR recommendations are very carefully reviewed by the projects and implemented and proto system fabrication is given a go-ahead. Once a prototype is realised, it undergoes evaluation tests and Critical Design Review (CDR) Phase-I is conducted at that stage. The system then goes through a complete qualification requirements in terms of ground testing and environmental cycle. CDR Phase-II is conducted to freeze the design for the flight system. When the flight system gets realised, then Flight Readiness Review (FRR) teams evaluate the worthiness of the flight article along with the detailed assessment from QA point of view. Once the FRR has been given a go-ahead for the flight the system is then reviewed by the Launch Authorisation Board (LAB) which clears the flight and the mission. The post flight analysis is then reviewed to arrive at needs for further flights. This cycle continues till the User Trials and certification are completed.

4.4.2 QUALITY ASSURANCE SYSTEM

The Quality Assurance Mechanism provides the following tools:
a) Preferred part list for electronic components and selection of materials for special applications.

b) Failure Analysis Board, even for a device which is undergoing development

c) Waiver Boards to consider deviations and to study the implications on the performance of the system

d) Standing Design Review teams for considering design changes proposed, based on the test results and achievability of the desired specifications

e) Test article review boards for critical testings. Further testing especially the propulsion system is authorised only after clearance by the Test Article Review Board.

f) Involvement of the inspection agencies for accomplishing the desired quality control and continuous analysis by the Quality Assurance Teams.

All the above tools are specifically meant for achieving the performance requirements for the subsystem as well as for the integrated system.

4.4.3 MULTI-INSTITUTIONAL PARTNERSHIP

Academic Institutions - Right from the beginning Academic Institutions, are the active partners of the programme, participating in the design, technology status reviews as peers and also undertake projects of a high-technology focus. The institutions interact effectively through the Joint Advanced Technology Programme Cells, Fellowship Schemes, Progress Review Committees and the Joint Programme Committees and constant review through the Programme committee, chaired by the Director of the institution. The infrastructure built up motivate the scientists working in the institutions. Exposure to the technology details of the national project, participation in reviews and highlighting of contributions motivate the people associated with the institutions in their involvement in the programme.
DRDO Laboratories - Number of DRDO Laboratories working for the programme have defined tasks with respect to each of the laboratories and the progress is monitored continuously through CASMS. PRCs are chaired by the respective DRDO Laboratory Directors and Cells have been established at various critical work centres. Participation and contributions are highlighted in reviews chaired by the Chairman, GMB. The technology developed in the DRDO labs., are transferred to industries for mass production. Hence, the tie-up between the DRDO labs and industry has been attempted to have a smooth technology transfer.

Industries - Both public and private sectors, are participating in the IGMDP. They are working on a high-technology either taken as a development project within the industry or production using the technology from the DRDO. The tasks are reviewed through Progress Review Boards and Production Management Committee. The tools used for the task control are CASMS and milestone linked payments. Infrastructure has been set up for a Limited Series Production at number of PSUs to enable required number of missiles and ground systems production for the Services. The motivation for industries comes from their getting recognition through their participation for the national venture, high technology inflow from DRDO, infrastructure built-up at industries under LSPF, Manpower development for advanced technology and anticipation of quantity production. Public Sectors are reviewed in the Progress Review Boards and the Private Sectors through the PRCs.

4.4.4 SCHEDULE CONTROL

Efficient interaction and communication are essential to progress the milestones. Hence, all the 64 major work centres are linked through a centralised computerised schedule monitoring system for identification of a task to be performed and also to evolve analysis reports. This system is based on a software called CASMS (Computer Aided Schedule Monitoring System).

The main features of the CASMS are:

a) Can handle a large number of the activities for each of the project

b) Provides qualitative information and assessment on the progress for the three levels of management normally
i) Milestone report to the Chairman, GMB

ii) Critical Activities report to the Chairman, PMB

iii) Work centre activities to the Project Directors as well as to the work centres

c) It becomes the place for reviewing and assessing the performance of various projects as well as of different work centres.

d) Allocation of multiple resources to single-project and same resource for multiple projects depending on the slack availability can be planned.

e) Provides “what if” analysis and enables incorporation of work around plans for achieving milestones.

In CASMS the major milestones set in the government approval of 1983 have been divided into work packages and detailed subnetworks. Achievement of the short-term goals in these subnetworks are highlighted with required priorities and resources. Summary plan for every year is presented to the Guided Missile Board and the approved plan is implemented through a computerised system. Master computerised PERT is reviewed once in a year and the short term targets with clear feasibility to IGMDP partners are detailed through monthly task lists generated through CASMS.

The CASMS report is provided to all the work centres on the first of every month and the feedback obtained by 25th of the month. The feedback is reviewed with reference to criticality of over-all schedule and achievability of milestones and the report of critical analysis is generated for task planning in the subsequent month. This has been implemented for various work packages as listed below:

4.4.5 CRITICAL ACTIVITY MANAGEMENT IN MULTI PROJECT ENVIRONMENT - THE CONCEPT OF PACE

One of the unique features of the IGMDP management is the concept of PACE. Programme Analysis, Control and Evaluation (PACE) is a management tool for 'Programme Management' which integrates the Planning, monitoring, control and evaluation functions to effectively execute the
projects within the schedules of time and cost and resource availability in a multi-project environment.

The key management issues to be tackled by PACE are:

i) Critical activity
ii) Resource sharing in a multi-project environment
iii) Resolving conflicts between organisational priorities and individual project priorities.

PACE concept handles multi-project programme with high uncertainty. The shared resources can be utilised optimally by assigning inter and intra project priorities through which the commitment from the system manager is elicited. Through PACE concept, the implication analysis of one project on other projects is possible through a standard analysis. The PACE evolves the action plan on the critical activity with a realistic time estimate.

PACE activity can be divided into the following stages:

1. Analysis

An analysis of the PERT network and progress of project activities leads to the identification of the critical activities of the various projects and the bottlenecks, resource limitations, etc. The respective project coordinator then discuss the problems with the System Manager of the critical work package to work out an action plan for overcoming the problems. If the problems cannot be solved at that level it is taken up for a PACE discussion.

2. Control

PACE meetings are called for critical work packages brought by the Project Coordinator to the PACE forum. In this meeting the Project Director and his team, the System Manager and team along with his Technology Director, and other managers from connected areas are invited to the PACE Chamber for a brainstorming. If intense activity is under progress in the concerned area the PACE meeting is convened at the concerned work centre itself for an on-the-spot review. The collective group along with Programme Planning team then discuss in depth the problems faced and support required for this specific work package. The
different feasible alternatives are identified and decisions are taken on the course of action to be pursued. In case of priority clashes between two projects, the Planning group decides the priorities and schedules for sharing critical resources. This course of action is converted to a detailed PERT plan, which is monitored by the Project Coordinator. If the desired results are not achieved, PACE reviews are conducted with the same team composition.

3. Evaluation

If after two PACE reviews it is found that the work package is still not progressing satisfactory, the Programme Planning group evaluates the work package activity and prepares a brief for the Chairman PMB. The Chairman may then deal with the problem himself or take it up in the PMB and/or GMB as the situation demands.

This forms a closed loop system whereby the project/programme progress is closely monitored and concentrated effort is taken by a number of groups working together - the work package execution group, the project team, the planning group, and the relevant support groups - to hasten the completion of critical activities and also to tackle problems on a real time basis. Planning Group has the full knowledge of tasks and milestones for all projects.

For this purpose a PACE Chamber has been set up at the DRDL as the control room for the whole programme under the Directorate of Planning and Programme Analysis. PACE, stands for Programme Analysis, Control and Evaluation. This Chamber provides progress of the project activities with respect to over all milestones and inter project priorities. A PACE meeting is conducted between 1200 hrs and 1300 hrs every day with one day allotted to a single project starting with Nag on Mondays and ending with Trishul on Fridays. Besides PACE Chamber as a venue, noon meetings are also conducted at the work centres in question when required, like system integration, control, and even at other DRDO Laboratories. Major issues are addressed depending on the criticality for the project and with an idea to remove the same of the system. It provides proper emphasis on critical packages and spot lighting, cross project priorities and resource allocation, raising recommendations to the top management for the project requirements beyond the authority of the Project Director, via media for tackling problem managers who normally
cannot be handled in routine for commitment to the tie schedule. PACE experience so far has been encouraging in view of the multi project environment of the programme.

The advantages of the PACE concept as experienced in the multi-project environment of the IGMDP have been the following:

1. Concentrated effort on the critical activities
2. Forum to tackle cross-project conflicts of priorities and resources sharing
3. Via media to tackle problem managers
4. Serves the job of coordination between the various work centres involved in the project
5. Enhances motivation of the working groups through solving their problems and also their continued participation in the planning process of their own activities.

If the activities are not on schedule as per the CASMS report and delay is critical to the milestones, it is reviewed in PACE meetings for working out actions to crash the critical activities. If the criticality continues, in subsequent PACE meetings a review is conducted by the Chairman, PMB with participation of experts, involving workcentres to solve the problem and to take corrective actions. GMB and PMB are informed of the delay, if corrective actions do not lead to achieving milestones as per schedule.

4.4.6 PROGRESS REVIEW SYSTEM

As explained under the Management Methodology, systematic reviews are essential for an ensuring performance, closure of technology options and assessment of the status with respect to desired goals. The performance assessment comes through the PDR, CDR and FRR during the life cycle of the Project.

These mechanisms along with a vigilant quality assurance team with participation of quality control agency ensure implementation of a QA plans to ensure the performance of the system. Reliability studies are also carried out for each of the subsystems performance and for the mission.
Programme Review:- The overall programme is reviewed by the Guided Missile Board once in 6 months time, reviewing major milestones, technology options, cost physical progress, mission performance and specific user requirements. The Programme Management Board meets once in 4 months time to review the critical activities, assigning priorities of various R&D Laboratories, performance of the systems, technology breakthrough, cost and physical progress. The Chairman, GMB conducts periodical reviews of the projects with participation of the experts for peer analysis. This is essential for proper technology assessments and to build confidence in the direction of right progress.

Projects Review:- The Project Management Board meets once in a two month period reviews monthly tasks and identifies priorities for a short term targets and also reviews procurement progress. As these meetings have members at the level of system managers, the recommendations are towards detailing of the tasks in the respective work centres. This is further reviewed based on the CASMS report at each of the work centres once in 3 months time by the Laboratory Director and the project executives. All Major contracts are linked through milestones, payment and progress review committees have been set up which meet once in a 3 months to review the performance of fabrication and technology contracts at industries and institutions. Project progress is also monitored once in a week through the project review meetings (PRM) conducted by the project director on day to day tasks. Critical activities are handled through PACE as well as specific task teams are appointed for day to day review of the short term targets.

Production Review:- The Production Management Committee with the participation of different General Managers of the PSUs which are identified production agencies for the Missile Subsystems with Managing Director, BDL as the Chairman and with the participation of the Project Directors and the Chairman, PMB reviews, technology transfer from the development and production agencies, status of licence agreements and establishment of limited series production facilities. This is carried out with an objective to realise the deliveries committed to the three Services. The PMC also reviews the funding methodology and recommends the GMB the investment patterns to each of the PSUs as a progress review board which meets once in a month for PSUs and once in two months for Ordnance factories. These reviews ensure smooth interaction between DRDO and participating Industries.
Task Linked Budget: The concept of budget allocation based on tasks has been introduced in the programme to bring effective budget management. The annual targets on the procurement scenario for the two years ahead are considered to work out the requirements of funding and establishing the cash flow pattern.

The Directorate of Planning & Resources is the focal point for the IGMDP budget management, linking the task and money towards achieving the results. Coordinators have been identified at each of the work centres and the budget reviews are conducted once in three months. The budget, once it is prepared, is approved by the Guided Missile Board and funds allotted from the DRDO HQrs. Depending on the reviews and progress suitable allotment is made out of the over all allocation by the Government to enable procurement progress. There is an exclusive financial advisor for Missile Programme who advises on financial matters.

The IGMDP established many national networks for the development of various critical technologies. These networks can be put to use for the dissemination of the spin-off technologies with only incremental efforts. The available scientific talent can be put to use to develop various spin-off products at a much less incremental cost. The technologies and the infrastructure already developed can be best used to bring the high technology health care products with in the reach of the common man. Keeping this in view, conscious efforts were made to develop spin-off products in the bio-medical sector.

Currently a number of bio-medical spin-off products are being developed through the consortium of Government departments, R&D laboratories, medical institutes, local administration and academic institutions, coordinated by a nodal agency. The products under development include polymeric composite rehabilitation aids such as the Floor Reaction Orthosis, calipers for paraplegics, prosthetic foot and sockets for amputees, cardiac pacemaker, tilting disc and hinged bi-leaflet heart valves, bone implants, hip prosthesis, bio-telemetry and many more are in the formulation stage.

4.4.7 SPIN-OFF PROCESS & TECHNOLOGIES

Technology connotates scientific, engineering and managerial knowledge that makes possible the conception, design, development, production and distribution of goods and services. The technology developed by R&D
organizations provides inputs to the other sectors of the economy in the form of spin-offs through patents, papers, process/product improvements, new process / product development, professional advice and consultancy, etc. The consequence of this technology flow is the overall socio-economic development and could be in the form of improved goods & services, improved productivity, quality and cost effectiveness, resource generation, conservation and development of alternatives, improvement of harmonious balance with environment through ecologically acceptable process and product development, improved communication, health care, entertainment and so on. Candidate technologies for the spin-off process can be selected based on any of the above considerations. Some of the spin-off technologies from the Indian Guided Missile Programme include:

- **COMPOSITE TECHNOLOGY**

  Primarily developed for the Radio transparent nose cones (Radomes), Rocket motor cases and ablative liners and light weight airframes, composites could be found wherever there is a requirement for light weight and high strength coupled with flexibility. These requirements in the non-aerospace sphere were located in the areas of polymeric composite rehabilitation aids for orthopedically handicapped and wind mill blades in the energy sector.

- **CARBON-CARBON TECHNOLOGY**

  This military-critical technology was developed for the nose tip of the re-entry vehicle of a technology demonstrator. Its spin-offs could be found in as diverse areas as the aircraft break discs and human heart value prosthesis. The excellent bio-compatibility of carbon made it ideal for use in the bone implants and hip prosthesis.

- **MICRO PROCESSOR BASED SYSTEMS AND SOFTWARE**

  Primarily developed for application in the missile on-board computers and multinode automatic check-out and launch systems, its spin off applications could be found in compact industrial process controls and pacemakers for heart patients.
MULTI-CHANNEL TELEMETRY SYSTEMS

The telemetry system that helps in monitoring and logging various performance parameters of the missile in flight, uses pulse code modulation techniques and provides reliable and accurate data communication. This system could find applications in the form of a remote patient monitoring system in intensive care units (ICUs) through bio-telemetry.

4.4.8 SUMMARY OF OBSERVATIONS FROM IGMDP CASE STUDY

Over the last 12 years, the programme has gone through several milestones, and this progress was possible due to the following factors:

a) **Leadership** - The programme was fortunate to have dynamism in leadership in the organisation level, programme level, project level and in technology build up. The right talent has been placed at right place for maximum contribution with the aim of achieving the goals. Leadership played major role in the motivation and building of ownership of the programme at every level.

b) **Goal Clarity** - Based on the overall milestones to be accomplished for the projects, a continuous visibility of the ultimate goal is maintained through short term and long term targets and the performance assessed periodically for the projects as well as work centres.

c) **User Participation and Commitment** - Highest importance has been given in the user participation and user commitment. The user has been integrated in the management of the programme as a partner and totally committed for the success of the programme. The demand of the User will be to employ the latest available weapon system. In this programme, it was ensured by selecting missile system of future technology, prior to the approval of the IGMDP. The users are continuously participating in the design reviews, development planning and for evolving the weapon system deployment scenario, threat potential analysis, simulators and training and also in evolving acceptance criteria. This provides visibility to the User from the beginning of the development as well as ensure his commitment to specification of the system and commitment from development and production agencies in terms of time and cost.
d) **Frontier Technology and Contemporary Systems** - The programme had a technological goal of ensuring that system are contemporary at the time of their induction. To realise this development of technologies have been undertaken based on technology forecasting for 15 to 20 years ahead. The systems have been configured to be of multi-role and multi-user. This approach helped in overcoming problems of technological obsolescence and helped in the success of the programme.

e) **Consortium Approach, Technology Empowering and Partnership** - For the realisation of critical technologies the programme adopted consortium approach through partnership with government departments, R&D organisations, academic institutions, public and private sector industries. The programme identified the pockets of excellence in various technological areas and built around them by providing the required technology, facilities and networking. This approach of technology empowering not only helped in the development of number of critical technologies within the country but also established the core competence for future missions.

f) **Review System and Openness** - From the concept stage to the flight, each of the projects is continuously reviewing for design, development, technology transfer, manufacturing and flight readiness, to ensure achievement of required performance for the missile system. Fabrication/process reviews and value engineering analysis are being carried out to lead the systems to production. All these reviews are conducted through generation of required documents and participation of experts from the relevant area. Sharing of information on need to know basis with R&D organisations, academic institutions and industries, and reporting of failures without fear help the programme to assess the problem area in clear terms and to identify solutions to overcome those problems. Mechanism such as Failure Analysis Board, Standing Design Review Committees, Test Article Review Board provide adequacy for the performance review. The management structure starting from the Guided Missile Board to the Review Committees at work centres establish necessary check points from the status of the programme. Thus, the Review System evolved for IGMDP provided multi point checks with clear identification of the role of review bodies to ensure performance, schedule and cost progress to the requirement.

g) **Innovative Management Practices** - The programme adopted number of innovative management practices such as the mission approach,
concurrent development and production, matrix management structure for multi-project management, reorganisations and renewal factor to keep up the overall organisational performance.

h) Schedule, Cost, Performance and Resource Management - The programme evolved number of tools such as the CASMS, PACE, PULSE, PACT for managing the schedule, cost, performance and resources. These tools have greatly helped in progressing the projects inspite of the dynamic multi-project environment with development-production concurrency and uncertainty.

i) Manpower Development - The programme gave lot of importance to the manpower development and devised many schemes for that. Youngness was given importance and the average age of the scientists is maintained low by a constant input of young scientists every year through various fellowship schemes. Programme adopted suitable rewarding schemes for the motivation of manpower.

j) Special Procedures - Fast decisions came from the three tier management structure and the supporting committees through participation, rather than details submitted through files. This was possible only through the management structure constituting membership from all concerned, Government and Technology groups. Each of the decision is supported by technical and managerial analysis from the programme through expert committees. In the case of establishments of facilities, the procedure of using consultancy, paved a way for faster construction of high technology infrastructure. Special procedures were adopted for financial approvals, procurement of critical items, etc., which helped in cutting down the usual delays associated with such activities.

4.5 INFERENCES FROM THE BENCHMARKING

As a whole the following inferences relevant to the present study can be drawn from the benchmarking.

a) Successful completion of a project depends on a large number of factors, most of which cannot be quantified. These factors include both the internal & external factors as well as controllable & uncontrollable
factors. The effect of various factors may vary at various phases of a project life cycle. Currently large variety of models are available for the project selection, but none of these models takes into account the problems faced during execution and the factors that will ensure successful completion of the project. And hence the existing models for project selection and execution are totally inadequate to handle the real life projects.

b) Whatever may be the amount of analysis made, the estimates made for any R&D project at the time of its sanction are bound to become invalid during the execution phase. Hence project selection can not be viewed as a one time process. Currently, once a project is selected, it will become a fate accompny for execution and the factors considered for its selection are never reviewed again. During the execution phase, the whole focus will be on monitoring & controlling of the time and cost overruns and the basic relevance of continuation of the project is not questioned. This situation can be rectified by viewing the project evaluation as a continuous process. The projects relevance and its continued need must be reconfirmed at every stage.

c) In all the real life projects, existence of multiple projects sharing common resources is a fact of life. In the practice all projects compete for the same resources and the low priority projects are endlessly delays for want of resources. This situation must be rectified with the help of a clear-cut policy on the portfolio mix of the projects and suitable mechanisms to implement this policy. One such model that can help in the formulation and implementation of a policy for the portfolio mix of the projects could be a good classification scheme that covers all desired types of projects and the sponsor can allocate the resources for ongoing and new projects based on this model.

d) Successful project completion requires a forward looking approach, where the progress of all the downstream activities are sensed and an early warning is given in case of any problem. The product development process can be viewed as a sequence of R&D, production & marketing, and the factors responsible for successful production & marketing must be monitored right during the R&D phase itself. Similarly the user commitment and involvement must be made to build the required commitment. None of the existing models provides for monitoring of the product cost effectiveness, which is vital for the project's success. Hence, suitable models should be evolved to monitor all such vital factors for project
success on a continuous basis. This requires an integrated approach that encompasses all phases of the project life cycle.

e) Unlike the present models which are isolated along the functional boundaries, the new model should completely integrate all functions such as the new project evaluation & selection, portfolio analysis, planning, monitoring and status evaluation of ongoing projects, and the closure evaluation. The parameters that are used for the selection of projects must be integrated with the parameters that are monitored during the execution of a project such that not only the status but also the relevance of the project is monitored. Thus the new model should be applicable throughout the complete life cycle of the project.

f) The present study is a major step in this direction. The next chapter describes a new concept called the integrated performance index that will integrate all the functions over a project life cycle.

4.6 INTEGRATED APPROACH

As whole, the benchmarking establishes the need for integrated approach for project selection & execution. The benchmarking also brings out the various factors responsible for the success of the projects during execution. Based on this, an integrated performance management system has been evolved, the details of which are presented in Chapter 5.