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Nuclear Power Project Management

A Guidebook

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1988

NUCLEAR POWER PROJECT MANAGEMENT

A Guidebook

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

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FOREWORD

Nuclear power plants are well proven installations, with nearly 400 commercial units operating and about 4000 reactor-years of accumulated experience. Nuclear power plants are capital intense, high technology, and complex systems, not least because of the continuously evolving and increasing safety requirements. Investment costs and their amortization make up the predominant part of the future power generation costs and effectively determine the competitivity of the nuclear power option with power from fossil fuels or hydroelectric stations. High interest rates have made nuclear power plants particularly vulnerable through the steep cost escalation that results from unforeseen changes or delays.

While the operating performance of nuclear power plants has been improving in recent years and has generally been comparable to or better than that of fossil-fired plants in the same size ranges, performance during construction has been variable. Construction schedules — from the first placement of structural concrete to grid connections — have ranged from less than five years to more than twelve years; as-built costs accordingly show increases of up to four hundred per cent in the worst cases. Although additional licensing requirements, public intervention and funding problems have been blamed for most of the delays and cost increases, there is growing recognition that lack of proper project management has been a major factor. Project management is a management speciality primarily concerned with the definition, co-ordination and control of large undertakings, from the points of view of technical quality, schedule and costs. Improved steering, control and expediting of nuclear power plant projects by competent project management would reduce costs not only through more efficient work sequences and higher productivity but also through the reduction of accumulated interest during construction.

Based on past proven practices in many Member States of the IAEA, this Guidebook provides specific advice and guidance to project management for the construction of nuclear power plants. With this guidance, it is hoped that project managers and their assistants will be able to obtain better performance on nuclear power projects and will help maintain nuclear power as a viable energy option.

The International Atomic Energy Agency received the generous support of several Member States in providing experts and submitting written material for the Guidebook. Appreciation is expressed for their valuable contributions. The Agency is particularly grateful to the members of the Advisory Group and the consultants who provided recommendations, information and comments relating to the purpose, content and form of the book.

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1. INTRODUCTION

1.1. PURPOSE AND SCOPE OF THE GUIDEBOOK

This Guidebook is primarily addressed to project management in prospective owner organizations of countries which are starting their nuclear programmes by embarking on their first nuclear power project under a turnkey contractual approach, though its content may also be relevant to the split package approach.

Project management activities start with the decision to go ahead with a nuclear project (following planning, feasibility and siting studies) and end with the handing over of the operating plant to another body which will be responsible for its operation and maintenance.

The function of project management can be defined as the overall direction and co-ordination of project implementation tasks.

This is a very complex responsibility involving large risks, and that is why in a first nuclear power project it is advisable for an inexperienced owner to delegate the function to an experienced main contractor under a turnkey approach, or to an experienced architect–engineer under a split package approach. However, the owner cannot delegate direct responsibility for control and supervision of the project and should therefore be prepared to fulfil this commitment in the most efficient way.

Errors in project management have in practice been partly responsible for significant schedule and cost overruns in nuclear power projects. Although general management, engineering management or production management could equally be blamed, project management is the one area which is entirely devoted to and specific to a particular project and should have clearly defined schedule and budget targets from the early planning stage right through to the functioning product. The careful choice of the right lead personnel in project management, proper planning, the establishment of correct project organization and its support are important steps towards successful project implementation.

In the project organization the project manager cannot and must not assume general managing responsibility nor an executive engineering role in particular disciplines; but, as ultimately responsible for the cost, schedule and technical performance of the project, he must be a model representative of good management practices throughout the project. Project management should also use its control and communication functions to assist in early diagnosis of any problems, which then must be brought to the attention of general management. In support of the technical quality and functioning of the plant, project management should provide directly or with the help of others (such as the quality assurance organization) a second, independent check on many of the important decisions and on project data.

Because of the generally long lead time of nuclear power projects and because of the continuing evolution of technology and safety regulations, the learning process in the management of the planning and construction of nuclear power plants has been difficult and sometimes costly. This has been true particularly for new organizations which have taken on the responsibility for a nuclear power project for the first time. It is the purpose of this Guidebook to facilitate and accelerate this learning process and to prevent some of the problems involved by outlining the main elements of internationally valid, good practices in nuclear power project management.

The Guidebook is not intended for the project management of main contractors, architect–engineers or experienced owners. When the activities of these project managements, as well as those of other partners involved in a nuclear project, are referred to, it is only to provide more complete information to the reader.

The Guidebook has been prepared within the framework of the series of technical guidebooks of the Division of Nuclear Power of the IAEA and complements the Guidebook on the Introduction of Nuclear Power and the guidebooks on Bid Invitation Specifications for Nuclear Power Plants, Technical Evaluation of Bids for Nuclear Power Plants and Economic Evaluation of Bids for Nuclear Power Plants: 1986 Edition (Technical Reports Series Nos 217, 275, 204 and 175). In order to avoid repetition, reference to these is made where appropriate and it is suggested that they be consulted for more complete information.

1.2. PARTNERS IN A NUCLEAR POWER PROJECT

Activities related to a nuclear power project are normally distributed amongst several different private and/or public (government controlled) organizations, each being responsible for a limited group of activities with a common goal, i.e. the safe, reliable and economic construction and operation of a nuclear power plant. The distribution of tasks associated with software (planning, engineering, etc.) and the manufacture of hardware follows traditional patterns common to other industrial projects, in particular that of a fossil-fuel power plant.

The definition of the principal partners in a nuclear power project and of their respective roles is important to an understanding of the features of a nuclear power project and of project management's role in it. The term 'partners in a nuclear power project' has been chosen here to emphasize the need that exists for co-operation. The following designations are used in the present text:

- Public authority
- Regulatory body
- Utility
- Main contractor
- Architect–engineer
- Consultants
- Subcontractors.

At the initiation of a nuclear power programme or nuclear power project a public authority may play quite an important role in implementing or handing down the government's decision and setting up infrastructure, regulatory and promotional activities. The authority may be a ministry of industry, a ministry of energy, an energy commission, a special presidential commission, etc. The public authority, which receives the necessary advice from the other centres of activity involved, could be responsible for producing the basic nuclear power plans, for promoting them and for monitoring their implementation.

While the public authority may be in charge of several types of industrial promotion, an atomic (or nuclear) energy commission may be set up to deal specifically with nuclear energy development, planning and/or regulation. Typically, a special regulatory body would be established to deal exclusively with nuclear safety regulation, surveillance and control, without conflict of interest with the promotional side.

The utility represents the future operating and/or owner organization of the plant and is responsible for forecasting power needs and for ensuring timely, economic and safe supply. From this follows the responsibility of management to ensure that the project meets the established needs, within the guidelines laid down by the public authority and the regulatory body and under the supervision of both organizations. The utility may have large engineering and construction departments, and they may take on certain portions of the nuclear project. These may include infrastructure and site preparation activities, the inlet and outlet for the cooling water supply and the processing buildings. Depending on the utility's capabilities and previous experience, such project tasks may be performed by its departments or via direct subcontracts.

Organizations in charge of the execution of complete portions (packages) of the nuclear power project are called main contractors. The scope of a main contract typically comprises a fairly self-sufficient package with a minimum of external interfaces, in the form of major sections of the plant, systems or services. The main contractor would plan, engineer and commission the contracted portion of the plant in a complete manner according to the specifications and requirements of the utility and with allowance for the interfaces to other contractors, often under a package contract with a fixed price and schedule. A main contractor independently manages the subcontracts for his portion of the plant, possibly with a consent right by the utility. In a turnkey approach, one main contractor has the responsibility for overall project integration.

The term 'architect–engineer' is generally applied to organizations which specialize in planning, engineering and managing industrial installations and buildings. Such organizations are entirely software oriented and provide their services on a paid-for basis to many customers. Architect–engineering firms can therefore combine a great deal of experience and accumulate expert know-how transferable from one project to another. Cost-plus type contracts can, however, sometimes lead to efficiency problems, if adequate incentives are not provided for fast and efficient work.

Consultants may take on specific planning and engineering tasks in contracts or subcontracts.

With regard to the broad participation of industry in power plant subcontracts, it has to be recognized that there are many specific nuclear activities and specialization is necessary in certain areas. Some components with stringent technical requirements are manufactured by organizations whose business is mainly nuclear. Other subcontracts may cover rather conventional equipment used in other industries. Nuclear power project engineering, project management and purchasing activities are usually handled by exclusively nuclear organizations or particular divisions of larger organizations. Such nuclear engineering divisions deal with the manufacturing divisions of the same organization almost as if they were outside subcontractors. The involvement of domestic industry is usually a major objective with countries constructing a nuclear power plant. The domestic industry is responsible for producing items of equipment and services contracted to it either directly or through foreign manufacturers. Foreign industry is responsible for producing items of equipment and services contracted to it either directly or through domestic manufacturers on behalf of the utility, and for transferring technology to local industry in the manner specified in the relevant contracts.

The major partners involved in nuclear power projects are listed in Table I, together with their usual functions and main responsibilities. However, it should be noted that there might be other, additional partners for a specific case, or some of the partners listed might not be involved at all. The functions and responsibilities will vary according to the contractual approach. Typical lead responsibilities for the different partners are presented in Table II. The list refers to the most common situations and the sequence applies to typical situations where the partner listed in the first place has the main responsibility in the particular task.

There is no universally applicable optimal distribution of functions and responsibilities among the partners involved, nor any organizational framework which is equally applicable to every country and situation. Nevertheless, it should be recognized that for each country and nuclear power programme an efficient organizational structure must be adopted and all principal functions and responsibilities, as well as lines of authority and communication, must be clearly assigned and defined. As the nuclear programme develops, changes and adjustments are usually required, and these can be gradually introduced according to needs and possibilities.

Each partner involved in the project is represented by its project manager, who will be responsible for the co-ordination of the work with the other partners.

TABLE I. PARTNERS IN A NUCLEAR POWER PLANT PROJECT: FUNCTIONS AND RESPONSIBILITIES

Partner/Principal function	Responsibilities[a]
Utility/U	
Pre-project activities Plant acquisition Plant operation and maintenance	— Overall responsibility for the project — Participate in the planning and implementation of the country's energy supply — Define and implement electric power generation programmes — Design procedure and/or build power plants, transmission lines and distribution systems — Apply for plant licensing — Procure fuel and manage supply contracts — Operate and maintain power plants in a safe and efficient manner — Assume liabilities and public responsibilities associated with plant ownership
Main constructor/MC	
Supply complete plant (turnkey)	— Provide complete project management for project implementation — Design, specify and procure plant components and systems — Install and commission components and systems — Describe systems and performance in safety analysis reports, procedures, manuals — Perform QA and QC — Fulfil warranty conditions on the plant
System supplier/SS	
Supply complete systems, such as the NSSS, nuclear or conventional island	— Main contractor's responsibilities for the system supplied — Provide inputs for interfaces between the system and the rest of the plant
Architect-engineer/AE	
Engineering Project management	— Prepare detailed design — Prepare construction specifications — Help owner to negotiate contracts — Prepare construction manuals — Prepare purchasing documents

TABLE I. (cont.)

Partner/Principal function	Responsibilities[a]
Engineering Project management	— Manage procurement, including inspection, expediting, transport — Prepare safety reports — Prepare QA procedures — Provide project and construction management — Provide documentation control — Develop training programmes — Prepare startup procedures — Provide operational manuals
Equipment manufacturer/EM	
Fabrication of specific equipment and components	— Fabricate according to specifications, standards and schedules — Implement QA and QC measures — Provide inputs for erection, commissioning and maintenance
Constructor/CO	
Construction or erection of buildings, structures or facilities	— Prepare detailed plans of the civil work — Perform stress calculations, dynamic calculations — Perform construction, erection or installation activities according to specifications, standards and schedule — Perform QA and QC activities
Regulatory authority/RA	
Independent regulation and control of all nuclear facilities	— Provide regulatory standards and guides — Review system and component design — Issue, amend or revoke licences — Enforce licences directly or with the help of inspection agencies, if any
Inspection agency/IA	
(Independent inspector) Conduct inspection, testing, QA and QC activities	— Perform inspections and issue certifications, conduct tests, audits and experiments according to specifications, standards and regulations
Fuel supplier(s)/FS	
Supply fuel and/or fuel cycle services	— Supply uranium concentrate — Supply conversion and/or enrichment

TABLE I. (cont.)

Partner/Principal function	Responsibilities[a]
Supply fuel and/or fuel cycle services	— Manufacture fuel elements — Provide services for back end of the fuel cycle
Consultant(s)/C	
Technical and economic consultant services	— Provide a wide range of speciality services in fields of activity related to nuclear power plant implementation, such as: geology, seismology, hydrology, meteorology, safety, stress analysis, etc.

[a] Responsibilities will vary according to type of contract; see Table II.

1.3. OUTLINE OF THE GUIDEBOOK

Project management in the widest sense means defining, steering, controlling and co-ordinating a project. The project manager is responsible above all for the completion of a high quality product. He uses the contract, the specifications, the budget and the schedule as control tools and applies numerous administrative and technical procedures together with his knowledge and authority.

Project management is, by definition, an interfacing and an integrating activity and its understanding and description require a certain amount of explanation of the accompanying functions such as engineering, quality assurance, procurement and accounting. In the context of this Guidebook project managers do not perform engineering work but must co-ordinate with it very closely. They also act as the lead section for dealing systematically with changes.

Major project management tasks for any one of the partners in a nuclear power project typically include:

— Establishing a project breakdown for hardware and software and allocating the project budget via individual project task orders;
— Preparing the project schedule and controlling deviations from it;
— Ensuring project definition in the form of project requirements and specifications and controlling changes;
— Setting up procurement procedures and controls;
— Expediting engineering and subcontractor deliveries;
— Controlling project interfaces inside and outside the organization in charge of the project;
— Controlling contract compliance;

TABLE II. USUAL LEAD RESPONSIBILITIES FOR DIFFERENT CONTRACT TYPES

Activity	Lead responsibility		
	Turnkey	Split package	Multiple package
Pre-project activities	U	U	U
Project management	MC	AE or U	U + AE
Project engineering	MC	AE + SS	U or AE
Quality assurance/Quality control	MC + U	AE + SS + U	U + AE
Procurement	MC	AE + SS	U or AE
Application for licence	U	U	U
Licensing	RA	RA	RA
Safeguards, physical protection	U	U	U
Manufacturing	MC	SS + EM	EM
Site preparation	U or MC	U or AE	U or AE
Erection	MC	AE + SS	U or AE
Equipment installation	MC	AE + SS	U or AE
Commissioning	MC	AE + U	U or AE
Plant operation and maintenance	U	U	U
Fuel procurement	U	U	U
Fuel fabrication	FS	FS	FS
Waste management	U	U	U

Symbols: AE: Architect–engineer
EM: Equipment manufacturer
FS: Fuel supplier
MC: Main contractor
RA: Regulatory authority
SS: System supplier
U: Utility

— Ensuring timely and proper preparation of licensing documentation and applications as well as adherence to compliance procedures;
— Providing problem solving leadership and assistance where needed, and establishing a project risk analysis and risk reduction programme;
— Monitoring and controlling costs;
— Ensuring progress payments and preparing claims for justified price changes;
— Ensuring quality assurance and control;

— Providing assistance, proper interfacing and transfer of information to the site management;
— Reporting progress.

The Guidebook deals with many aspects, from project initiation to the handover of the plant for commercial operation. The specific roles of different project partners are also considered.

In the planning of the book, it was felt that some differentiation between the preparatory (pre-contract) and execution phases was desirable since the tasks and the responsibilities of project management are somewhat different in the two phases.

Thus, Section 2 describes to the extent necessary (since all these subjects have been presented in detail in other guidebooks) the involvement of project management in pre-project activities, bid invitation preparation, bid evaluation and negotiation and the closing of the contract.

Section 3 considers the main subject of the Guidebook, which is the activities of project management in the execution phase. This section is subdivided into five parts.

The structure of project management is defined and explained in Section 3.1 with emphasis on those tasks, functions and features which are common to different types of projects.

Section 3.2 deals with the execution of the project with special focus on tools and methods. The subject of control is covered in Section 3.3.

In Section 3.4 the main internal partners, such as the engineering, quality assurance, procurement and accounting organizations which provide project related activities and therefore must be well co-ordinated with project management, are covered as organizational interfaces.

Finally, in Section 3.5, other important activities such as licensing, assurance of fuel supply, documentation management and the preparation for operation are explained in relation to all the partners involved in the project.

A glossary of terms provides brief definitions and the necessary standardization of terminology for this Guidebook.

In general, it is assumed that in most countries the execution of the first nuclear power project would be left to an experienced contracting company, which would have to be controlled and supervised by the utility. Therefore, project management is mainly seen as the task of the supervising partner, namely the utility, and of the contracting partners with major executing responsibilities, such as the main contractor, the architect–engineer and the subcontractors. Other approaches would in principle not change the overall picture but only the distribution of the tasks among project partners. The regulatory authority's involvement in project management is also covered in Section 3.5.

Each area of specific project management activity is first considered in relation to the utility project manager, followed by the other project partners, where relevant, i.e. main contractor, architect–engineer and subcontractor.

2. PROJECT MANAGEMENT — PREPARATORY PHASE

Once the questions of the long term supply of electricity, of economic policy, and of political and other considerations in the energy field have shown that nuclear energy has a role to play, project planning can begin. This first phase generally starts from the established basic feasibility of nuclear power in the country and the decision to plan a concrete project, and it ends with the acquisition of detailed feasibility and contractual information. The planning phase is intimately connected with and will benefit from accompanying activities such as manpower development and the establishment of the legal framework and regulatory infrastructure. Although the main responsibility in energy planning may be in the hands of the government, i.e. the public authority, the future operating organization, the utility, should have at least one person or preferably a small group following and/or participating in these early activities. Further project management related tasks will commence with feasibility and siting studies, and evaluation of the type and size of the proposed plant and the safety requirements for it. The utility may decide to establish a formal project organization of up to ten persons long before contract closing, or could alternatively contract most of the initial project work to a specialized consulting or engineering firm. In both cases project management steering and control of these efforts is needed.

The utility project manager will emphasize planning during the pre-contract phase, when the organizational, problem solving and controlling components of the job are less prominent. Different characteristics (and even a different person) may therefore be required from those in the execution phase. The project manager's main concern would be that all planning for the future project is done properly and on time and that the project becomes well defined within a certain cost range. The basic documents to be produced are the bid specifications; these provide the technical information describing the projected plant, including the economic, legal and contractual requirements of the utility and government authorities concerned; they also define the scope and limits of supply and responsibilities. The specifications form the basis for the contractors for their bid preparation and for the utility for evaluating the bids. Later, they serve as an input to the contract documents. In addition to the specification, the preliminary licence application to the regulatory authority should be pursued and project engineering activities initiated. Procurement of certain heavy components and of fuel may have to be started and the corresponding pre-contract financial obligations may require special commitments, such as a letter of intent.

At the beginning, the utility project team could work as a task force and serve as the project representation for the utility, typically with at least one responsible and experienced professional for each of the following areas: systems analysis, radiation protection, reactor systems, auxiliary systems and secondary cycle, electrical systems, civil and structural engineering, nuclear fuel, licensing, commercial and legal questions. Internally, the project management group has to deal with established engineering and production departments and a matrix type organization for project management is advisable. The project manager in a matrix type organization has the authority to tell all the members of the project team what to do and when, but not how to do it. Externally, with other project partners, a fairly equal ranking, co-operative but business-like relationship should be established. The contacts between partner organizations are the respective project managers, each one directing the project activities within his own organization.

Depending on the type of contract, it is assumed that the responsibility for design and construction of the plant is delegated to a main contractor or architect–engineer, who therefore requires a larger project management and project engineering effort, but not necessarily as early as does the utility. During the first discussions on a nuclear power project the potential contractor organizations are usually more concerned with presentation of standard product information and marketing activities; these are usually taken care of initially by experienced specialists in marketing and negotiations. The special identity of a particular project for the contracting organizations may only become established when a preliminary engineering contract or letter of intent is in sight or when concrete proposals for the main contracts are being prepared. Before formal project management is set up for a specific nuclear power plant project it is very useful, if not essential, that the designated project manager or a key member of his staff participates in the marketing and proposal efforts.

2.1. PROJECT MANAGEMENT IN PRE-PROJECT ACTIVITIES

Project management's involvement in the pre-contract planning area is possibly rather indirect, depending on the organization of the national planning efforts and the nature and extent of foreign support. It also requires a different type of personnel than the management of the actual project.

Power system planning is generally a continuous activity and should consider the possibilities of meeting the established demand in the most effective way using fossil-fuel, hydroelectric and nuclear power plants. Because of the importance of the results, the future utility project manager or a member of his team should ensure that they stay updated and realistic throughout the project planning phase. The data should indicate the optimal timing and sequence of initial operation for each plant.

Feasibility studies are more project oriented than power system planning. Within a nuclear power programme which includes a number of successive projects the activity may acquire a continuing character. In such cases a task force could be maintained as an organic unit with the purpose of performing these studies and acting as an advisory body to the decision makers and project planning teams in matters that require in-depth analysis. The relevant staff should preferably have professional experience in the co-ordination and performance of complex interdisciplinary studies. The eventual transfer of some of the personnel into the project management effort may be considered.

The siting of a nuclear plant is a major effort which may require outside expertise from specialized organizations and/or consultants. A typical period of about 18 months for site qualification may be included in the overall schedule for a nuclear power project; this phase may be a direct continuation of the site survey and an integral part of an alternative site evaluation activity. As a technical speciality involving only a few professionals, siting by itself would normally not require project management, but the need for timely performance of siting tasks and the provision of data to the design efforts would make project management participation and surveillance advisable.

Once nuclear power is considered a viable option, expert knowledge on nuclear power becomes necessary. External assistance or an independent external expert's review and opinion could be very helpful. If requested by a Member State, the IAEA would send a preliminary advisory mission to the country to analyse the situation and recommend whether a nuclear power planning study is warranted.

A complete description of site survey and site evaluation activities, including the content of the studies, the methodology and procedures for their development and the tasks to be performed for the feasibility study can be found in Chapters 9 and 10, respectively, of IAEA Technical Reports Series No. 217, Guidebook on the Introduction of Nuclear Power.

2.2. BID SPECIFICATION AND BID EVALUATION

Specifying, obtaining and evaluating nuclear power plant bids is the most important and most concise project related activity during the pre-contract phase, i.e. from the end of planning to the beginning of execution. Although utility engineering and planning personnel from different departments, as well as outside help from architect–engineers and consultants, might be involved in this effort, it can appropriately be organized as a project management activity, starting, for example, with two to four senior professionals supported by 10 to 20 engineers. During later contract negotiations the project group could grow to about 30 experienced people, consisting of the project manager, assisted by a project management staff of 5 to 10 professionals, with the remaining engineers representing the beginning of the involvement of engineering departments in the project. This team has to handle all technical and commercial discussions which lead to the awarding of the contract(s).

Depending on the utility's own capabilities, the first action could be the selection and contracting of an engineering firm, which from then on would assist in pre-contract work. The architect–engineering firm or consultant chosen during this stage could be different from the one selected later for project execution, since the important factor is long experience with a number of competing concepts and suppliers. Once a particular concept or supplier has been chosen, the need for a project partner with the necessary specific experience may become the overriding consideration.

Utility project management must pay particular attention that pre-contract work will result in complete, clear and accurate technical specifications. Any subsequent requests for changes may weaken the utility's position during contract negotiations. Major items to be specified in this phase are:

- Selected site and site parameters
- Plant size (if the feasibility study considers alternative plant sizes)
- Reactor type; the choice of reactor type is often made after bid evaluations (though it may be made before in cases where government policies on the subject have been previously defined)
- Applicable codes and standards
- Degree of domestic engineering and industrial participation
- Required transfer of technology for plant systems and fuel cycle
- Main characteristics and responsibilities within the project organization and overall project management
- Required type of contract (turnkey or split package) depending on the country's infrastructure and nuclear experience
- Design data to be submitted to the owner
- Quality assurance programme to be used during component manufacture and plant construction
- Detailed specification of codes and standards (including local codes and standards) to be used by the bidders
- Schedule for supply
- Schedule and responsibility for developing preliminary and final safety analysis reports
- Responsibility for plant startup and commissioning (specially important for non-turnkey projects)
- Supply of fuel and fuel cycle services
- Training of personnel
- Financing
- Construction schedule
- Role of the plant in the electric grid (base load or load follow operation)
- Special requirements for plant structures, systems and components and for their redundancy (if not covered by applicable general design criteria)
- Requirements on warranties
- Scope of supply and services for all contract partners (domestic and foreign).

The plant technical specifications must be developed from these main parameters as a comprehensive document which includes all information for the bidders necessary to develop a proposal. The bid specification should be written in such a form that the bidder will be able to understand the requests clearly, should be properly organized and the sections numbered so as to facilitate the subsequent evaluation of competing bids.

This work could best be handled by the designated future project manager, who would primarily look for:

— Correct usage of in-house and outside expertise
— Completeness and clarity of all bids
— Cost and schedule information
— Interfacing and co-ordination considerations
— Monitoring and consideration of political constraints, which may result from assurance of supply issues and bilateral or multilateral government agreements.

Bid evaluation involves the consideration of contractual, organizational, political, technical, economic and financial aspects.

The evaluation of the contractual conditions consists in identifying any exceptions or deviations in the bids with respect to the specifications and of assessing their effect and importance.

Most of the differences between the requests made by the buyer and the offers made by the bidders can be resolved during contract negotiation through compromises and agreements, but some might be of such a fundamental nature that they could eliminate the prospective supplier from the bidding procedure, unless he is willing to modify his position. It is desirable to identify such fundamental exceptions or deviations at any early stage of the bid evaluation procedure. Negotiations should then be immediately started to try and resolve the differences, because if the positions of the buyer and bidder are not reconcilable and mutual agreement does not appear likely, further evaluation of the particular bid would be useless.

The evaluation of organizational aspects could be considered separately or included within the scope of the technical evaluation. Its main purpose is to establish a measure of confidence, based on technical judgement, that the project can be implemented within the schedule and cost commitments. The project management set-up of the supplier is possibly the most relevant aspect to be analysed in detail, together with the organizational structure proposed for handling the subcontracting and interfacing.

The political implications can probably not be evaluated by the project management. However, it does have the task of providing the national decision makers with all relevant information on the issues involved, pointing out advantages, disadvantages and potential problem areas, such as international commitments and agreements, export licensing and the assurance of supply.

The two aspects which require the greatest efforts for project management are the technical and economic ones.

The main activities of the group involved in the technical evaluation will be:

— Checking the bid for completeness of the information requested
— Checking the scope and limits of supply of services and interfaces
— Evaluating the technical features of the equipment and structures and the adequacy of the services
— Preparing questionnaires, evaluation reports (including the identification of problem areas) and technical documents.

The details of technical bid evaluation are covered in IAEA Technical Reports Series No. 204, Technical Evaluation of Bids for Nuclear Power Plants.

The purpose of the economic evaluation of bids is to prepare an economic order of merit. The basic procedure is to evaluate the current worth of all cost items involved in plant capital investment, the nuclear fuel cycle, and operation and maintenance, and also the corrections to each bid, once they have been made economically comparable by the technical evaluation. Full details of approaches and methodology are given in the Technical Reports Series No. 175 guidebook Economic Evaluation of Bids for Nuclear Power Plants.

To ensure completeness, the deliveries and services offered should preferably be based on an existing reference plant design. This concept of reference plant design is convenient and sometimes essential for establishing a common basis for the many detailed drawings, specifications and analysis reports. In many cases the period of time between issue of the letter of intent and the signing of a contract will be used to further check the completeness of the scope of supply and responsibility for interfaces between various contractors.

Several months of analysis and meetings with the bidders are usually required to clarify important points that might not be properly defined; financial or political aspects can stretch negotiations for years. Ultimately, the evaluation team (preferably led by the utility project manager) will perform the evaluation of the different tenders submitted, and produce a final recommendation on the technical and economic aspects to the utility upper management. It is nearly as important that the future project manager or one of his assistants participates in the bid evaluation as it is to draw on experienced procurement and contract specialists within the utility (who act as the counterparts to the sales specialists within the supplier organization). Early and complete project management involvement will ensure detailed knowledge of the tender and of all associated agreements and their interpretation.

2.3. NEGOTIATING AND CLOSING OF THE CONTRACT

Selecting reliable contractors is probably the most important and most crucial decision in implementing a safe and economic nuclear power plant project. Case studies of nuclear power and other complex projects have shown that it is not only the provenness of a product and concept that counts, but also the provenness of the project set-up and of the organizations backing it. A newly formed consortium which has never executed a certain type of contract, domestically or for export, will have to undergo a learning process and may have startup problems. An inadequately defined contract scope, communications problems, delays and cost overruns are likely consequences of an unproven and unprofessional team. Similar criteria must also be applied to the consultant or architect–engineer whom the utility may have chosen to assist it during the pre-contract phase if they are to qualify for a more important part in contract execution.

When preparing for contract closing, utility management in general and assigned project management in particular should ensure that the partners who are chosen completely cover the deliveries desired and the interfaces to adjacent scopes of supply and that one of them can accept a lead responsibility for the entire plant as part of one of the contracts (unless the utility can take on this responsibility itself). It is important to check at this time that supplies of equipment and fuel and their financing as well as any other long term items have the backing of bilateral or multilateral government to government agreements. The reliability of a possible project partner (contractor) would in particular be evidenced by proper projections of costs and schedule and good prior performance on contract fulfilment. Discussions with other utilities for which the particular contractor has worked under similar conditions can be very valuable. Utility project management must also gain the appropriate and informed involvement of general management, various technical departments, legal staff and possibly consultants.

Project partners should insist on a well defined scope for all hardware and software deliveries. The details would usually be prepared by the contractor and reviewed and amended by the utility before signing. Utility project management must ensure that product specifications are as complete as possible and contain all the necessary design information so as to avoid problems with unnecessary changes. The additional cost and effort required to prepare definitive specifications as part of the contract can be justified by comparison with the potential delay in construction and startup, or the costs of potential future changes or even outages. A typical nuclear power plant contract contains, as a minimum, sections providing:

— Complete technical description of the plant
— Regulatory status and/or preliminary safety analysis report
— Quality assurance programme
— Scope (hardware list and documents list)
— Set of conceptual drawings
— Schedule
— Organizational chart.

Another important item for project management is the early fixing of payment terms and contract conditions. The utility should always be in a position to use payments as 'reward' or 'punishment' in contract fulfilment. A well proven method is to tie contractual payments to 10 or 20 milestones in the project schedule and, possibly, to establish incentives for early completion. In summary, the contract activities of the utility, which are usually started during the detailed discussions and negotiations with the bidders, consist of the following:

— Selection of contract type
— Definition of contract scopes
— Definition of systems and supplies in the utility's scope
— Arrangements regarding transfer of technology
— Negotiations of the price, payment conditions and warranties
— Commercial and financing arrangements, together with their legal implications
— Procurement of lead materials, components and services
— Procurement of fuel cycle materials and services; assurance of the supply of fuel and essential reactor materials and components
— Preparation of site
— Selection and definition of the codes and standards that will be adopted in plant design and construction
— Support of regulatory-licensing and public information activities
— Signing of contract(s).

Project partners contracting hardware and/or services from the utility must match their contract proposals with the above requirements. Again, the future project manager or a project management type person, possibly coming from a marketing or sales department, will lead the contracting effort, aided by technical and legal personnel. Contract attachments in the form of specifications should not only describe the scope of equipment and services completely as discussed above, but should also provide convincing evidence to the utility that it is buying a high quality product which meets the specified functional requirements and is backed by a competent, experienced organization.

Contracts to subcontractors from the main contractor or utility can be very similar in principle. In terms of time, subcontracting usually takes place later and thus falls into the execution phase. Particular attention has to be paid to local subcontracting.

Once all items have been clarified to the satisfaction of both contracting parties, the buying utility and the supplying contractor, the contracts are signed at the highest executive level of the partner organizations involved, with specific acknowledgement (initialling) and complete listing of all contract attachments and associated letters or memoranda.

This act of signing creates a new situation for the project and its management: there is now an obligation to execute the work within an agreed budget and time schedule.

3. PROJECT MANAGEMENT — EXECUTION PHASE

3.1. STRUCTURE OF PROJECT MANAGEMENT

From the standpoint of resources, time span and complexity, the execution of a nuclear power project is a major undertaking which cannot be comprehended, directed and controlled by a single person. The necessary team effort and the highly professional approach needed to engineering and manufacturing require specialized directon in many different disciplines under delegation from top management. To co-ordinate and control such a large and diverse operation, project management is needed.

3.1.1. Definition of project management

Project management in the widest sense is the function of defining, steering, controlling and correcting a project or major parts of it. Steering a technically, organizationally and financially complex project usually implies a complex management structure but simplified and streamlined co-ordination. Project management therefore constitutes a management arrangement and involves a system of special management techniques.

The project manager is responsible above all for the satisfactory completion of a high quality product. He uses the contract, the specifications, the budget and the schedule as control instruments and employs numerous administrative and technical procedures as well as his personal contacts, knowledge and authority. Figure 1 shows an organization structure that might be used for a nuclear power plant project and Fig. 2 summarizes the project management concept. The various tools used involve planning, execution and controlling elements. The project management function requires that the project manager reach agreement with all technical and administrative disciplines and departments involved. On the other hand, the project manager should have the ultimate authority, courage and knowledge to slow down or speed up activities where necessary in given circumstances. A project manager may also assume concurrent line functions in certain situations, such as those of chief engineer or chief of a construction site. However, a clear distinction and separation of project management functions is the assumption used in this Guidebook. Although, then, the project management does not carry any direct engineering or manufacturing responsibility, since these are typical line functions, it is committed to the technical function and quality of the final end product.

The project management, as a group, and the project manager, as a person, provide the more or less exclusive communication channel from one project partner to another (from project manager to project manager). It is therefore apparent that people with skills in communication and problem solving are sought for the project

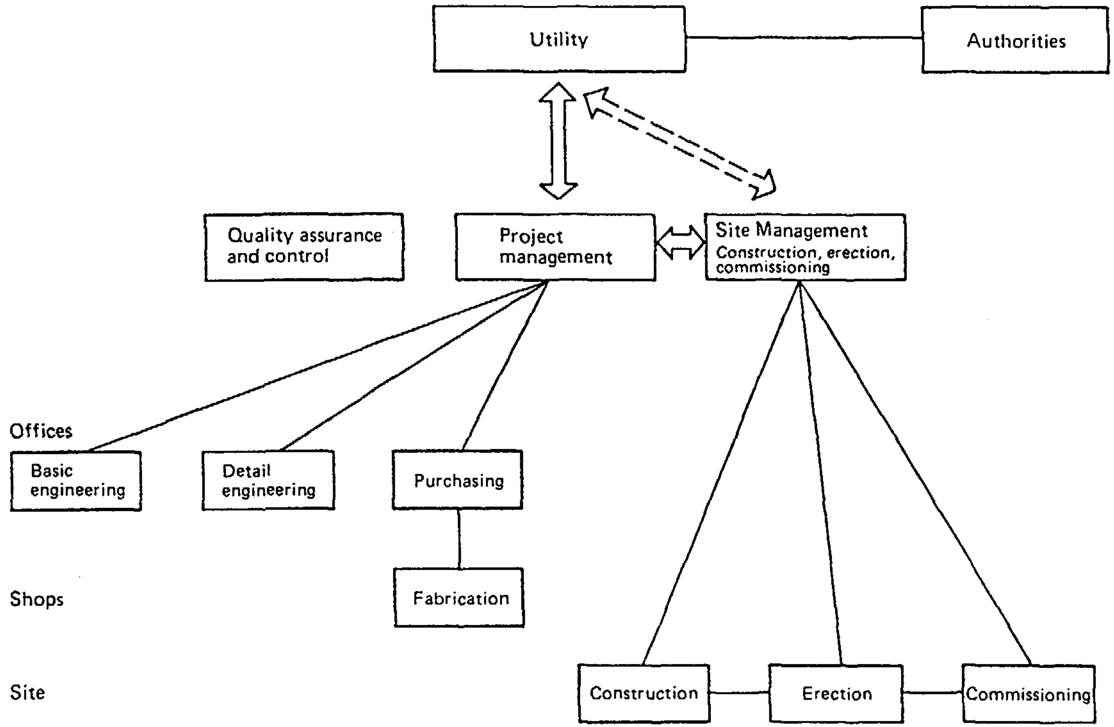

FIG. 1. Organization structure for nuclear power plant construction.

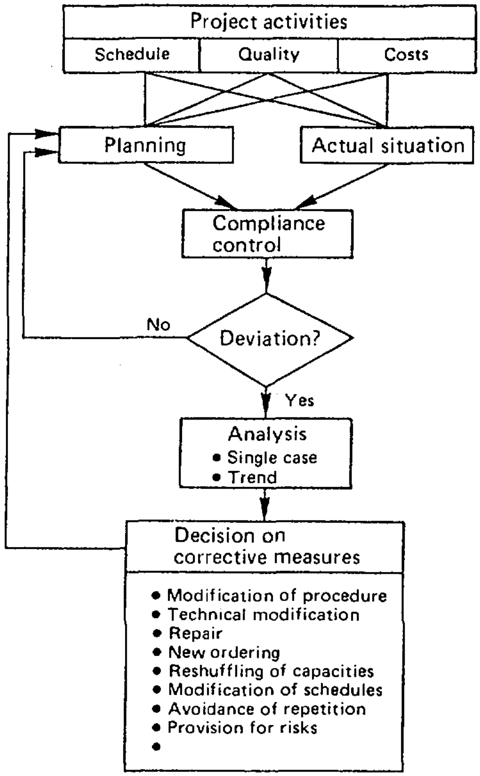

FIG. 2. Project management concept.

management job. Since universities do not issue degrees in project management, the principal source has been the engineering professions. Ideally, the engineer should have broad training and experience — a good appreciation of problems in many fields and not just one technical speciality. Some years of technical work and an engineering management responsibility can greatly add to the capability for understanding engineering co-ordination and personnel and accounting problems. Experience in all these disciplines is probably the most valuable asset for project management personnel, and should have been built up gradually through moves from smaller to larger projects and from assistant positions to higher management responsibility.

3.1.2. Project management hierarchy

Just as there is a carefully established working relationship between project management, engineering and manufacturing departments in the same project partner organization, normally under a matrix management concept, project management in one partner organization has to relate to that of another. There is usually a defined or tacitly accepted hierarchy amongst different project managers in the overall project, based on contracts between partners and on a willingness to co-operate and achieve results. A disciplinary reporting relationship will of course continue to exist between project manager and general manager in each partner organization.

The lowest level of the project management hierarchy may be found in a subcontractor or within one large partner organization at the task level. When project management requirements, such as planning, co-ordinating and controlling (schedule and cost), exist in a small project (say manufacture of a highly standardized product) this function may be assumed by an existing line manager. However, a special

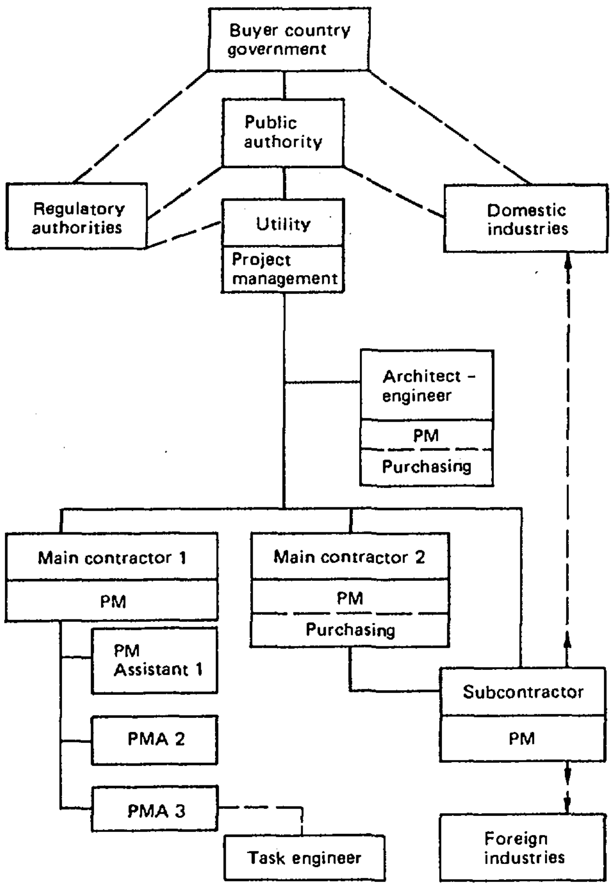

FIG. 3. Project management hierarchy. (PM — project manager; PMA — project manager's assistant.)

co-ordinator is usually nominated, sometimes on a part time basis. This individual may be called 'project manager for ....' — the blank being filled in with the name of the task or perhaps the name of the subcontractor concerned. In smaller organizations and/or for smaller portions of the plant, the person may also be called a contract engineer, contract manager, project co-ordinator, task manager, project engineer, contract administrator, etc. The basic function still remains project management — that is co-ordinating, controlling, communicating and ensuring that the job is done properly. The co-ordinators for the various tasks must be made aware of overall project management procedures and tools, and should if necessary be provided with special training. In the project management part of their work, they should act as an extension of, and should report to, a higher level of project management. This higher level could be found within the same organization or in another partner organization from which the task was delegated as a subcontract. Within a consortium acting as a main contractor there would normally be an overall project manager to whom the individual project managers would report, again in a non-disciplinary sense. Within a typical hierarchy for a nuclear project the ultimate level of project authority would be that of the project manager for the utility, as shown in Fig. 3.

The task of each higher level of project management is the integration of several lower levels, possibly from different organizations, into a single efficient project team, working towards the same project objectives. In the context of this Guidebook the highest level within each parnter organization is referred to as the project manager.

3.1.3. Project management organization

Project management must control the activities of many technically based groups (such as the various engineering disciplines) without necessarily having any direct line authority over them. Its authority stems principally from its competence and the fact that it authorizes work, dispenses it to the technical groups and controls the funding for it. When the work is finished, project management could be viewed as delivering it to another organization (fulfilling a contract) and seeing that the revenue for the services performed or goods supplies is received. Thus, project management is the essential financial and technical link between technically oriented internal (within a particular partner) and external (other partners) groupings. While the project manager must initiate and control the activities of many diverse groups or departments, he cannot belong to, or be the head of, each and every one of those departments. Such positions are usually reserved for senior people with line management skills who are well qualified in a particular technical speciality. This difference and sometimes conflict between project interests and skills and line interests require special organizational forms. Two alternative approaches are applied to larger projects: the matrix approach and the team approach, with the former being more common.

A typical matrix organization is shown in Fig. 4. It allows technical responsibility to reside with department (discipline) managers and the planning, scheduling, monitoring and controlling with project management. Matrix functions, going horizontally across the line management, are necessary to provide a co-ordinated approach to design and construction, and for the control of interfaces. Although there are other integrating or common functions and services working across the line organization, the main such function is project management. Within the matrix organization the project manager is clearly the man who is in overall control of the project. Line managers should be primarily concerned with the quality of the work in their own discipline, the distribution of work (sometimes between several projects) and above all with the effective use of human resources.

In the matrix organization the project staff and the project manager have to recognize and take into account the characteristics of the line organization. Conflicts would be settled mostly at the intersection of the matrix, typically between the individual engineer and project assistants, possibly with the consent of the next management level, i.e. project manager and section or department head. Only in exceptional cases will the line management or the project management take the problem to the general management of the organization. The necessity of agreement within the matrix organizations means that the project manager has to perform an important check function on any project decision being made in the functional line organization.

The matrix approach also ensures the establishment of the permanent specialized functional groups needed for subsequent projects. This allows a gradual buildup of expertise and experience and a concentration of specialist skills. Pooling of skills provides for flexibility in deploying resources for various projects. There is also a notable element of transfer of know-how and experience from one project to another in this organizational form.

Alternatively, and in particular for an organization's first large project, the company concerned could take all key people who are going to work on the project and group them into a project team. Such a team approach appears initially very attractive, clearly directed at project objectives and project efficiency.

Project teams are completely autonomous, and there is no clash of priorities resulting from different projects in competition for common resources. However, once a project gets above a certain size, co-ordination problems arise in the team approach. The project manager could find that much of his time is devoted to sorting out technical problems and personnel matters instead of co-ordinating and controlling the project. When the project is completed the team has no further purpose and will be dispersed or reassigned in various ways. Such organizational changes usually bring problems, with dissatisfaction and rivalries created among those whose roles have been changed and corresponding motivation problems in anticipation of such difficulties. Another possible danger is that should something go wrong with the project after its supposed completion the team organization no longer exists to deal with it.

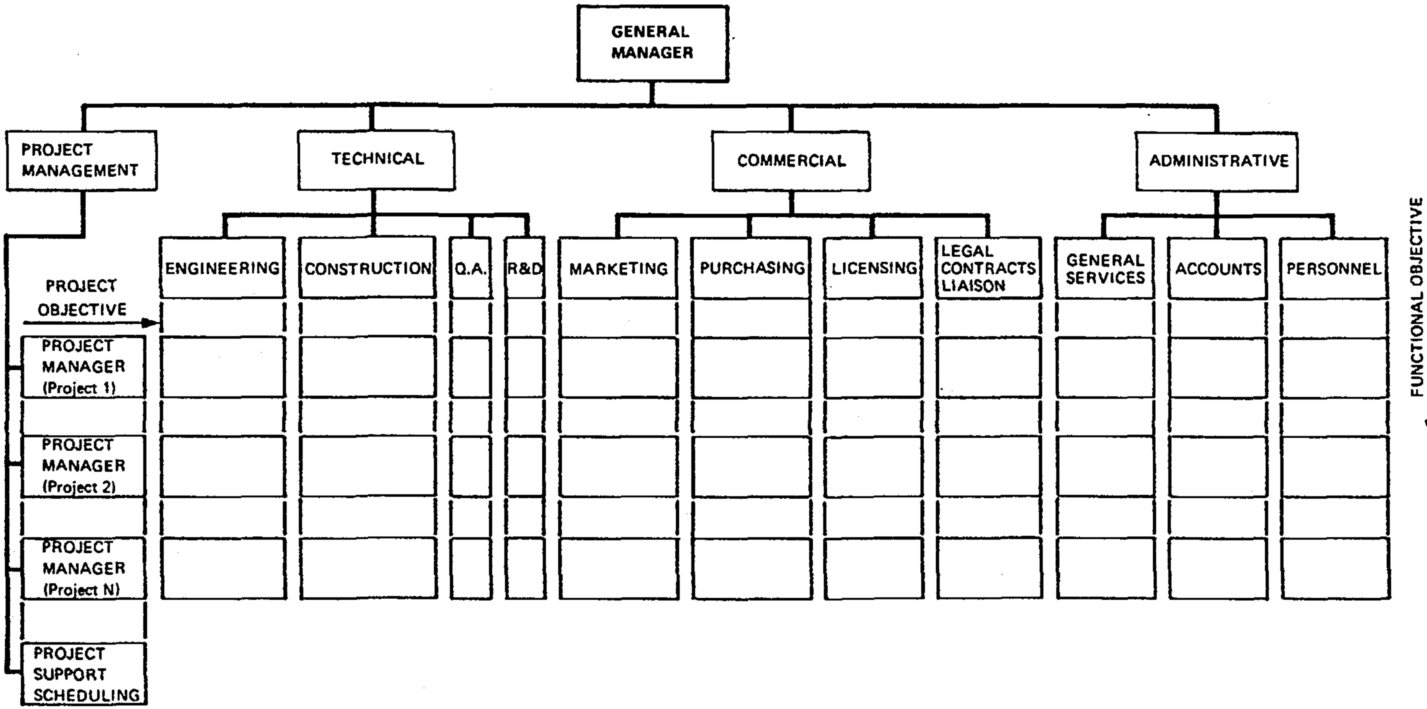

FIG. 4. Typical matrix organization for project management.

There is another possible problem with a small project team. If, for example, purchasing is made project specific within the team and only one person is responsible for it, the fate of the project may be dependent on the capabilities or health of just one individual, who becomes virtually indispensable.

Arguments will no doubt continue as to which is the better of the two principal project organizations. On the surface, the team approach appears to offer a number of advantages, in particular a clear chain of command and priority within the project. On the other hand, the complex intersections within the alternative project matrix organization, requiring agreement between line and project managements, provide an important and largely independent checking function. Also the availability of expertise and continuity of engineering specialities and central support functions appear to be better in the matrix situation. Nuclear projects employ high technology and high quality components and this encourages the concentration of expertise and delegation on the one hand, and independent, centralized control on the other. Therefore, most successful nuclear power plant project organizations have been of the matrix type.

The matrix approach is therefore recommended for a nuclear power plant project and its features are taken as reference in this Guidebook.

Figure 5 shows a typical organizational structure for utility project management and Fig. 6 the corresponding structure for main contractor project management.

3.1.4. Project management tasks and functions

The main functions of project management can be grouped into two categories:

— Getting the job done
— Controlling the project work.

Getting the job done usually involves:

— Defining the project requirements and regulatory and quality assurance requirements;
— Setting aims and milestones, defining, sequencing and initiating the tasks of the project in agreement with the sections and departments involved; ensuring the availability of funds and manpower;
— Dealing with problems which hinder the progress of the project or threaten its quality;
— Co-ordinating the project activities.

Controlling the project work involves:

— Conducting regular meetings with project staff, line organizations and project partners to monitor progress, take necessary corrective actions and communicate essential project information;

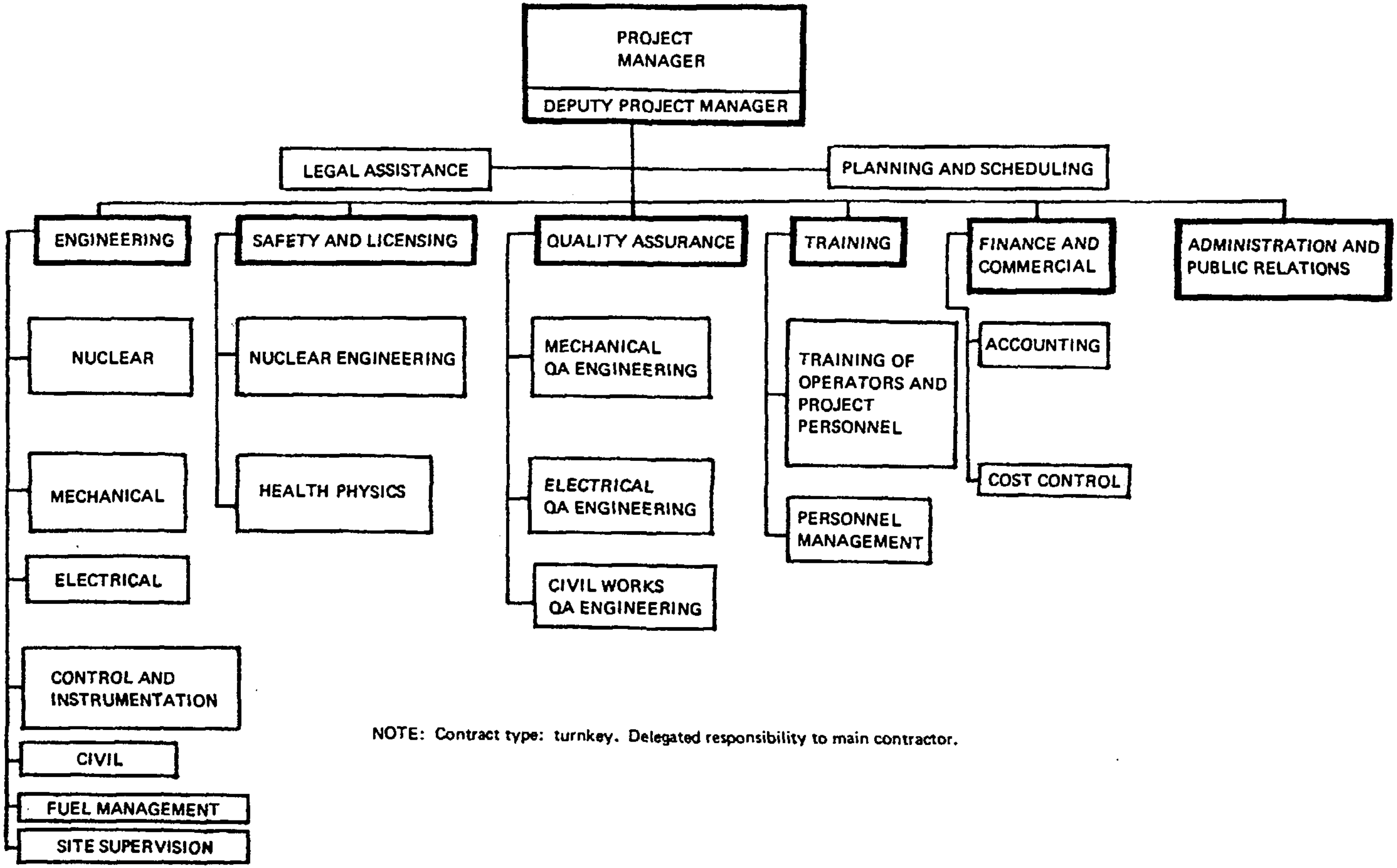

FIG. 5. Example of organizational structure for utility project management.

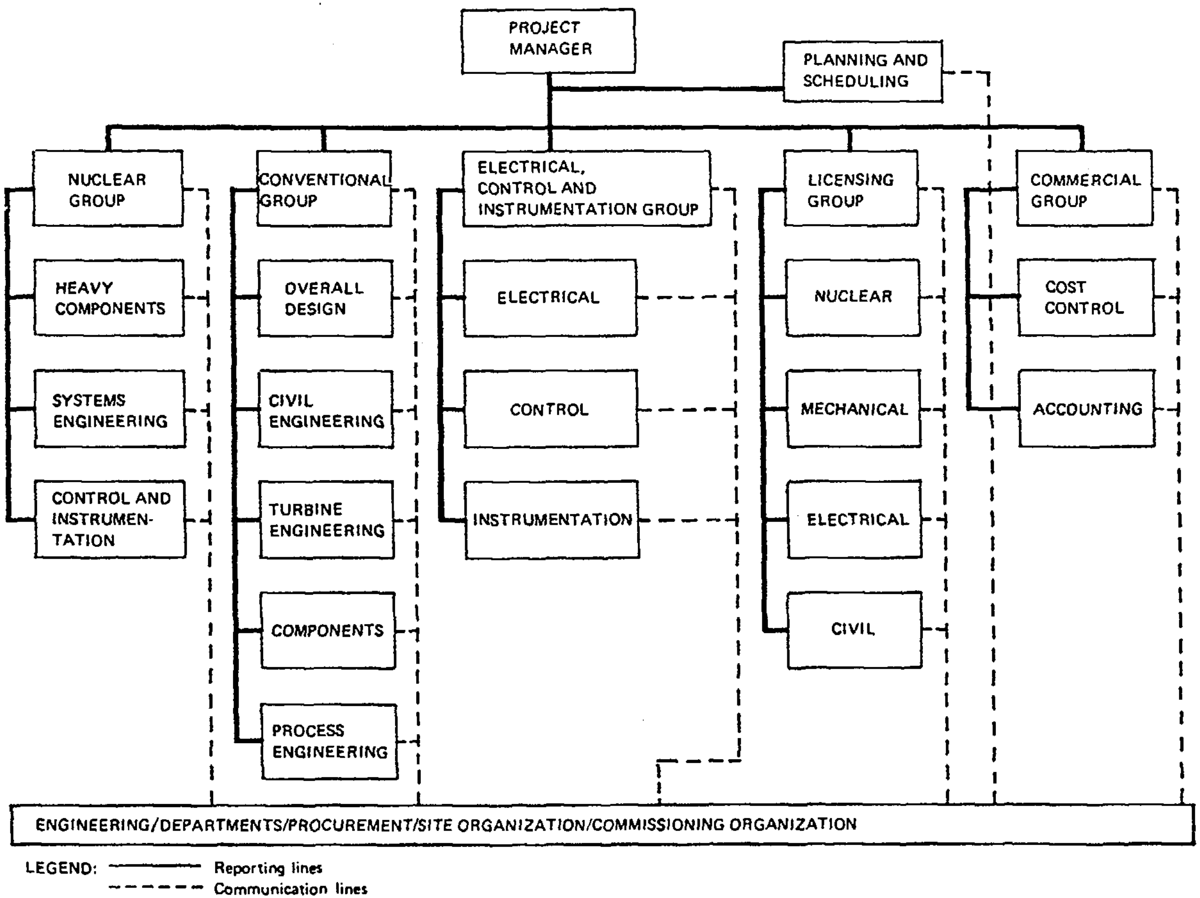

FIG. 6. Example of organizational structure for main contractor project management.

— Controlling expenses and project performance against the contracts, budget and schedule, and obtaining proper authorization for major changes;
— Monitoring the technical progress of the project in terms of analyses, specifications and drawings by ensuring high quality and compliance with requirements, authorizing equipment specifications for manufacturing and construction.

The emphasis within the above functions is somewhat different for the two typical partner categories in a project — the utility (which will own and operate the plant) and the main contractor. Whereas supervision and control activities would be predominant for the utility, getting the job done with the necessary quality would be the main concern for the contractor. An architect–engineering organization in a nuclear power project may fall into either category, depending on the contract, i.e. working essentially as an extension of the utility or taking the lead as a contractor. Subcontractors have a project management responsibility similar to that of the main contractors, only on a smaller scale.

The leading but not necessarily the largest application of project management is in the utility which has overall responsibility for the project in all phases and usually assumes ownership and operation of the plant. The degree of involvement and level of effort in the utility and therefore the personnel requirements will depend upon the amount of delegation applied in the plant contracts. It is assumed, for the purpose of this Guidebook, that in general a utility in a country building its first nuclear power plant may want to delegate most of the work to experienced contractors. It will have to observe national plans and standards and accept supervision by the public authority and the regulatory body in drawing up contracts for the plant with the main contractors and architect–engineers, with subcontractors representing the different industrial sectors involved, and with foreign consultants and equipment manufacturers as needed. The utility and its project manager will then monitor and control the project with regard to the partners' compliance with the contracts. It will also have to satisfy the regulatory authority and the general public and will frequently have to take the lead in problem solving.

The responsibility of project management in a contracting type organization differs from that in the utility because of the different relationship to the plant and generally the much larger volume of work and higher level of proficiency required. Unlike the utility, the contractor will neither own the plant in the future nor have to operate it for thirty to forty years. Instead, the company has to fulfil a contract within given constraints of schedule, costs, warranties, etc., and to do this at a profit. At the same time the organization's reputation with regard to its product and its performance may be at stake. The construction of large portions of the plant requires the constant involvement of project management in ensuring the proper technical quality, drawing up plans and procedures and implementing controls.

In a nuclear power plant project all project partners will experience a peak work load during the project execution phase, in which their project managers have to take the leading role. Planning and controlling tasks will interrelate with project execution and will require the project managers to be concerned with many different types of activity at the same time.

The utility project manager always has the lead in the project management hierarchy but will have to be particularly attentive when the plant is being cast into concrete and steel during project execution. If a turnkey contract is chosen for the first nuclear power project and the engineering and construction activities are essentially all delegated, utility project management is left with the following typical tasks (which could reflect an internal job description):

- Preparing, reviewing and adapting the necessary project planning and implementation schedules
- Steering overall requirements, monitoring progress and giving detailed approval of engineering
- Ensuring timely delivery of items within the utility's scope of supply
- Ensuring the transport of equipment and the availability of site services
- Carrying out expediting services
- Maintaining effective project cost control
- Certifying interim progress payments
- Giving final approval and authorizing payment of bills from suppliers
- Preparing and issuing progress reports
- Carrying out plant design reviews to ensure adherence to contractual conditions and regulatory requirements
- Introducing and co-ordinating quality assurance and control programmes
- Reviewing the quality assurance and quality control procedures of contractor(s)
- Ensuring quality control and proper construction supervision at the plant site
- Surveilling component manufacturing
- Preparing for commissioning and operation
- Applying for plant licences and revisions
- Reviewing and approving plant safety and engineering procedures, as well as plant operation and maintenance manuals
- Supervising plant commissioning and reviewing test results
- Training operations personnel.

The monitoring of expenditures and maintenance of up to date budgets will be accompanied by technical supervision, such as approval of specifications, drawings and purchase orders, certification of work performed, inspections and quality control, provisional and final acceptance, study of discrepancies and corrective action, and preparation of reports. Most important, however, are the contracts, their definition, administration and enforcement.

The responsibilities undertaken by the utility project management in relation to software include:

- Supplying interfacing information and progress reports on work within the scope of the utility
- Controlling the overall schedule and seeing that only one valid schedule is being used by all project partners
- Evaluating alternative options originating from the main contractor during the early development of the engineering work, or assessing necessary changes
- Approving the list of qualified subcontractors put forward by the main contractor
- Checking the bids received within the scope of the utility
- Reviewing and approving project requirements, analytical reports, drawings and technical specifications
- Closing subcontracts or contract amendments, as needed
- Supervising the administration and execution of contracts delegated to the main contractor and/or architect–engineer
- Verifying compliance of design and manufacture with the established project requirements.

The utility in general and its project management in particular is responsible for the economic control of the project, including financial management, approval and payment of bills from contractors. In any type of contract the details of cost control, payments and/or financial resources must be clearly defined. Finally, the utility project management must be very much aware during planning and execution of the project of its future responsibility for the operation of the plant. This involves the proper preparation for operation and maintenance, the securing of appropriate documentation and the drawing up of plans for spare parts supply.

In the case of a turnkey contract, responsibility for the design, engineering, construction and functioning of the nuclear power project would normally lie with one main contractor or consortium.

Inside the main contractor organization, the project management is in charge of the project's technical and commercial success, and in this way is an arm of executive management. In relation to the other project partners, the project manager is the main spokesman and the information link on project matters and sometimes on company matters. A co-operative and business-like relationship between the utility and the main contractor project managers is essential; they should be of fairly equal rank. In general, the project management of the main contractor must pursue the main objective of producing a high quality, reliable product within the constraints of schedule, budget and project requirements. The principal tasks are:

- To define the project requirements resulting from contractual terms with the project partners;

— To establish a project breakdown for hardware and software and allocate the project budget through individual project task orders;
— To define, sequence, and initiate the project works in agreement with the sections and departments involved; to ensure the availability of funds and manpower;
— To deal with any problems which hinder the progress of the project or threaten its quality, to provide problem solving leadership and assistance where needed, and to establish a project risk analysis and risk reduction programme;
— To conduct separate regular meetings with project staff, line organization and project partners in order to monitor progress, take any necessary corrective action and communicate essential project information;
— To monitor expenses and project performance against budget and schedule, and to obtain proper authorization for major changes;
— To monitor the technical progress of the project in relation to the specifications and drawings (software) by ensuring compliance with project requirements;
— To co-ordinate the project activities and control project interfaces inside and outside the organization;
— To authorize specifications for manufacturing and installation of equipment;
— To set up purchasing procedures and controls;
— To expedite engineering and subcontractor deliveries;
— To ensure timely and proper preparation of licensing documentation and applications as well as adherence to compliance procedures;
— To monitor and control costs;
— To ensure progress payments and prepare claims for justified price changes;
— To help perform quality control and establish independent quality assurance;
— To provide assistance, proper interfacing and transfer of information to the site management and the utility;
— To report progress at regular intervals.

The project management tasks for an architect-engineer during project execution may be very similar to those of the utility or the main contractor, depending on the contract type:

— As an engineering consultant to the utility the architect-engineer may help to expand utility interest and activities in project execution, and its project management would act very much as the utility project management.
— An architect-engineer can also be seen as an engineering contractor for the plant. In such a case the project management tasks would be similar to those of the main contractor.
— A somewhat in-between and more specialized role for the architect-engineer can result from a split package approach and deserves further explanation with regard to the project management functions involved. In particular, the utility would act as a principal designer and co-ordinator of the entire plant but would

sublet (contract) this task to an experienced engineering company, the architect–engineer. In this position the architect–engineer is an engineering contractor but, at the same time, takes on much of the utility role and also provides an independent checks-and-balance function on principal engineering packages performed by contractors for portions of the plant; this function is important for the plant's technical quality control.

In performing the principal tasks in this last case the architect–engineer's project manager will have to assume some of the utility project management roles described above. The exact arrangements will depend to some extent on contractual and traditional relationships between architect–engineers and utilities and to a great extent on trust and personalities. In all cases, the architect–engineer's project management group will have to co-ordinate very closely with the utility. Major tasks and responsibilities of the architect–engineer project manager will include:

— Managing own services, supplies and subcontracted services
— Co-ordinating all services at the site (including those of third parties) by:
  (i) optimizing sequences in construction and erection activities
  (ii) minimizing project interfaces inside and outside the architect–engineer organization (in consortium and subcontractor relationships)
— Ensuring project definition in the form of project requirements and specifications and controlling changes
— Providing problem solving leadership and assistance where needed and establishing a project risk analysis and risk reduction programme
— Monitoring all activities by means of project control tools
— Measuring progress
— Implementing and maintaining the quality assurance programme
— Ensuring timely and proper preparation of licensing documentation and application as well as adherence to compliance procedures
— Managing contracts and dealing with supplements and claims.

During the transition phase to operation the architect–engineer's project management has, in addition, to see to the:

— co-ordination of late works/repairs, etc.
— follow-up of guarantee works and additional services
— preparation of as-built records and documents
— preparation of final acceptance.

The subcontractors in a nuclear power project may have quite different scopes and types of contract. Depending on the size and existing internal organization, they will establish and execute project management tasks fairly similar to the ones described for the main contractor. On the other hand, the tasks may be of small enough volume to be combined effectively with engineering co-ordination or production control.

The following specific example of the supply of valves for a nuclear power plant project illustrates typical subcontractor project management tasks in the execution of an equipment subcontract:

- Arrange for quotations on specified valves and accessories for the nuclear plant by the sales department
- Draw up a definite contract in terms of quantity, scope, delivery date, price and identification of each separately shippable item (box, assembly, package)
- Fix an internal order number, after award of contract; appoint a temporary project manager to be in charge of the project and report to the divisional manager
- Compile complete and specific requirements documentation for the nuclear production (standards and procedures and their interpretation)
- Check with the customer (from whom the order comes, i.e. architect-engineer) on accuracy of established requirements; arrange countersigning by both parties on the purchase order
- Schedule the production according to the required delivery dates and establish control by a list of manufacturing design details and manufacturing milestones
- Provide shop documentation for each piece of equipment and its parts, including engineering, quality assurance and manufacturing information, in order to establish a permanent record
- Establish and enforce engineering change control
- Ensure timely shipment of hardware items and associated design and quality assurance documentation to the designated site (end of the work on contract)
- Follow up installation, startup and initial operation for warranty purposes.

On the basis of the overall project schedule or major system schedule specified by the ordering project partner the subcontractor prepares a detailed manufacturing schedule, which has to be closely studied and discussed prior to the contract award. The responsibility for the follow-up and updating of the schedule lies with the subcontractor, who will periodically issue a corresponding status report. The utility, the architect-engineer, or the main contractor will supervise the observance of the schedule.

Subcontracted equipment and components are usually specified prior to the order, either as standardized products or as the result of engineering efforts by the main contractor or architect-engineer. However, detailed design work is normally performed to the specified requirements by the manufacturer, who must perform his own design control in accordance with the relevant quality assurance criteria and standards required. For some subcontractors this effort will require a special training programme and the use of new procedures and equipment. Subcontractor project management must carry a particular responsibility for nuclear related quality and the project managers of the ordering partners must verify compliance in this area.

3.1.5. Project management rules and procedures

The project manager in each partner organization should be carefully selected. The hierarchical level at which the manager is to work must be compatible with that of section and department heads in charge of typical technical specialities in a nuclear power plant. In a team approach the project manager should be able to lead these technical managers and in the preferred matrix approach he should have the necessary authority to ensure his views predominate; his co-signature should be required on most project actions.

Since not all of the technical sections may have been involved in the pre-contract and contract phases and some of them could be working on other projects, a written instruction from the organization's highest management level is a first practical step to get project work started in a properly authorized manner. Such an announcement should immediately follow contract signing. It should serve to present the project manager, provide basic information on the type of project organization chosen, establish budget codes, and clarify preliminary communications and signature procedures.

The implementation and control of project definition and the communication of decisions are continuous tasks during project execution, but are particularly important at the beginning. As far as possible, front-end definition should be achieved, even if corrections have to be made later. The interpretation of contractual terms into concrete project requirements usually involves a special effort by project management. Whatever is decided and detailed in a permanently valid form for the project organization should be established in writing and collected in an appropriate form, i.e. in manuals. The object of a project manual within any partner organization is to make readily available the rules governing the relations and task distributions between the various participating departments and with other project partners. The characteristics of such a project manual can be outlined as follows:

— The rules described in the procedures should be compulsory for all the organizational entities over which the management of the partner has disciplinary authority.
— The project manual should observe the hierarchy of project contracts and partners, i.e. make clear who is holding what type of funding and approval authority in which type of contract. The utility's manual may serve as a general guide and may be used by the architect–engineer, main contractor or consultants, as needed.
— The manual must include a procedure to be followed for its own modification and updating.
— The manual will refer only to the principal relations with other project partners, in particular communications and approval channels, without including in detail their individual internal organization.

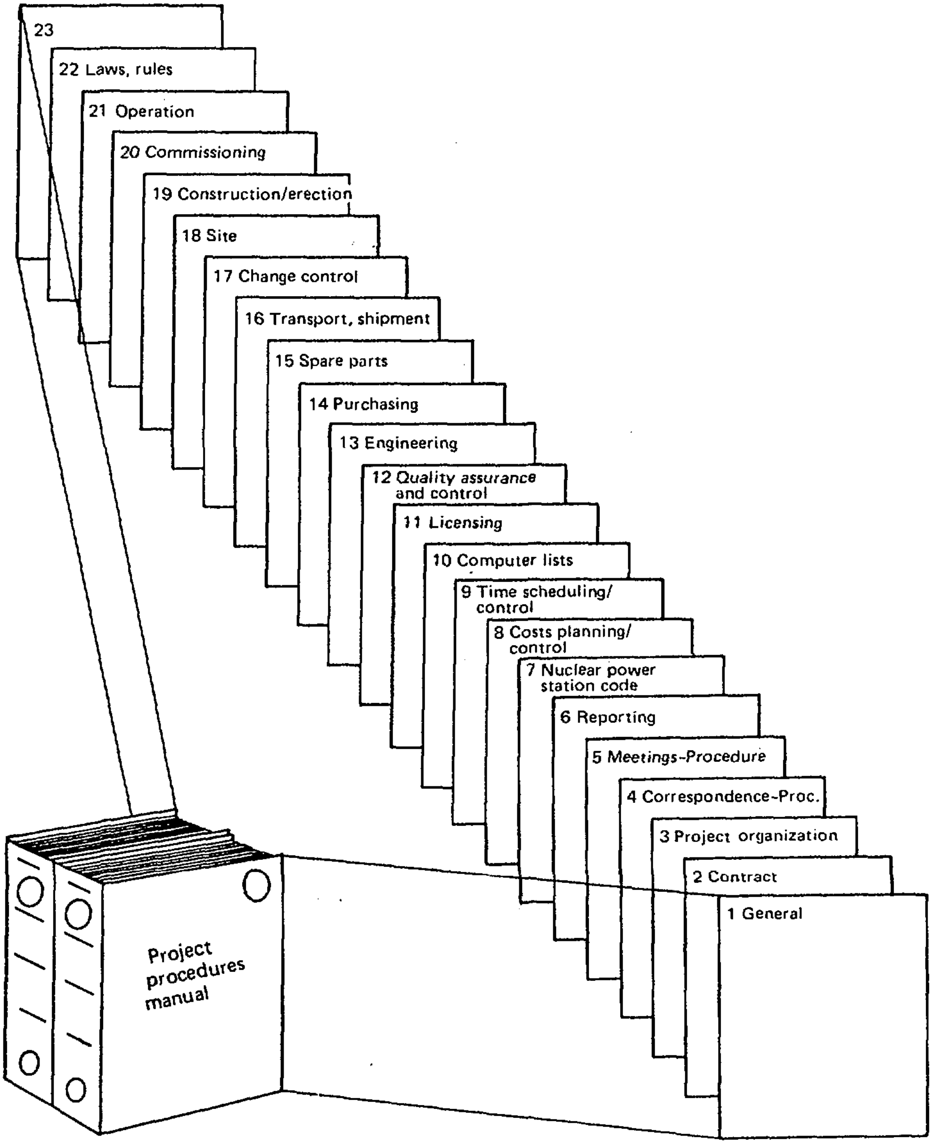

FIG. 7. Project procedures manual.

— The contents of the manual must be discussed with the main project partners involved, at least between utility and main contractor or utility and architect–engineer and contractors.

A sample contents list for a project manual is presented in Appendix I.

Just as there is an organizational hierarchy for the project management of the project partners, there is a hierarchy in documents (such as procedures and manuals) for project direction. While the utility would have the lead in compiling the general portions of the project manual, other partners would add details and their own internal procedures. If one of the project partners is a consortium, there would most likely be a further hierarchy of project management and of manuals from the consortium level to that of individual organizations.

There is also a need for manuals which delineate internal procedures in each of the project partner organizations (which could have more a line management character) and would apply to a product line and/or to several different projects. It is a recommended practice for nuclear power project management to prepare a single document for any particular project, in which the project specifics are outlined and proper reference is made to other more general procedures of the organization. Where in some particular case or for some purposes the standard procedures are not applicable to the project, specific procedures have to be prepared. These will be written following the directions or specification of the project manager and are sometimes referred to as a project organization manual.

The project manual may also be in the form of a set of manuals, for example:

— Project reference information
— Project procedures manual
— Internal procedures and guides
— Codes, standards and regulatory requirements.

In Fig. 7, an example is given of the content of the project procedures manual.

The parts of manuals applicable to quality assurance (QA) must have the approval of the appropriate QA units within the partner organization. The project manual (or portions thereof) is sometimes a part of the QA programme of the project. In these cases a controlled distribution must be made and change control and enforcement of the manual will have to comply with regulatory requirements.

The documentation of communications, planning and control procedures may generate a large amount of paper. Once project procedures have been established and made known (i.e. via a manual), associated forms and reports can be developed, listed in the manual and distributed. Administrative or organizational specialists in the partner organization may help project management to develop these documents. The project manager must be careful to watch the time he spends on this type of activity and should ensure that not too much beaurocracy is introduced.

3.2. PROJECT EXECUTION

The project management involvement in the realization of the nuclear power project is explained in this section. Since large amounts of materials and equipment are ordered, produced and installed in this phase and the most important manpower resources are mobilized, the largest part of the overall cost is incurred and the highest degree of co-ordination is necessary. It is in this phase that project management has to show its strength and use all its tools. The stage begins with the signed contract and ends with the handover of the completed and tested plant to the operating unit.

3.2.1. Definition of the project

3.2.1.1. Start of the project

Although the project management activities may be continuous from the pre-project phase to the execution phase, the contract signing represents a major step in project work. The project ceases to be merely a planning exercise and becomes instead a real entity. Clear and well defined commitments have been made between the project partners and signed by the highest level of their management, expenditures will be incurred in orders of magnitude higher than before and the project execution is started. Each day lost on a critical activity may now become crucial and give rise to penalties. If a project management organization has not already been established, the very first task is to appoint a project manager in each of the organizations, the utility and main contractor in a turnkey approach and utility, architect–engineer and contractors in a split package approach. It is, however, definitely preferable to appoint project management during the pre-contract phase and involve it in all pre-contract activities.

If project management is established after contract signing, it would be sensible to designate sales and acquisition experts from the pre-contract phase to become key members of the project groups of the respective partners. This would mean a senior person from the bid specification and contract negotiation effort of the utility, for example, or a senior sales person from an architect–engineer or main contractor. If this is not practicable or possible, the pre-contract team should prepare an information package, highlighting important technical and commercial commitments which are already in the contract explicitly or implicitly, together with background details and notes on instructions contained in letters, memoranda of understanding or attachments. This package is handed to the new project manager and should help guide him through the contract portions relevant to his organization and assist him and his team in initial activities and in project definition.

When the project manager has been named, he should be officially introduced, by memorandum, in his own organization and to project partners. Details of the overall project organization should be established and promulgated to indicate the key people in the organization and relevant information on other project partners. Principal contact points and other senior staff members who have project responsibility (e.g. the licensing or QA manager) must be made known. Organizational charts showing the project hierarchy inside and outside the organization can be helpful additions. Project code numbers for filing and documentation, major budget areas, project objectives and major project procedures should also be made known as quickly as possible. All these activities will help to streamline project work and increase productivity. On the other hand, the final versions of documents may need additional work and a negotiated consensus. It is therefore necessary that initial organizational actions and procedures be announced in stages.

For the utility, be it a public or a private company, the contract means a commitment to a major investment and a commitment to the partners. As the highest executive level in the project, the utility has the ultimate responsibility for ensuring that work is started and performed in accordance with project objectives and requirements. Holding the financial resources, the utility has the means and power to delegate work and control and supervise the corresponding contracts. The utility has to see that the requirements established by the public authority and/or the regulatory body are met. As ultimately responsible for the safe and reliable operation of the plant to be built, the utility project manager has to look into all aspects of the project, including the establishment of requirements, target setting, overall co-ordination, decision making and communication processes, and monitoring and surveillance. The utility must provide channels for all relations with governmental organizations that might be required in connection with the project as a whole, and the utility project manager will act as the communications link for these.

Regardless of the type of contract and the partners chosen, the utility project manager must first verify that his counterparts in other partner organizations have been assigned. Every partner must be made fully aware of the particular role that he will be expected to play and the goods and services he is expected to supply. Even when a clear technical specification has been prepared there are often many loose ends to be tied before actual work can start.

The contractual approach chosen by a utility has very little effect on the overall manpower requirements of a nuclear power project, but it does have a substantial influence on the distribution of personnel amongst the partners involved according to their particular functions and scope of work. It also affects the distribution of the responsibility, quality and staffing of the project management functions amongst the project partners.

During the contract execution phase a typical utility will require at least 50 to 60 engineering professionals. This group will be involved in construction and erection up to the point where the operations and maintenance group takes over the completed plant. These numbers are typical of the case where most of the work on the project is delegated to main contractors and they may vary with contract scope. The utility will contain about 15 to 20 highly qualified and experienced professionals

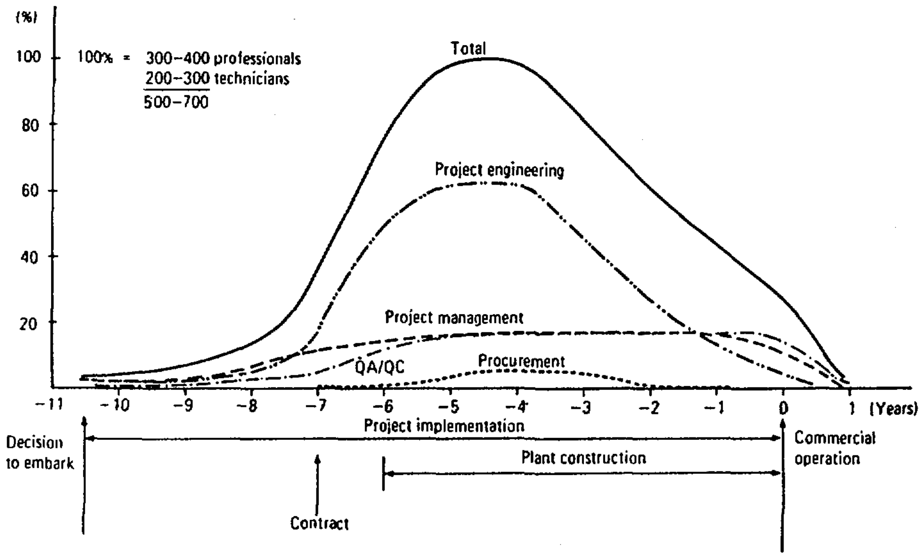

FIG. 8. Manpower loading for project management.

primarily responsible for project management tasks. Figure 8 shows typical manpower loading for project management and Appendix II contains a summary of the manpower and technical qualification requirements for utility project management.

One of the first duties of the main contractor project management is to make certain that realistic preliminary plans and schedules have been developed. A conflict of interest (requiring certain compromises) may arise for the project manager between starting work immediately (in order not to lose schedule time) and defining the work first in more detail. The project manager must anyway straight away involve affected line managers. A summary of the contract information, in particular the contractual schedule and/or the first draft network based on it, should be distributed to every department involved as soon as the order is received. Either the schedule diagrams themselves may be reproduced and circulated or tabular presentations of activities, resources and their scheduled dates can be issued. In this way, the sections and departments affected will become aware of commitments made for them or be reminded of obligations and objectives resulting from the contract closing. Apart from the schedule information, budget aspects are also very important. A detailed project budget, based on the best available estimates, should be compiled. Any figure which appears unrealistic must be questioned immediately and difficulties must be resolved. Involving the relevant departments in schedule and budget verification and detailing is an important way of obtaining commitments and increasing motivation. Finally, the leading project tasks must be formally authorized.

The project manager for the main contractor should be a professional with at least five years prior nuclear power experience and demonstrated ability in a project team. He will normally start with a relatively small staff of two or three engineers (at least one with several years' experience in nuclear power projects), but should quickly build up his unit to full size by the time plant construction is initiated (see Fig. 8). Appendix III lists the manpower and technical qualification requirements for the project management of a main contractor with a large project team. The preferred and more frequently used scheme, however, would be a matrix organization. In such an organization the project manager would typically retain between 5 and 15 lead professionals as project asssistants and leave all line responsibilities to engineering.

In summary, the major aspects that require special attention at the start of a project are:

— Assignment of project managers and establishment of project organization
— Issuance of project procedures and project numbering schemes and budget codes
— Refining of the project schedule and budget
— Definition of project requirements, in particular applicable codes and regulations
— Authorization of leading tasks
— Setting up of work breakdown structure and assignment and authorization of work.

In a split package approach, the architect–engineer under contract to the utility will also set up and/or expand his project management organization when starting contract work. Depending on the type of contract, the architect–engineer may perform utility tasks in co-operation with or instead of the utility.

3.2.1.2. Project communications

One of the first needs of project management will be to take decisive steps in setting up efficient communications. This will certainly be the case where there are long distances between different project partner organizations or scattered offices within one organization. The utility project manager is the natural person to initiate this work. It is good practice for each partner organization to nominate one person in the project group as a control point for receiving and sending all written communications. These individuals become responsible for seeing that everyone within their own organization is kept correctly informed — either by the direction of incoming mail for action, or through the distribution of correspondence copies. For the rapid communication of written records, telex or facsimile installations can be considered. The administrative portion of this function may also be delegated to a central dispatching and registry office, as long as accurate performance can be ensured.

Every partner should take project correspondence seriously — there could be difficulties if vital letters are lost. It must also be borne in mind that records of decisions and data may be required by quality assurance and regulatory authorities at a much later date; this affects the future plant owner, the utility, as much as contractors or the architect-engineer.

Since a large amount of correspondence is expected, unique letter reference serial numbers must be agreed on. Each project partner could allocate serial numbers to all letters sent, prefixed with its own code and possibly supplemented by a unique project designation accepted by all partners. Letters from organization A to company B, for example, would be numbered in the series AB1, AB2, etc., and letters from B to A would be numbered BA1, BA2, etc. Apart from making filing and future retrieval easier, this means that any gap in the sequence can be investigated to ensure that documents have not been lost in transit.

To set up a standard internal distribution scheme for written communication a matrix can be used, with the names of recipients along one side and the documents along another. A number is written at each intersection on the grid to show how many copies of the relevant document each person should receive. It is one of the tasks of project management to strike a good balance between meeting information needs and maintaining the motivation of people working on the project, and keeping administrative paper work to a minimum.

The project managers will be very busy with a number of competing startup tasks depending on the level of pre-contract preparation and/or experience in their organization. This may mean setting up first only rudimentary and coarse communication procedures, to be expanded and detailed later as the volume of project communications increases. A lack of established communication procedures can cause substantial logistic problems and delays. It is a wise investment of time and effort for all project managers and particularly for the utility project manager to see that as many as possible of the project designations, correspondence procedures and documentation standards are compatible with each other or even identical. Early establishment of regular project progress meetings within each partner organization and between project partners will supplement the formal communications.

In all projects there will eventually be mistakes and misunderstandings which lead to claims and counterclaims between contractual partners. Additional staff (accountants, lawyers and general management) will become involved and relations and communications might be spoiled for some time. All partners, and in particular their project managers, should make an effort to maintain a sincere, practical and, wherever possible, unemotional approach in times of difficulty in order to ensure the necessary co-operation.

3.2.1.3. Project requirements

The identification, proper documentation, explanation and enforcement of project requirements (sometimes also called design criteria) are among the most important means of achieving efficient project management. Experience has shown that late identification of requirements will usually involve much greater expense in software and possibly hardware.

Thus, the complete definition of project requirements is probably one of the foremost tasks of project management. As with communications and documentation, the utility project manager should take the lead in ensuring that a complete set of requirements is established and used within and between project partners, including the regulatory authority. The principal effort of writing detailed requirements will lie with the main contractor or architect-engineer, depending on the contract. This activity may create conflicts of interest or priority with other project management tasks, but time and money can be saved by following the rule that no engineering or manufacturing activity should be authorized before the detailed requirements have been written down.

Before the beginning of project execution (already in the bid invitation specification document), all applicable requirements and design criteria laid down by the regulatory body should have been properly identified and listed. In the context of this Guidebook, regulatory requirements mean the collection of relevant regulations that are in force in the country where the nuclear power plant is being built. Three major categories can be identified:

- Laws, decrees and other applicable government rules
- Regulations established by international bodies or agencies to which the government of the country adheres
- Other rules and regulations included in specific permits and authorizations issued by the regulatory organizations of the country.

Source documents for the requirements will include the project contracts, permits related to the plant, and internal standards of the project partner organizations. The list of regulatory requirements must be kept up to date, especially when the site permit, construction permit or operations permit are received and when a new regulation or revision of a former one has been issued and/or enforced by the government or the regulatory body.

Codes and standards may include:

- Codes and standards which are generally accepted
- Codes and standards mandatory according to the internal rules and different authorities of the country
- Codes and standards from the country of origin of the contractor for the plant or part thereof
- Codes and standards imposed by the utility
- Codes and standards of the main contractors and subcontractors.

The difference between regulatory requirements and codes and standards is often not very clear. Since both become project requirements, the two lists above may be taken as complementary.

A list with the definition and validity dates of all the codes, standards and regulatory requirements for the project must be prepared as a project document under formal change control. It could be included in the Project Manual, made a contract attachment or a separate, more technical, project requirement document.

The content of the document at its most general level starts with the project contract and the licensing requirements. Major requirements can then be dealt with in greater detail for particular systems, together with interpretations, notes on relevant standards and possibly descriptive information. A third level of content may be equipment specifications, with the important requirements for a particular piece of equipment spelled out in detail. These specifications can serve as a purchasing and manufacturing document.

The overall plant requirements document is of key interest to utility project management, but is likely to be compiled by a main contractor under a turnkey contract arrangement for the plant, or the architect–engineer in a non-turnkey situation. The contracting partners would primarily use this document to control their internal work, but its use between project partners (preferably including the regulatory authority) as a basis for understanding and agreement is equally important.

In the case of a turnkey contract a definition of project requirements may read as follows: 'project requirements are those norms, codes and regulations, together with other information, including utility requirements, which are used as design basis for the project'. The writing of project requirements assists project management in:

— Producing a definitive basis for the project engineering and production tasks with precise timing agreed upon between project partners
— Providing a common engineering database
— Serving as a basis for quality control
— Establishing a starting point for future design changes.

In some projects a task force is established immediately after contract closing to define in more detail the major requirements and data for the entire project. Such an effort may take some six months and involve several man-years of effort on the part of the most experienced engineers of the main contractor, possibly assisted by other project partners, in particular the utility and the regulatory body. The main contractor project manager may lead this important activity. The output would be a separate specific requirements document. Updating has to be performed regularly and changes have to be approved and documented.

Project requirements must be put under formal change control and no changes will become effective without formal project management approval and announcement. Changes in requirements and their interpretation must involve the source of the requirements, affected project partners and, above all, the cognizant engineering sections; requirements changes should normally be subject to utility consent. When a main contractor, architect–engineer or subcontractor holds a commercial licence for the work and plant portion he is responsible for, chiefs of affected sections in the licensing home office must also be consulted and approve the requirement or its change. After signature by all affected persons in accordance with a formal release and change control procedure, requirements or their revisions should go to the quality assurance department for final checking and approval before release by project management.

In a split package approach, the architect–engineer would be responsible for the requirements definition and control work described above.

3.2.1.4. Work breakdown structure

The final, largest and most important step in project definition from a project management point of view is the work breakdown structure. The main work in establishing and maintaining a breakdown structure rests with the project partner having the largest engineering effort, i.e. a main contractor in a turnkey contract.

In terms of the overall organizational and engineering integration of a project and the emphasis on the co-ordinating and integrating aspects, a breakdown of the project into groups of people and products is a paradox. However, the size of a nuclear project and the number of people working on it mean that some type of division into manageable segments and units of work must be made. A manageable piece of work might be conceived as one which can be understood and controlled by one person, or a part or component which may be produced, tested, packed and shipped to the site as one entity. Whatever the level of detail, there will be such subdivisions and they have to be logically structured, documented, made known and enforced. The resulting arrangement is called the work breakdown structure (WBS). A WBS essentially relates all hardware, software and manpower so that they can be budgeted, scheduled and controlled. These three ingredients together make up the contract for a particular project partner. A project structure which could serve as a basis for a WBS may in some cases exist from previous projects, may be part of the contract or could have been elaborated during the pre-contract phase.Normally, however, the detailed structure has to be established and confirmed as a co-operative effort between the project management and the engineering and production departments at the beginning of contract work. The faster and the more completely the project can be structured and its tasks defined, the easier it is to assign, control and co-ordinate tasks.

The detailed pre-contract planning of engineering work, schedules and resources will serve at least as a temporary breakdown for project tasks until a final degree of detail is worked out. The project manager will also have to consider the accuracy and detail of hardware definition available at the beginning of contract work. When establishing and enforcing the WBS, project management has to be aware of its potential fragmentation aspects and has to employ integrating measures as a compensation and complement. Before establishing a WBS for the entire nuclear power project or major portions thereof, it is important to understand traditional ways of structuring hardware, engineering and personnel.

The breakdown of the project usually starts with major plant portions, namely the nuclear steam supply system (NSSS), the balance of the nuclear island (BONI), the turbogenerator (TG), and the balance of plant (BOP). Between these major plant portions there are interfaces and they have to be kept simple and clearly defined.

Within one major plant section, for example the NSSS, a breakdown into major systems is used. Systems are differentiated according to their major functions as well as by the type of hardware used. Interfaces between systems would typically be identified in drawings and descriptions. Ultimately, the systems are made up of components, which have to be treated through their engineering manufacture, licensing, erection and commissioning phases in great detail. Large orders of similar or identical components have to be split up quite often in order to accommodate specific system requirements, delivery problems or unique erection conditions. For this and other reasons, most project partners with manufacturing or construction responsibility end up using a computerized material flow scheme.

The thousands of people, including hundreds of engineers, who work on a nuclear power plant project are grouped into partner organizations (companies), subdivisions and sections. Since most of the project manager's co-ordination tasks deal with engineering or software, engineering specialities provide a basis for structuring the project which often overrides that of the hardware breakdown. In the organizations of the project partners, engineers must generally be ascribed to separate sections in order

- — to provide control through delegation
- — to obtain quality through specialization, and
- — to motivate through the allocation of specific responsibilities.

As an example of a project partner leading the construction effort, the planning offices of a main contractor or architect-engineer dealing with the nuclear steam supply systems can be considered. A relatively large engineering staff with a strong functional specialization would be needed. The structural breakdown could be based on one of three approaches:

(a) By hardware, such as

- — fuel design
- — primary system and components
- — auxiliary systems
- — buildings.

Corresponding functions, represented by organizational units, could include development, design, analysis, licensing and procurement.

(b) By software, such as

- — core analysis, physics, thermohydraulics (structural, safety)
- — safety analysis, accidents
- — systems analysis, steady state performance, operating transients, design support
- — structural analysis, steady state loads, dynamic loads, stress/strain.

(c) By staff functions

- — project management
- — plant integration (project engineering)
- — licensing
- — cost and schedule control
- — development/detailed technical support
- — organization and general services
- — personnel.

A combination of all three points of view usually provides for a logical structure and delegation of responsibilities to specialists. The patterns being used are rather uniform throughout the nuclear industry. Traditions which appear to minimize interfaces have been developed. However, a perfect breakdown, i.e. one not leaving any interface problems, does not exist.

The work breakdown structure not only provides a necessary step in project definition, but may also be considered as an important project management tool.

3.2.2. Tools and methods for project execution

3.2.2.1. Work packages as a project management tool

In organizing and planning the project, project management may have to get involved in the line organization set-up. If the first organizational structures deviate substantially from traditional forms, this can lead to either a lack of specialized skills in certain areas or an excess of interfacing problems. The project manager would in such cases help to analyse the problem and possibly suggest appropriate changes.

Once the line organization is established and its lead engineers and managers known, the project manager can define and assign the work and section of the plant within the scope of his organization. These items are identified in the WBS and can now be assigned to the competent organizational units in manageable portions called work packages. A complete work package would typically involve a system or major component and/or several man-weeks or several tens of thousands of dollars worth of engineering; with this, a relatively fine control of the project could be ensured while keeping administrative work to a reasonable level. Above all, the work package becomes a kind of subcontract between project management and the line organization, typically containing the following information, in a document known as a task order:

— Identification
— Start/end dates
— Ownership (lead engineer)
— Budget data
— Task description
— Changes
— Outputs (project documents, data)
— Associated hardware items
— Signatures required.

Of the many aspects for the project management and engineering to consider, the most important are discussed below, namely:

— Budgetary aspects
— Manpower loading aspects
— Project control aspects
— Motivation aspects
— Accompanying documents
— Problem areas.

The task order has to include a brief task description and the budgetary figures for engineering and hardware. This is a crucial area for project management and the engineering section and must be jointly agreed in writing. When a sufficiently detailed contract proposal or bid has been developed before contract signing, detailed estimates should already be available internally to the main contractor organization.

It might be expected that the project manager could just go to the engineer and section head who made the original estimates to obtain their signature on the task order. However, it is quite likely that the engineers will already be having second thoughts on the budget figures. Reasons are often given for substantial increases. Unless there is very good justification for such increases and they are covered by contract funds, project management must insist on the original estimates, if available. In any case they must insist on sound and well justified estimates. It is therefore best to obtain the budgetary commitments as early as possible, when memory from contracting and bidding is fresh.

It is also necessary early on to establish via the task order figures a complete reference budget as a basis for future change control and claims. The standardized task orders with their data and identification can also form the basis for manual or computerized accounting, cost charging, recording of expenses and progress reports.

Concurrently, manpower aspects have to be considered both in support of the engineering budget estimates and for verifying manpower availability and schedules.

Early inclusion of agreed manpower estimates in the task order will provide man-hour summaries over parts or all of the contract and help in the setting of manpower priorities.

The task order provides a number of controls, including:

- Definition of work
- Definition of work outputs (to provide task connections and schedule information)
- Starting basis for the contract work (for future changes)
- Mechanism for applying changes
- Recording of changes and supporting of contractual claims
- Computerized reporting system, together with:
  - man-hour records
  - schedule.

Finally, the task order often imparts a form of positive motivation, both for the project management group and the line organization unit involved. The latter should preferably assign a specific engineer (task engineer) to be in charge of the task, and back this assignment at the section or department head level. Principal considerations for a well-working task order system are that:

- the task engineer knows:
  - what to do
  - how the task relates to the overall contract
  - how he is committed
- the line manager knows:
  - how he is committed
- record keeping is simplified (automated)
- tasks are comprehensive, but not too detailed to become prescriptive
- reporting and control frequencies are such that no constant watch is felt
- status and progress reports have a format that is helpful and positive.

However, written assignments in the form of task orders may lead some engineers to do exactly the work stated and nothing else, regardless of whether it is right or wrong and regardless of what is happening elsewhere. The project manager should be aware of this danger and develop formulations, objectives and methods of communication to minimize it. There is also the danger of creating too much administrative beaurocracy and the project manager must see that this is kept under control. Partly for these reasons, the work package document should not be loaded with redundant information from other project documents, but should rather be cross-referenced. The referenced documents should include:

- Input requirements
- Output specifications, drawings and analysis reports
- Change orders
- Purchase orders.

In addition, there are informal project documents which can be referenced in the task order; these may include interface information, details of the task description, internal/external memoranda and schedules. The quality assurance and/or licensing status is usually not directly reflected in the task order but rather through the review and approval status of referenced specifications, drawings and analysis reports.

In summary, the WBS and the work package descriptions or task orders resulting from it become a project management tool as much as a line organization tool. As shown in Fig. 9, the WBS clarifies the association between work items for the plant and the people working on them in each project partner organization and its specialized engineering and manufacturing departments. The project management organizations (shown horizontally in Fig. 9) assign specific items of project work in a certain time frame to the appropriate line capability (indicated by the shaded elements in the matrix). These may be understood as specific task orders.

Figure 10 gives an example of a work package used as a tool for project co-ordination in the control of engineering activities.

3.2.2.2. Hardware scope definition

Since the project in its final operating form is an integrated system of millions of individual pieces of hardware, the early, continuous and controlled definition of all hardware and hardware interfaces is an important project management task, especially for a project partner with major execution responsibility, such as a main contractor. In a nuclear power project it is common to have a complete hardware catalogue, as contract attachment, often computerized and broken down to the last shippable items (i.e. items which make up a shipment or package when received on the construction site). A reasonably detailed hardware scope will be used among other things:

— to relate hardware with internal task orders
— to relate hardware with external contracts
— to ensure completeness of all necessary deliveries within the contract
— to define external interfaces
— to define internal interfaces
— for purchasing and expediting
— for accounting and cost control
— for warehousing and material flow.

The various hardware lists must together make up the entire hardware scope of the contract and should typically include:

— component name
— unique identification

— system description
— contract or task number, cross-references
— location
— origin
— quantity
— manufacturing specification
— date of shipment (order, erection)
— material classification
— standards
— certification status (licensing or QA)

and possibly cross-references to:

— drawings
— specifications
— purchase orders
— work packages
— material flow schemes
— other project documents.

The cross-referencing of project documents and hardware on computerized lists can sometimes be used to produce one list automatically from another. For example, the listing of all hardware items on specifications and drawings could lead to an inverted file, showing hardware items with the specification and/or drawing number from which they come. Such documentation can provide a smooth transition to material flow schemes.

3.2.2.3. Steering the engineering effort

The technical aspects of a project will normally fall outside the jurisdiction of the project manager, unless he happens to assume a double role (i.e. is also chief engineer for the project). From the standpoint of proper control it is better to separate the two functions. The project manager provides the leadership and control of the project and engineering performs the bulk of the work. Basically, project management establishes what has to be done and engineering determines how to do it; the commitment to quality control is in many ways shared.

A typical nuclear engineering and construction firm produces primarily software, i.e. documents in the form of equipment specifications, drawings and descriptions or analytical reports. A task such as 'design of the heat removal system' would be assigned to an engineering department and possibly to a specific engineer, budgeted and scheduled. The task responsibility would be discharged by delivering an equipment specification approved by the regulatory authority and ready to be used by the purchasing department in ordering the hardware from a subsupplier or from

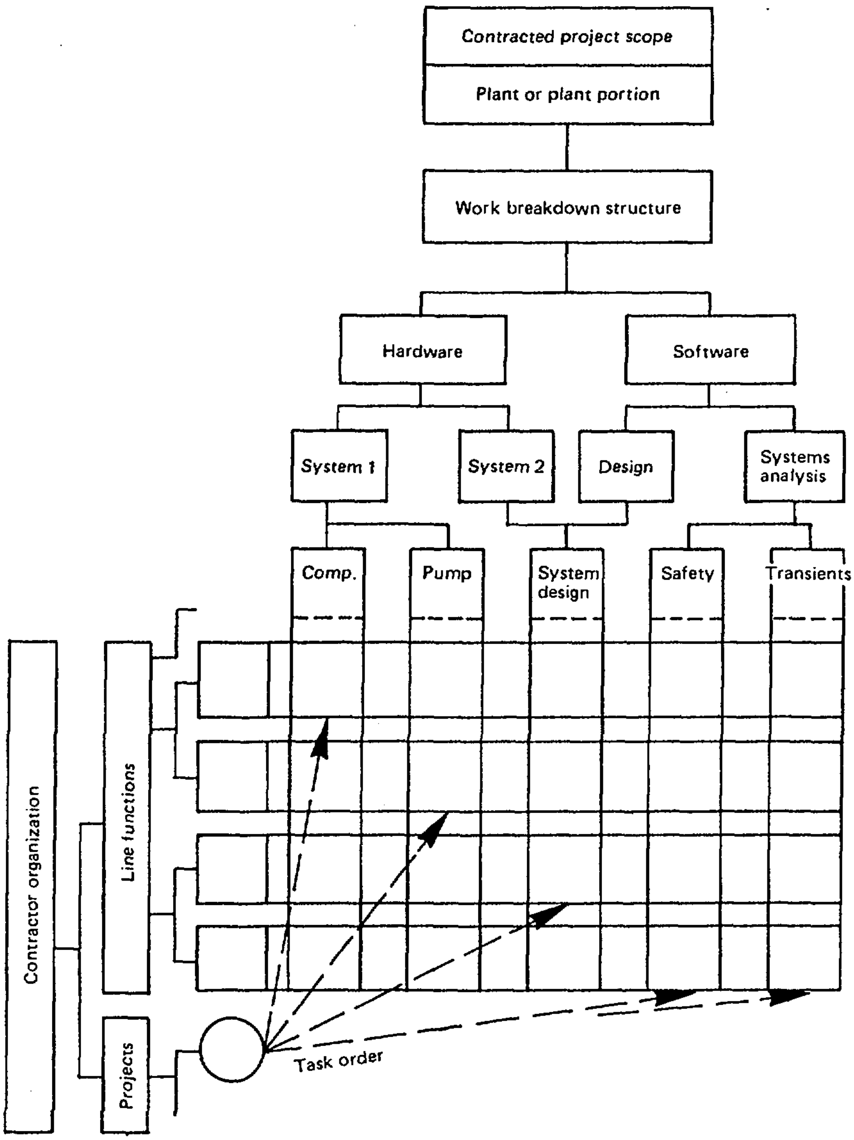

FIG. 9. Assignment of project tasks.

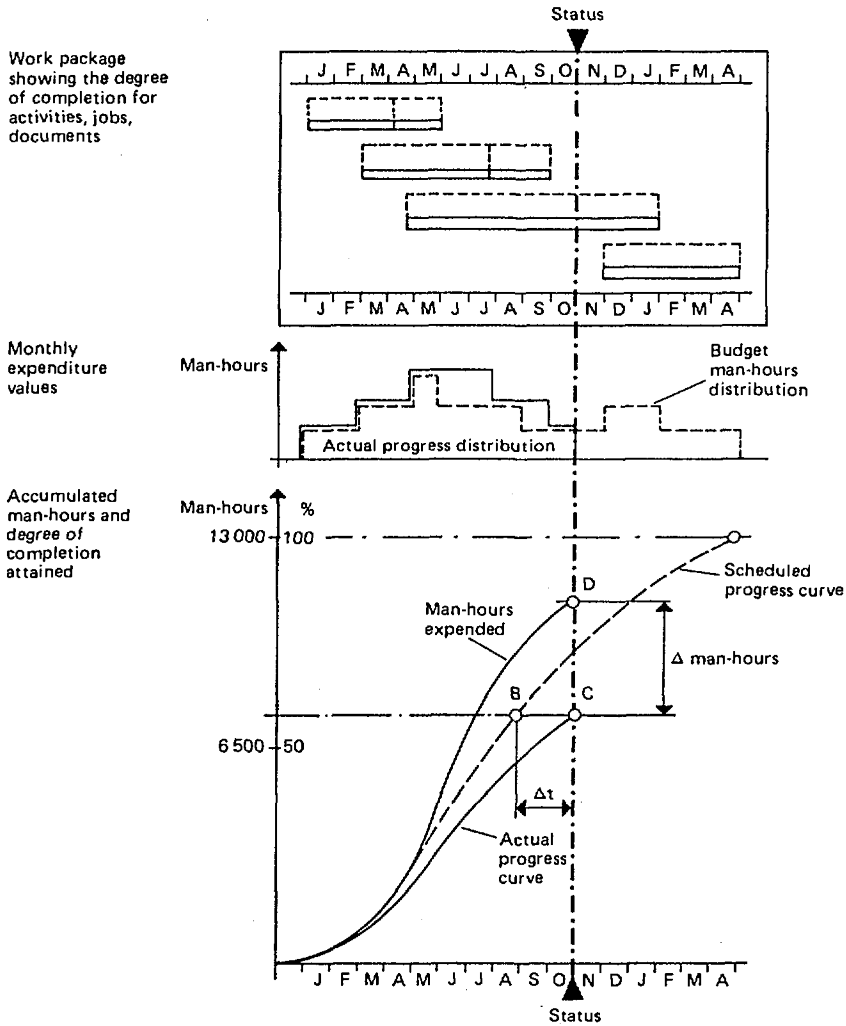

FIG. 10. Project co-ordination: productivity control of engineering activities.

a manufacturing shop in its own organization. Sometimes the task may also include follow-up during manufacturing, erection and commissioning. In this case the task responsibility may ultimately be discharged when the equipment is functioning in the running plant. During the front-end definition of requirements and scope, it is essential to do the detailed planning with the engineers who carry out the work in order to ensure their commitment. Project management authorizes the start of such work by signing an appropriate task order and checks and approves the results by countersigning the documents for release and further use.

Besides this formal aspect of the engineering interface, namely project documents from a well structured engineering effort, there are engineering tasks which are difficult to assign and which require more detailed project management co-ordination. Overall system and plant integration is one such area and system analysis is another. The analysis of the overall functioning and response of the entire system involves many sections, whose work has to be co-ordinated and controlled. Moreover, the level of effort invested in such analyses can vary substantially, depending on the models chosen, the assumptions made and the inputs used. All too often false or premature cases are analysed and complicated computer models are used instead of simple ones. The project management assistant in charge should see that the assumptions and models are verified, should co-ordinate inputs and probably arrange meetings to this end with the engineers involved. Costs and schedule time can sometimes be saved if the quality and correctness of engineering work are checked more closely.

The internal layout of buildings and the co-ordination with piping, electrical conduits and ventilation is another wide ranging task which deserves particular attention by project management. Arrangements work is — in a sense — co-ordination by design, and the output is in the form of drawings. This task must be closely co-ordinated with project management, whose participation in decisive meetings will be required. Again, a considerable engineering effort is at stake and the results (drawings) must be checked for quality, because once the concrete is cast the conditions for later erection work are fixed. Recently a new discipline, called constructibility, has emerged as an important support to project management. Detailed studies on sequencing and optimizing work on the site and in the shops, on preventing overcrowding or waiting times and on utilizing prefabrication have revealed the potential for major savings in the construction time and cost of a nuclear power plant. Differences in constructibility have been found to be one of the explanations for the still relatively wide variation in schedules and total capital expenditures for recently completed nuclear power plants. Therefore, project managers, site managers and their staff should pay increasing attention to these aspects during the engineering phase. This requires a look beyond the regular engineering co-ordination and document production to the ultimate implications on the site or in the workshops. For instance, when building changes are discussed, erection sequences and space requirements should be considered. Project management can help establish awareness in this area by raising questions of constructibility or even having formal constructibility reviews performed. Occasional visits to similar construction sites and manufacturing shops can be helpful. However, engineering disciplines and the line organization will be in charge of implementing constructibility ideas. Once the site is opened, constructibility aspects can be monitored on the spot and with the actual plant project management in charge. This is a good time for the project manager and his staff to pay occasional visits to the site, to get to know regular work sequences and control procedures, to support the site manager and establish good working relations between headquarters and site.

Eventually project managers and their assistants have to decide engineering priorities, monitor progress or promote engineering solutions. The project manager will give any necessary recommendations or instructions in the full knowledge that he has no direct authority over any one of the departments involved. Each departmental manager is generally responsible for the performance and day to day running of his own team. The weight which project management's requests carry must be a result of their soundness and conviction. Once agreement or even consensus has been reached on an engineering decision, project management must see that it is established in writing.

To compensate for any lack of comprehension or acceptance of project methods in engineering, the project manager should have facilities for training. He can then explain his objectives and methods, such as scheduling techniques or the task order system, to section heads and task engineers.

3.2.2.4. Project management integration

Integration is a widely used term in engineering and management and can mean different things to different people. Difficulties in the performance of nuclear projects have often been associated with a lack of project integration.

Product, system or engineering integration is a major concern for nuclear power plants. The overall plant must function as a reliable and safe system despite the fact that many different organizations are involved in its construction. System integration is primarily an engineering task, accompanied by supporting measures from project management.

However, the need for overall project management for the plant poses a challenge at the organizational and procedural level, that of project management integration. As a first basic level of project integration one might consider the individual project assistant or project manager, who exerts a co-ordinating, problem solving and conciliatory influence when working with different engineering and/or production sections with different opinions or priorities. Project management personnel have to harmonize actions and keep the project moving no matter how difficult or divisive a problem may become.

At the next level one might consider the project group in each partner organization. An important but difficult precept is that the group must speak with one voice when it comes to project strategy, objectives, procedures, communications, etc. Sufficient attention by the project manager to the management of his own group and frequent communication within this group are the best assurances for project management integration at this level.

The ultimate and most complex aspect of project integration is co-ordination between project partners. Project failures have often occurred as a result of such things as uncooperative attitudes, differing objectives, different contractual roles of the partners and reporting relationships to management. It is necessary, in particular, that utility project management takes steps to find compromises between potential conflicts of interest and harmonizes the decisions and actions to be taken.

Integration is also achieved by recognizing the project management hierarchy. Such a hierarchy may be obvious in a consortium, where the overall project manager may have the final say on certain objectives, procedures or decisions which affect the entire consortium, although the project managers of the partners do not directly report to him but rather to their respective managements. A more subtle relationship may be the one between the project management of the utility and that of its contractors. Even if not formalized, a hierarchy would become apparent at common project meetings. In such meetings the utility project manager usually takes the lead and has the final say, particularly when utility directives or approvals are needed. The recognition of a hierarchy, the holding of common meetings and the establishing of effective communication and problem solving mechanisms provide effective project management integration between the partners. Questions of seniority, salary level or reporting relationships with a partner organization should play a secondary role in project integration, since the project managers of the partners generally come from a matrix type company organization which requires internal co-operation with and the consent of engineering and manufacturing management at many different levels, sometimes higher, sometimes lower than that of the project manager. In summary, integration throughout the project is best ensured by:

— clearly stated project requirements
— harmonized project management objectives
— recognized hierarchy and decision making and communication paths
— common, up to date, structured project schedules
— a co-operative, business-like working relationship.

Project management integration must also be seen throughout the project schedule. Maintaining a logical and complete sequence of organizing, planning (budget and schedule), executing, monitoring and controlling activities for overlapping regular and newly introduced tasks or changes is a major challenge to project management. Priorities have to be reviewed frequently to obtain good performance in terms of schedule and costs. Continuity in project management personnel can help significantly to provide this type of integration.

3.2.2.5. Working with contracts

Project contracts are legally binding agreements between independent organizational entities, the project partners, and carry financial, warranty and liability implications. In cases of doubt, the contract is always right and settles the relationship between project partners. Although the contract is signed at the highest level, the project manager in each partner organization is the real guardian of its content. This does not mean locking it away, but rather knowing its content fully, passing on its requirements in project documents (often with the necessary interpretation), and controlling its fulfilment. The contract is a working document primarily for the project management group and is passed to engineering with discretion. The project manager must see to it that the contract is used by his staff and not forgotten when the project work has developed its own set of documents and dynamics.

It is not unusual that in the day to day working atmosphere between the project partners, with the main goal of getting things done, minor contractual problems are deferred and carried forward as a list of open items sometimes until the very end of the project. It has to be recognized that a decision to do something absolutely necessary in a particular way may be taken by consensus between the partners without working out the contractual implications if no alternatives exist. Although this may appear a bad business practice, the gains in time, cash flow and harmony can be substantial. Moreover, collecting many such problems in an organized open list maintained by project management can provide a better overview of the contract situation and promote a more fruitful and efficient discussion than would be possible by dealing with them item by item.

Therefore, at or before the time of plant or system acceptance, an additional contract negotiation phase is common, in which the accumulated open items from the construction phase are settled financially. Additional items may pertain to acceptance problems, warranties or spare parts. The relevant negotiations have to be properly scheduled. They are conducted by project management, lawyers and engineers and may take several months. Only when all issues have been settled and all payments have been made is the project manager's job done.

3.2.2.6. Project meetings

Project meetings and project status reports are among the main tools of management and of project managers in all partner organizations for monitoring and controlling the progress of the project. They are one of the basic sources of information on project status and enable project managers to undertake timely corrective actions. Project meetings are a means of communication and co-ordination and are particularly important for utility project management. The duties of project partners in relation to the preparation of and participation in project meetings and to progress reports have to be specified in advance in contract documents and/or project procedures.

Institutionalized regular project meetings, covering status, progress, major problems and upcoming tasks, are justified at any level of the project management hierarchy, i.e. within each partner organization and between partners as necessary. Most project management problems are best resolved locally, in the partner's own meetings. This saves travel expenses and man-hours and has the advantage that extra people from the same office can be called in when needed. There is a case for holding meetings once a week on a formal basis with room for informal agenda items at the supervisor level. These could be backed up by meetings at a more senior level, including the engineering manager, at less frequent intervals. These two types of meeting might also be combined. Project review meetings to discuss overall status and financial questions can also be arranged at longer intervals, and the general manager would probably want to be present at these. If meetings are held more often than is absolutely necessary, there will be some danger of creating apathy. Departmental managers and project managers are individuals whose time should not be wasted. For the same reason meetings must be kept as short as possible. Further up in the hierarchy, project meetings will more and more involve the project partners, particularly at the utility level, and will be held somewhat less frequently.

There are certain dangers associated with the mismanagement of project meetings. For instance, it often happens that lengthy discussions arise which really concern technical design problems affecting very few of the participants. Such discussions will lead to loss of concentration and interest by those members not involved in the particular design aspect. Although it is not possible to remove design problems entirely from project meetings, they should rather be referred to special meetings or to a wider design review. The project meeting must concentrate on important current project activities.

The selection of topics for a project meeting would generally be based on a 'management for trouble-shooting' approach and the list should be handed to the participants before the meeting with sufficient time for preparation; for less frequent meetings the agenda can include biweekly or monthly progress reports. Regular tasks which are running within defined requirements and within budget and schedule do not normally require to be discussed at a project meeting, except as part of a brief overall status report by the project manager. On the other hand, problematic items, which need particular attention and resolution and on which an interchange of opinions and ideas is important, do belong in the meeting.

It is inevitable that arguments may break out between individuals during the course of meetings. These may not be altogether undesirable, as meetings must be kept alive, provided agreement is reached before the members disperse, otherwise unprofitable stalemate conditions will be generated and team harmony disrupted. Although the project meeting may be chaired by a senior executive or the utility project manager, the project manager of each partner should take responsibility for conflicts in his organization. One clear duty of the project manager is to discover the true facts which underlie any interdepartmental problems. He will need to do this not so much to apportion blame as to ensure continued progress towards a solution. Often matters become more difficult where two departmental managers give different reasons for a common problem. The project manager then has to do his best to resolve the conflicts within or outside the meetings.

When a meeting ends, it will have been successful only if all participants feel that they have achieved some real purpose, that they know what they have to do and that decisions have been made which will have some practical effect on project progress. Demands made of participants during the meeting must be achievable. There is no point in attempting to impose actions without obtaining the commitment of the individuals and organizations affected.

Publication of the minutes must be undertaken without undue delay in order that they do not become outdated by further events before distribution. Minutes should be clearly and concisely written, combining brevity with careful layout so that each action demanded stands our from the page. If the document is too bulky, it may not even be read by some recipients. Short pointed statements of fact are all that is required. Every person mentioned in the minutes must receive a copy — a point often overlooked. No ambiguities must be allowed as to the person responsible or the time-scale involved. Expressions such as 'as soon as possible', 'at the end of next week', or 'towards the end of the month' should be discarded in favour of actual dates. Names of those in charge should appear rather than designations of organizational units.

3.2.2.7. Problem solving

No matter how well the preplanning, co-ordination and control of a project works, there will always be problems which will interfere with the smooth running of the project and its contracts. A problem may be defined as a deviation from the planned schedule or from the foreseen technology or a change from budget costs. Today, problems for which no technical solution could be found have become quite rare. More typical are situations where the interaction of technology and entire systems with manufacturing, regulatory requirements, schedules and costs are at the root of the difficulty. The role of management in general, and engineering management and project management in particular, in the resolution of such problems has therefore become very important in all nuclear projects. The most likely causes for problems in a nuclear power project are:

— 'Daring' technology
— New requirements
— Unclear responsibilities
— Uncooperative sections, divisions or partners
— Demotivation as a result of executive beaurocracy.

The phrase 'daring' technology signifies the frequent tendency of eager engineers to be too inventive. Either during the conceptual design or as a response to later changes in requirements, highly innovative partial solutions may be promulgated, which may either bypass existing company experience or neglect effects on adjacent hardware and software. Such solutions often appear ingenious and are well meant; they may also be candidates for future research and development work. However, in the middle of a contracted project, project management should be highly suspicious of any change and innovation and check it completely with regard to its overall effects and the consequences in terms of costs.

There may be a tendency in a large organization to ignore or intentionally overlook rumoured problems which may be too small to have a real immediate impact. While there is often collusion between engineers and line managers in such matters and even a tendency to consider those who raise them as trouble makers, the project manager must carefully examine and list all such 'hidden' problems since they are generally easier to resolve as they surface than later in the project schedule. The risk management approach is one way of giving such problems proper attention and bringing them to a timely resolution.

The number and the importance of problems with a significant impact on project performance are greatest in the project partner organizations with a major execution responsibility and therefore typically large engineering staff. Major steps in solving engineering problems are:

- Nomination by project manager of problem owner (task force leader)
- Meeting with all concerned, division of work, initial action plan
- Possible solution, with total effects and resulting changes defined and documented (requirements, technology, schedule and costs)
- Responsibility defined and accepted and approach shown to conform with project and company goals
- Requests for priority and funding
- Solution defined, declared to be feasible, accepted by upper management, utility and regulatory body
- Upper management informed and their approval obtained
- Further tasks for implementation entered into regular engineering work — task force (if any) dissolved — problem removed from problem list.

Of these items, the most important is the ownership. Often a voluntary and therefore committed owner can at first not be found and the cognizant project assistant may have to assume this responsibility temporarily. Since — in the context of this Guidebook — the project management group does not have a direct engineering responsibility, such an ownership role can only be temporary in order to initiate and direct the resolution of the problem. As soon as possible an owner in the relevant engineering area should be found. Project management must then see to the application of the further steps in problem solving and ensure the support of other parties involved. The project management of the main contractor or architect-engineer must also negotiate with the utility and/or the regulatory organization and obtain agreement to substitutions. The total impact of the new solution on the entire plant must be assessed and the relevant changes documented. When the feasibility of the chosen solution is clear, it can be properly planned as an engineering, manufacturing and/or

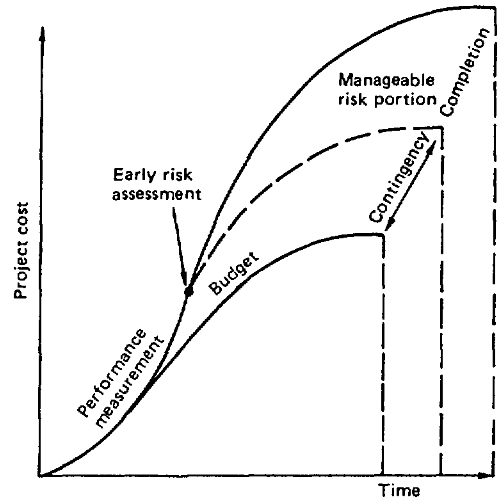

FIG. 11. Management of risks.

construction process and introduced into the project schedule and budget; only then can the problem be dropped as 'a problem' and become part of the regular work. This is the moment when project management's task of problem solving is fulfilled.

3.2.2.8. Risk management

Risk management should be seen as a tool for improving the management of the project and limiting the financial exposure of the project partners. A concerted effort between several partners, co-operation and fairly open information exchange may be needed to properly manage project risks. It is common practice that the identification of risks is made at the time of contract negotiation and is considered in the fixing of contract prices and contingencies.

In principle, risk means financial exposure, in direct costs or through unavailability of the plant. Each project partner has to minimize these risks in his area of responsibility. Project management has the responsibility for managing risks, as well as for resolving them with the other project partners. However, since a risk is only something anticipated and not yet real, it is hard for risk management to compete with day to day real problems, many of which may be former risk items which were not considered in due time. The effectiveness of risk management is very much a question of timing. Risks should be reduced or eliminated at an early stage (see Fig. 11). The assignment of one person within the project team to be exclusively concerned with risks can provide the necessary attention to risk management. Such a risk manager would not carry out the risk assessment himself but would perform project management type co-ordination and performance evaluation. This would typically include the following steps:

— Brainstorming session with competent engineers and project management staff in each technical area
— Formal declaration and definition of important risk items with the support of the department or section heads within whose scope the risk item falls
— Listing, sorting and weighting of risks
— Further definition and cost estimates for the most important ten or twenty risks by an objective group effort
— Adding to projected costs significant identified financial risks which have been assessed
— Definition of action programme for early risk management, i.e. action to reduce the risks
— Follow-up of actions and reassessment of risks
— Periodic observation of inactive, but listed risks
— Updating of the risk list and its priorities.

Each active (listed) risk item is matched to an action plan, resources and monitoring, very much in the standard way of problem solving. The objective of the action plan is to reduce, contain and eventually eliminate the risk and to gradually adapt any initial deviations into the regular technical description, budget and schedule of the project.

3.2.3. Site management

In a turnkey contract the overall site management is the responsibility of the main contractor, while in a split package approach it remains in the hands of the utility, who can delegate it to the architect-engineer.

The function of site management is the direction and co-ordination of all activities performed on the site. These activities are related to civil works, erection and commissioning.

3.2.3.1. Civil works

If the utility has the leading executive responsibility in construction and is in charge of overall contractual and technical aspects of the civil works of a major portion of the plant, it will perform this task through its site management. If it does not have this experience and capability, the task would be subcontracted to a highly qualified construction company, closely controlled by the utility, and sometimes to an architect-engineer running such a construction department or subsidiary. A separate construction company may also receive a separate main contract on civil works, with similar contractual and management features.

The utility's own activities or those of a civil (main) contractor will require headquarters project management in the usual sense, but also site management. Since the prime task on the site is the actual realization of hardware, in accordance with pre-defined (by headquarters) drawings and specifications, a simple line organization (non-matrix) with a strong chain of command is most effective. The site manager should have proven authority and management capability, preferably acquired at the site of another nuclear plant or at another large construction project (e.g. fossil-fuel plant). The type of person needed as site manager is therefore somewhat different from the case of project manager.

Varying degrees of headquarters support for site management are needed throughout the construction phase. Sometimes a small site engineering or field engineering group will be needed and this normally reports to the headquarters engineering department. Its objective is to suggest/approve/reject on-site modifications if required, and to ensure that the design requirements are met and that quality is maintained during construction. Rigorous change control and documentation is a difficult but most important task for project management under such circumstances. It should be put through with the support of site management, but also, if necessary, without it. The site manager is responsible for the execution of authorized instructions (drawings, specifications, etc.), but the project manager stays in charge of all major project authorization and control.

The civil construction management on the site is responsible not only for execution but also for planning and co-ordination tasks. The leading co-ordination function on site is best combined with the leading executive responsibility in the person of the site manager, with, however, close liaison with headquarters project management. With a civil main contractor in charge of executing civil works the utility may appoint a separate site manager for the principal co-ordination tasks; again close co-ordination between the two types of site management would be necessary. The main tool in co-ordinating construction and erection work on the site, with headquarters and with subsuppliers, is the master schedule; co-ordination and supervision of the different contractors working on the site must be emphasized. Detailed site planning during the different phases of the construction and erection effort is necessary in order to establish schedule and space requirements, or prepare target programmes for every one of the contractors on site and for different phases of the project. Such target programmes are included in the request for bids sent to the different subcontractors. These subcontractors will prepare phased site space allocation and work programmes in accordance with the target programmes. Site management may have its own planning and scheduling unit. It is necessary in such cases to ensure very close co-ordination with headquarters project management to maintain a uniformly valid overall project schedule. The site scheduling unit may also be supported by the headquarters organization in terms of computer services, if these are not available on site. Effective, formal and informal communication and co-ordination with headquarters engineering must be established. In summary, site management has the following principal tasks:

- To execute the construction contracts according to requirements and specifications in the most efficient and expedient manner and to the required quality; to lead and manage the large worker and engineering teams;
- To steer all activities on site by means of the project schedule and to oversee the qualified engineering and construction personnel, taking into account time, cost and quality considerations;
- To administer and control subcontracts for the site;
- To keep day to day contact with site managers, project management representatives and/or resident engineers of the other main contractors on the site in order to maintain good communications and a common information base;
- To explain and document the status of the site activities, initiate corrective measures, optimize authorized alterations in schedule, cost, etc., and contribute to regular project meetings on site and at headquarters;
- To obtain all necessary control results regarding cost and schedule, in order to be able to report internally to the management and externally to other project partners.

In addition, the site manager has a number of generic co-ordination tasks as a delegate for the overall (headquarters) project manager of his partner organization and for the utility, unless the utility handles these tasks with separate site management or within its project management team. These include:

- First local contacts. The leading site manager and his organization are usually the first to arrive on the site. They will therefore have the responsibility of making the first contacts with local and central government officials, local labour officials, local contractors (to whom the site manager may eventually subcontract part of his work), and local suppliers of equipment and material.
- Indirect controls. Site clearing and establishment of infrastructure are usually subcontracted locally. During the important first phase of this work the site manager may have to deal with other project partners and outside organizations, over which he has no direct (contractual) control. The site manager and his organization's project manager must therefore exercise particular care and caution to incorporate effective controls and clear interface agreements in these first local subcontracts.
- Choice of material suppliers. The civil contractor's work involves enormous quantities of material (such as sand, earth, aggregate, cement, steel, etc.) and supply is often limited to one local source. The site manager, with the support of headquarters and the utility, if applicable, is thus often obliged to negotiate for the best terms from an unfamiliar supplier who knows that he has a virtual monopoly.

- Quality of concrete. An important point for the entire site logistics and possibly even for the building design is the availability of high quality and high strength concrete; this implies high quality cement, rebar, machinery and test equipment, sometimes not available locally. This aspect must be examined early, preferably before the civil works contracts are signed.
- Use of local labour. A high percentage of indigenous workers are usually included in the civil contractor's work force. The site manager is therefore obliged to study and incorporate into the planning the details of the traditional locally accepted methods for doing all the tasks associated with the civil work. He should obtain for himself and his staff detailed advice from the utility and other companies with local experience.
- Starting on critical path. It is often the case that when the civil contractor closes his contract and begins work, he is already on the critical path of the master project schedule with little contingency. Site and civil work may therefore be started early, with some financial risks, before it is completely assured that the project will ever materialize. The civil contractor may be obliged to repeat this type of risk in order to gain schedule time, up to the point (perhaps two or three years later) when his activities are no longer on the critical path.
- Subcontractor engagement. Some subcontractors for whom the nuclear power plant construction is a unique project (with generally less standardization or prefabrication than they are used to from other types of work and with stricter quality control) may have to plan for sizeable management and engineering support on the site amounting to about 8–10% of the workforce. The proportion is on the higher side at the beginning and becomes lower during workforce peaking. It is important that the necessary site buildings and infrastructure, offices, warehousing, waste disposal facilities, energy supplies, etc., are planned and co-ordinated with the utility and/or its main civil contractor.
- Utility supervision. If the utility retains the overall site management task, its site management staff will be somewhat larger than that for the main civil contractor, because it must carry out the responsiblities of both the supervising owner and the leading constructor, possibly involving two different utility departments. The utility's site management staff is included in its project management organization, with the assumption that only a supervisory role will be played.

3.2.3.2. Erection activities

Site work includes, apart from pouring concrete, a multitude of activities such as installing, welding, handling, shipping, storing, cleaning, inspecting, testing, modifying, repairing and maintaining. Many of these activities can best be handled on site and combined with civil construction work and should be under the control of the key representative (or resident) of each project partner on the site, i.e. their site manager. However, many mechanical and electrical erection activities are handled more like subcontracts on the shop floor and they are steered or supervised via headquarters engineering, purchasing and project management.

During the execution of the erection activities each contractor must submit regular progress reports to the utility and/or the main contractor, related to the programme schedule. These reports must describe the progress of the work and of course must be coherent with the master construction schedule, which in turn is aligned with the master schedule of the entire plant. When required by the overall construction management, the contractor must prepare special or more detailed schedules to deal with specific co-ordination problems.

3.2.3.3. Commissioning

The responsibility for providing and training the future operating team of the plant rests primarily with the utility, though the training is performed by the main contractor or the architect-engineer. As part of the training programme (and with the help of its own engineering personnel or operating personnel from other plants) the utility should participate in and supervise commissioning. This provides a unique opportunity for utility engineering and operating crews to get to know the plant. Project management's interest in this phase is mainly that of proper contract execution and preparation for plant acceptance. In particular, the utility project manager will see to the completion of the following tasks:

— Preparation of administrative procedures for commissioning and operation
— Preparation of technical procedures and manuals
— Drafting and/or review of the Operating Manual
— Preparation of maintenance procedures
— Preparation of maintenance schedules
— Participation in the commissioning phase of the power station
— Establishment of a permanent plant documentation system
— Planning and scheduling of tests
— Checking fulfilment of contractual terms associated with all the above items.

Commissioning of the primary or secondary systems of the nuclear power plant is usually the responsibility of an experienced contractor who has carried out the design and manufacturing of these components and the major system. A special technical group co-ordinates related activities horizontally in the matrix, in close co-operation with overall project management and site management, and generally resides on the site. For site activities it should report to the site manager of the main contractor, while responsibility for the quality of its engineering work remains with its organization's headquarters. Because of the important interface with the erection activity, detailed site schedules and programmes for startup must be updated at very short intervals (i.e. weekly). The startup group interrelates, in particular:

— with engineering and design during the preparation of the administrative and technical procedures for test and startup and their execution
— with construction and erection efforts on site during the execution phase
— with its own project management for overall co-ordination, scheduling, deciding contractual questions, etc.

Project management's task in the final stages of plant completion and during commissioning is mainly to see that a functional high quality product is completed within the budget and on schedule. These responsibilities in general, and maintaining the schedule in particular, can be as complex and demanding from a project management standpoint as the earlier peak of manufacturing and construction activities. Using essentially the same tools and methods described for the control of engineering and construction, but adapted to this phase of the project, project management can contribute to the objective of achieving the earliest possible final acceptance test for the entire plant. In particular, it can see to it that preparatory documentation (i.e. procedures) and test results are available in a timely manner.

Subcontractors have a similar commissioning responsibility to main contractors, only on a much smaller scale. The project managers of the subcontractors must ensure the close co-ordination of commissioning work with the other project partners and provide technically competent teams on site.

3.2.4. Project termination

3.2.4.1. Contract fulfilment

The task and scope of the project management groups of each partner in a nuclear power plant project are generally quite well defined by the contracts. The portion of the overall plant project covered by the contract specifies the project for the group concerned and is basically completed when all the provisions of the contract have been met. For the nuclear power plant as a whole, and for many of its systems, the contract is fulfilled when the system is functioning and has been accepted by the operating team which takes over. This may require rectification of malfunctions or inadequate performance and adjustment in manpower, schedule and budget, both for engineering and project management.

While the engineering tasks in any prolonged acceptance phase might be quite similar to those found during erection and testing, utility project management during that phase has to look after contract fulfilment in greater detail than before. In settling and initiating any final tasks or improvements, the utility project management must often negotiate solutions and sometimes make compromises with other project partners. Every item has now to be checked carefully and accounts have to be settled and closed.

3.2.4.2. Warranty verification

Before final plant acceptance and settlement of the last project payments it is important to review the major warranty terms agreed upon, to check that they are still up to date and realistic under the as-built and operating conditions, and to see they have been fulfilled. In this area, utility project management must take the obvious lead, with the support of the line organization and management and possibly also of consultants. The project manager will use the contracts to ensure that every relevant warranty item is checked.

All contracting partners (including subcontractors) should make a careful check of the warranty situation in their own interest at the time the equipment they contracted for is handed over. The project management team with its contractual and technical experience, assisted by the operating and engineering teams, would be most qualified to perform this task, in line with its checking and verifying role in general.

3.2.4.3. Project group demobilization

It is the nature of project management work that it begins and ends with the project itself. By definition, the management group has to disband when its tasks have been completed. In a matrix organization this applies only to project managers and project management assistants, who should be made aware of this situation when hired for a project and for reasons of continued motivation be presented with future career prospects from the beginning and with concrete possibilities 6 to 12 months before demobilization. Since project management is a rare skill, not taught in universities, each partner organization should attempt to retain and reassign its project management personnel. Ideally, the project management group could gradually be transferred to another nuclear power project just beginning, or possibly to a fossil-fuel power project. Where this is not possible, the liaison and overview experience of project managers and their assistants can be used very efficiently in engineering co-ordination and management, operation and maintenance support, marketing, acquisition, purchasing or administration.

3.2.4.4. Documentation and archives

After successful project hand-over and the start of plant operation there may be no one in charge of project management for the plant. Personnel of the demobilized project group may be in charge of completely different things or even have left the organization; under such circumstances memories fade fast. Although a lot of the technical information may have been properly handed over to the operating team, and a quality assurance archive and a complete licensing file exist, there will typically be additional information requirements associated with late warranty claims, spare parts, maintenance and services, backfitting and licensing support.

Utility project management's central correspondence file and all technical specifications, analysis reports and drawings which are not already in the QA files should be well organized for the purposes of retrieval and readily accessible for a number of years. This means proper archiving.

Architect–engineers, main contractors and subcontractors should agree to make essential information available to the utility confidentially, but generously, to the extent needed for future plant operation and maintenance. Provisions relating to the scope, filing and storage of such documentation should preferably be included in the initial project contracts.

3.3. PROJECT CONTROL

Controlling the project is one of project management's key tasks. While planning and organizing have an initial peak and executive activities vary considerably over the duration of a project, control measures must always be present and applied to both near term and long term tasks. Control therefore affects all partners and all phases of a project; however, it naturally peaks during project execution.

3.3.1. Schedule control

3.3.1.1. Types of schedules

Among the specific tools, namely the contract, procedures, budget, documents, etc., the schedule stands out as the one which is most frequently used and which penetrates all phases and aspects of the project. The schedule has therefore correctly been closely associated with project management, although the idea that project management is just scheduling is incorrect. If schedules are to be established and maintained as an effective tool throughout the project, they must be realistic and must stay reasonably up to date. The preparation of a logical schedule, with a foreseeable time frame, a meaningful degree of detail, and justification of the underlying assumptions, is an important task for project management.

The best form of schedule presentation — e.g. a bar chart (which presents specific activities as a line or bar in time), or a highly interconnected network (as shown in Fig. 12) — depends on the size and nature of the tasks to be performed and sometimes on the inclination and the capability of the persons involved. For nuclear projects computerization is preferable in view of the many interconnections and the large amounts of data. In any complex undertaking solutions tend to be subject to trade-offs and computerization of schedules can offer more systematic and quicker ways of examining and evaluating alternative approaches. There may be many ways of varying schedules, resources and work sequences, and attacking or trying to prevent problems. With the speed of the computer and the availability of

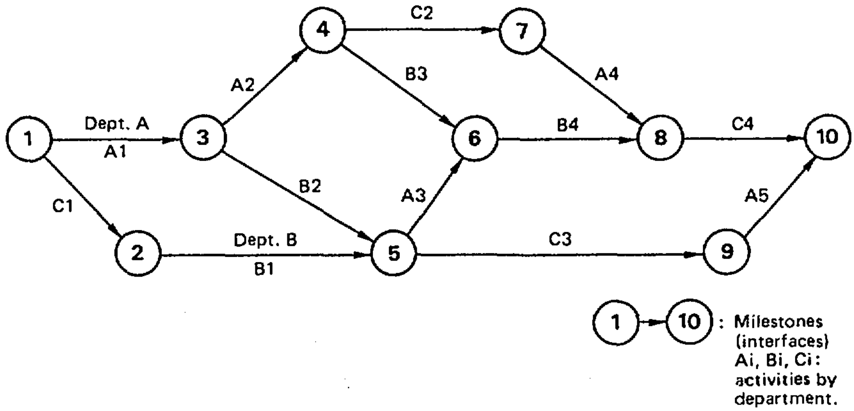

FIG. 12. Simple schedule network.

specialized software tools, it is possible to realistically examine the permutations and combinations and provide project management with information on which to base its decisions and strategies.

Various types of schedules have developed which satisfy most of the basic needs for communication and co-ordination at the right level of detail for different management or technical groups. Although the names and functions are by no means standardized, typical examples are presented below.

— Milestone schedule. A milestone schedule for a project is designed to identify only key events or decision points. Such schedules are generally variations of bar charts and are easy to understand. However, they do not show all the necessary interrelationships in between the milestones. They are not therefore an effective tool for detailed planning. A typical milestone list, more detailed than most but quite useful at the overall project level (i.e. for utility project management) is shown in Table III. Such lists or schedules in the form of bar charts can often be found on executive office walls as well as in contract documents.

— Integrated and detailed project schedule (critical path networks). The integrated project schedule is the prime tool for project planning, scheduling and control. Generally, the interfaces and interdependencies between project tasks, disciplines and partners are depicted as schedule activities in a network (see Fig. 12). The critical path method (CPM) is probably the best known and most widely used technique for setting up and analysing networks in nuclear projects today. As a result of advances in computer software, many different commercial CPM packages are available. They can be used to draw up complex project networks from individual activity or task inputs, including

TABLE III. MILESTONE LIST

Geotechnical data and soil survey
Preliminary safety analysis report
Construction permit
Basic design criteria documents
General arrangement drawings approved for design
Basic electrical studies
Approved single line diagrams
Electrical systems cabling diagrams (approved for construction)
Instrumentation and control system cabling diagram (approved for construction)
Nuclear systems approved flow diagrams
Non-nuclear systems approved diagrams
Reactor building
— Civil construction drawings
— Construction of the building
— Polar crane erection
— Reactor vessel erection
— Steam generator erection
— Primary loop piping erection
— Containment erection
— Recirculation system erection
— Other pressure components erection
— Approved composite piping drawings
— Approved high voltage AC drawings
— Approved cable tray and conduit drawings
— Special equipment and materials purchase
Auxiliary building (similar to above)
Other buildings and substations (similar to above)
Condensor erection
Turbogenerator erection
Main control panel erection
Cooling tower contract award
Cooling tower construction
Piping supply and pre-fabrication contract(s) award
Piping erection contract(s) award
Piping erection
— Reactor building or Phase I
— Auxiliary building or Phase II
— Reactor building
— Auxiliary building

TABLE III. (cont.)

Mechanical erection contract(s) award
Mechanical erection
— Reactor building
— etc.
Cable trays, conduits and cables supply contract(s)
Cable trays, conduits and cables erection contract(s)
Cable trays, conduits and cables erection
— Reactor building
— etc.
Electrical execution contract(s) award
Electrical erection
— Reactor building or Phase I, etc.
Piping supports supply contract(s)
Piping supports erection contract(s)
Hydro tests
Hot functional tests
Nuclear tests
Fuel safety analysis report
Fuel loading
Operation permit
Commercial operation

data on start and end constraints, duration and interconnections. A computer generated integrated project schedule can show in detail the involvement of all functions (engineering sections, contractors, utility efforts, etc.) and the time phasing for the tasks, and can analyse and show the schedule paths which determine the end date of the project and are thus critical. Any conceivable sorting of the analysed schedule events into lists is possible. In the development of the schedule, all relevant experience and all available estimates should be considered. These are best combined during a schedule production meeting led by the cognizant project assistant or a special scheduler. Estimates of time and resources, manpower, budget costs, computer hours, etc., should be made and a loading plan produced to show the manpower required at various times and places. Based on these requirements, manpower availability and commitments must be worked out between project and line management (see Fig. 13).

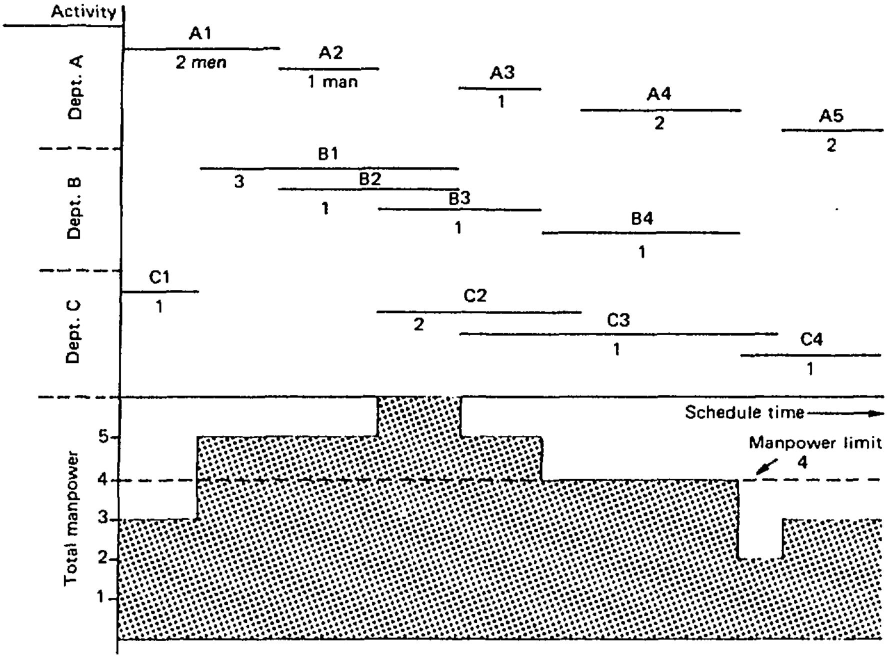

FIG. 13. Sample bar chart with manpower loading (compare with Fig. 12).

— Summary schedule. If all detailed project schedules within all the project partners of a nuclear power project were to be linked into one detailed network, it would not only exceed the capacity of most computers, but would be expensive to analyse and extremely difficult to update. Therefore, a schedule hierarchy is usually developed. In addition, overall schedules are sometimes simplified to show only the most important skeleton activities. From an integrated detailed project schedule a summary schedule can automatically be produced to present the major activities and milestones or the involvement of specific groups within the total project. The printout is often in bar chart form and provides a manageable overview of the principal current activities in the project.

— Database schedules. Database supported schedules are not schedules in the true sense because they lack interconnection logic and updating mechanisms. Nevertheless, they can offer planning and scheduling units a powerful tool for managing large volumes of information. For example, thousands of drawings and specifications must be developed and released in a project, and listings and simple charts can be used to provide detailed monitoring tools. There is a close relation between the database schedules and material flow and document control systems. Project management needs a way to schedule and track the status of large numbers of items and can use listings (with due dates), scheduling systems or a database management system to generate status or reminder reports.

3.3.1.2. Schedule levels

Planning and scheduling personnel have found it convenient to talk in terms of schedule levels for nuclear projects. A series of schedules which presents information from a very broad viewpoint down to the level of task networks is referred to as a schedule hierarchy. A nuclear power plant schedule typically shows four distinct levels of detail; Fig. 14 gives an example of the relationship between them.

The first level, level I, represents the overview or summary for the whole project, usually in the form of a bar chart or a milestone schedule, which may emphasize specific aspects such as contractual obligations, project partner interfaces and major systems.

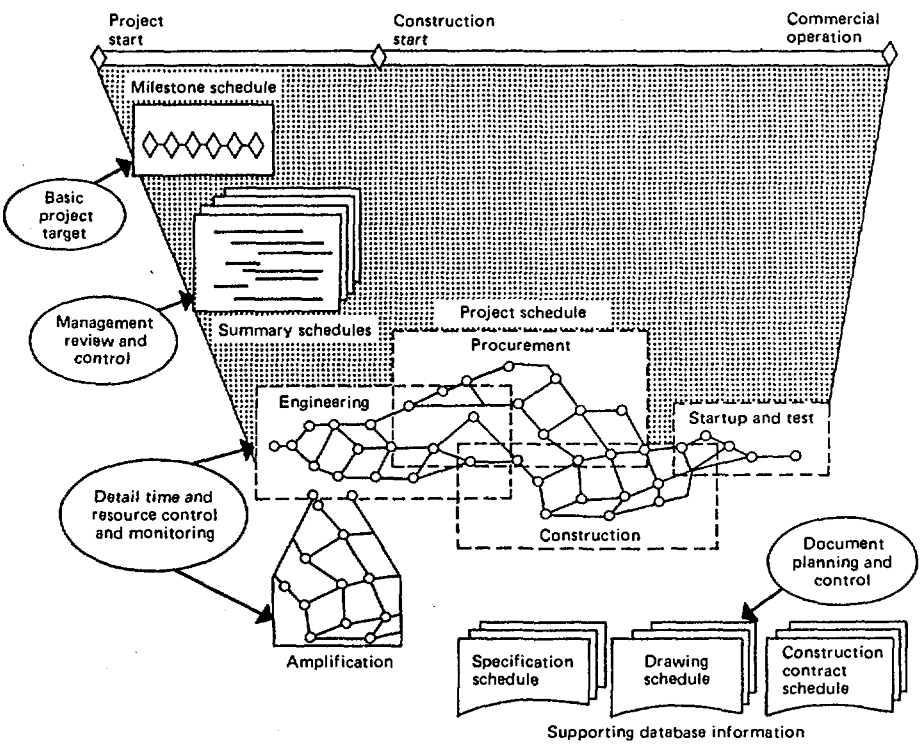

FIG. 14. Schedule levels.

The next level of detail, level II, is still a summary level, but is more complete and relates just to part of the project. As noted, this schedule defines the work unique to a particular portion of the contract and/or the project. In effect, the level II summary schedule pulls out a particular segment of the level I schedule and expands the information to present a comprehensive package relating to a specific discipline or portion of the project, e.g. the civil works. Generally, the level I and level II schedules present their information by way of relatively simple bar charts and milestone notations, but level II would more likely be computer generated from a larger integrated network.

At level III, all required task elements for the project or major portions thereof are specified in detail to produce a complete integrated project schedule. Normally the level III schedule is a CPM network. By using CPM computer software packages it is possible to generate level II and possibly level I schedules as a by-product.

Level IV, the most detailed level of information in the schedule hierarchy, could be an amplification for a particular task (in the level III notation), as shown in Fig. 14. For example, the level III schedule may show a single activity called reactor vessel procurement, which would correspond to a particular purchasing activity and subcontract. The detailed task network in the manufacturing shop for this major component may, however, fill an office wall and would serve the subcontract manager, engineers and foremen in day to day co-ordination and monitoring. Such detailed schedules may also serve as progress information or co-ordination tools, i.e. for the utility on a critical component or the regulatory authority and its inspectorate for planning fabrication surveillance. Level IV schedules could also deal with large volumes of serial schedule events or database generated information. Drawing lists with due dates, and specification schedules with target dates for first draft and preliminary reviews are included at this level. Usually, the type of information being managed and the volume of detail involved lends itself to so-called database management systems (DBMS) application, and current trends in advanced scheduling methodology in nuclear power plant projects are to use computer software to the fullest extent to support this scheduling function. Further advice on computerization of schedules can be found in Appendix IV.

3.3.1.3. The project schedule as a tool

A successful nuclear power project is one where the plant is designed, constructed and put on line within the schedule, budget and technical parameters established. The primary focus of project management is on how to expend project resources (staff, money, material and time) most efficiently to produce a high quality plant. If project management is to derive maximum benefit, scheduling must be much more than just setting target dates and monitoring accomplishments. A well developed schedule in the hands of a skilful manager can pay for itself many times over when it is used to spotlight problems and analyse various ways of solving them.

In a nuclear project, scheduling acts as the catalyst for project co-ordination and control because it:

— helps define the project scope of work
— identifies areas of responsibility for the work
— establishes goals and targets
— identifies potential problem areas
— identifies when decisions need to be made
— becomes the focus for project communications.

The schedule is really a model of the project. It employs various graphic or mathematical techniques to depict how the job is to be done. To be useful for planning and control, the schedule should provide the following information:

— What has to be done (the task)
— How the task relates to other tasks (the sequence)
— When it must be done (target or milestone dates)
— How long it will take (the duration)
— Who will do it (the function, discipline, organization)
— The resources needed (manpower, skills, equipment)
— A unique designation (numbering) for computer handling and sorting.

Many techniques and systems are available for establishing a schedule, some of them simple, others very sophisticated. Whatever technique is chosen, it must realistically depict the project work. It should be remembered (see also Appendix IV) that the schedule model and its results are as good as the inputs and that people working on the project have to be involved at regular intervals to keep the schedule correct and alive. If the schedule cannot be understood by the users, either they must be given schedule training or the schedule technique or its computerized printouts must be changed. Otherwise the schedule will become an intellectual exercise for the scheduling specialist and not a useful monitoring and control tool for the project.

In summary, controlling through the project schedule means for the project manager receiving up to date, accurate, relevant and foresighted reports on the project performance as seen against the target schedule. By means of this reporting system deviations from the target schedule should be noted or automatically listed and reviewed by the project manager (magnitude of the deviation, consequences, etc.). This allows the setting of priorities. This analysis of the project situation via the schedule, however, is not the end of the control process. The project manager must also initiate actions with the appropriate departments of his organization and/or other project partners to start resolving, i.e. removing or reducing, the schedule deviation. Rescheduling may involve shifting of resources, accelerated work plans, parallel work, different logic connections in the schedule, accelerated preceding or following tasks (to gain overall time), and — only as a last resort — extended target dates. To implement such actions realistically and firmly, quite substantial work and time is needed and it is better to leave the schedule deviation standing until everything has been carefully decided in terms of new task orders instead of making an illusory and premature updating. In the end, however, the corrected schedule will show no deviation and will bring the particular task out of the management-by-exception area into the normal range.

3.3.1.4. Use of the schedule

The real value of planning and scheduling work is the presentation of the right kind of schedule information to the appropriate level of technical and management personnel. While a project manager may want a single status report on project tasks (i.e. sorting by task number) as a complete overview, line management may prefer a sorting by technical disciplines or by task engineers to obtain an overview for a specific section or department.

For the project manager of a utility which has a supervising (non-executive) role, it would be most important to obtain biweekly or monthly reviews of the critical events in the overall project.

The utility project manager should obtain the relevant information from the main contractor or architect–engineer, who would maintain a detailed schedule network for the project. A list of critical items is also needed for reports to upper management and should be communicated among project partners. The utility project management should have its own scheduling effort and easy access to various levels of detail.

In a split package approach, the utility project manager should:

— insist on a single uniform reporting system at the highest level of schedule hierarchy, i.e. the overall plant. The system should be linked to the contractual schedule and would also be regulated in the contracts.
— Insist that the schedules be updated at intervals of less than two weeks.
— Encourage compatibility in computer software and reporting formats between the project partners.
— Have access, on request, to details of lower level schedules coming from the other project partners.
— Assign responsibilities among project partners and/or utility personnel for schedule items which need corrective action by special assignments, memoranda, task orders or meeting minutes.
— Allow only one set of co-ordinated schedules, authorized (signed) by the project managers in charge, for official purposes.

With regard to the last item above it should be noted that in many large projects co-ordination of all schedules is difficult. A common problem is that the site manager, individual engineers and/or contractors close to the action, i.e. the site or the manufacturing floor, show up with new schedule information at meetings and claim that project management (at headquarters) is not up to date. The utility project manager should not accept such discrepancies and if a communication problem exists between site and headquarters of one partner should make clear that that partner has to resolve the problem and produce a single set of valid up to date information authorized by the project manager.

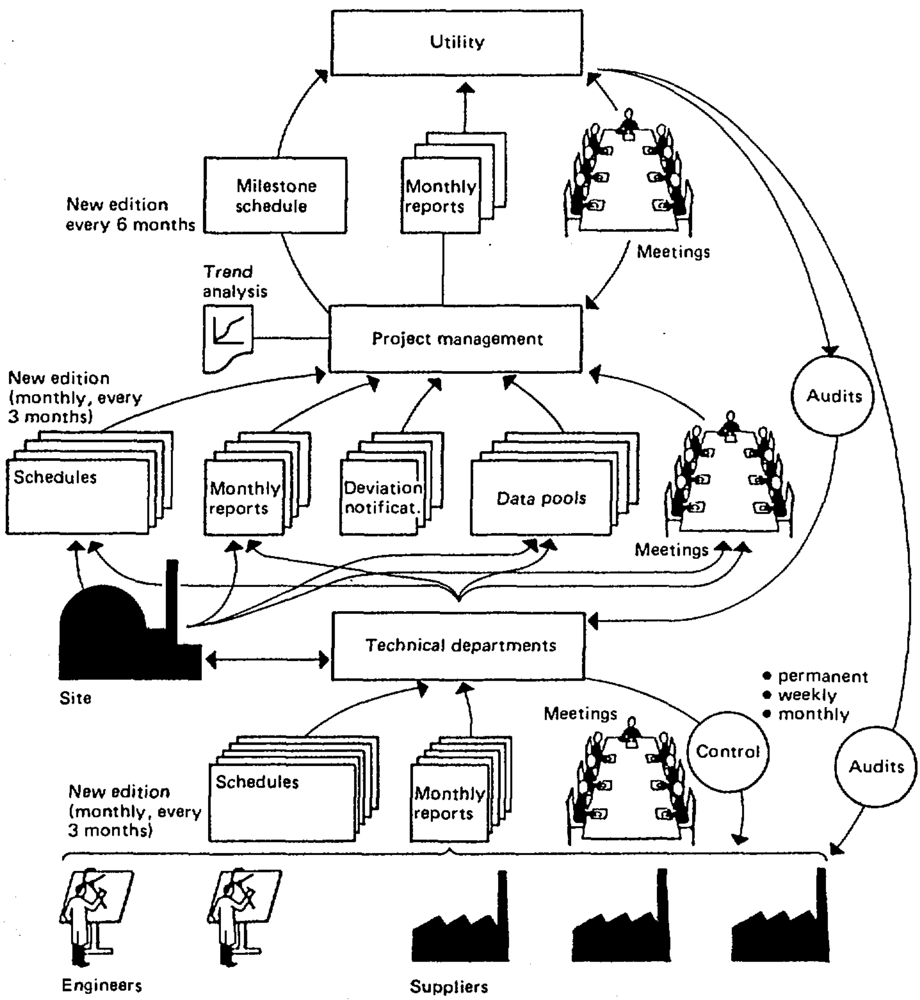

FIG. 15. *Follow-up of time scheduling.*

3.3.1.5. *Schedule updating*

To keep the schedule alive and up to date and to maintain its usefulness as a continuous planning and control tool, routine updating is necessary in all project partner organizations with the possible exception of the utility, which just co-ordinates the results. Reports on actual status, milestones, terminated actions, etc., as well as expected new completion dates should be gathered on a biweekly or monthly cycle from the engineers in charge of the various tasks. Such data could be gathered by the scheduling technicians on return forms, but in some cases might require meetings with the engineers or approvals of section heads. It is not uncommon that entire series of small updating sessions are held at least once a month to involve all concerned. The project manager may want to attend such sessions from time to time, whether the scheduling unit reports directly to him or not. Such spot checks by the project manager or his assistants can help ensure honest updating and provide project management with important background information. As in problem solving and risk management, an important contribution made by project management to the updating process is foresight. Task engineers and production personnel may very well let a problem rest until the execution of the task and report the deviation after the fact. It is much more important to look ahead in the schedule as much as possible so as to introduce planning estimates and performance measurements into updating. A correlation with the project management's problem list and risk list can be helpful. Subcontractor performance and schedule updates and forecasts must be introduced into the project schedule by the leading engineering sections (which issued the specification for the subcontract) of the partner organization together with the purchasing department.

An additional aspect which may need the influence of the project manager from time to time is the prevention of unrealistic updates, possibly made by a line manager who wants to give optimistic forecasts simply to avoid appearing on a critical items list for the next schedule printout or project meeting.

Large subcontracts will require scheduling and updating efforts similar to those for main contracts and will involve many of the above project management actions.

Figure 15 shows the tools available for follow-up of the schedule.

3.3.2. Cost control

3.3.2.1. *Basic principles*

The project budget is not only an essential planning tool but also a most powerful control tool. The project manager must have authority over the project budget to control it effectively. This also helps to underline his authority over project tasks. The planned or target budget (basic cost plan) is usually set up for all project partners along with the project contracts and refined at the start of project execution. Once

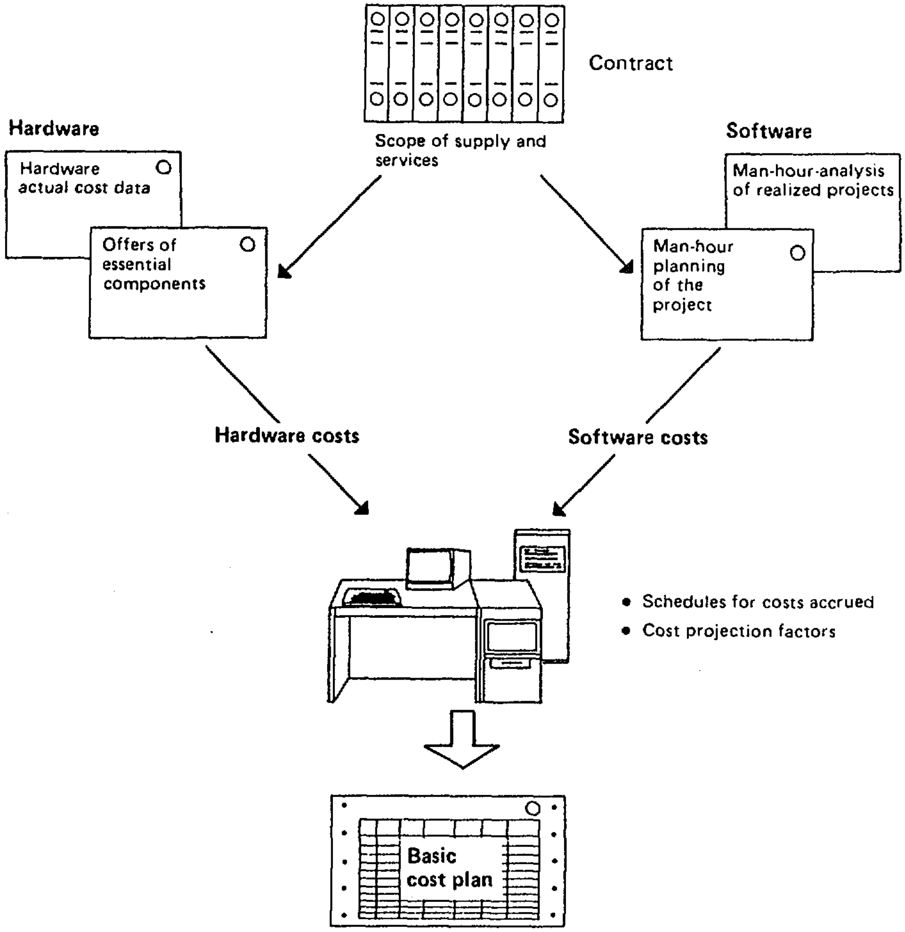

FIG. 16. Basic cost plan.

these planning and control elements have been defined and agreed to they become a fixed (usually computerized) project basis. Figure 16 shows the components of the basic cost plan. At any one time the committed budget should match the authorized resources; otherwise the project manager has to urge for new appropriations by his organization and/or renegotiations with the project partners. The overall economics of the project and its very feasibility can depend on keeping close to the foreseen budget.

Internally, the budget and scope agreements should be part of specific work authorizations or work orders, co-signed by project management and the responsible engineering or manufacturing unit (including subcontracts through purchasing).

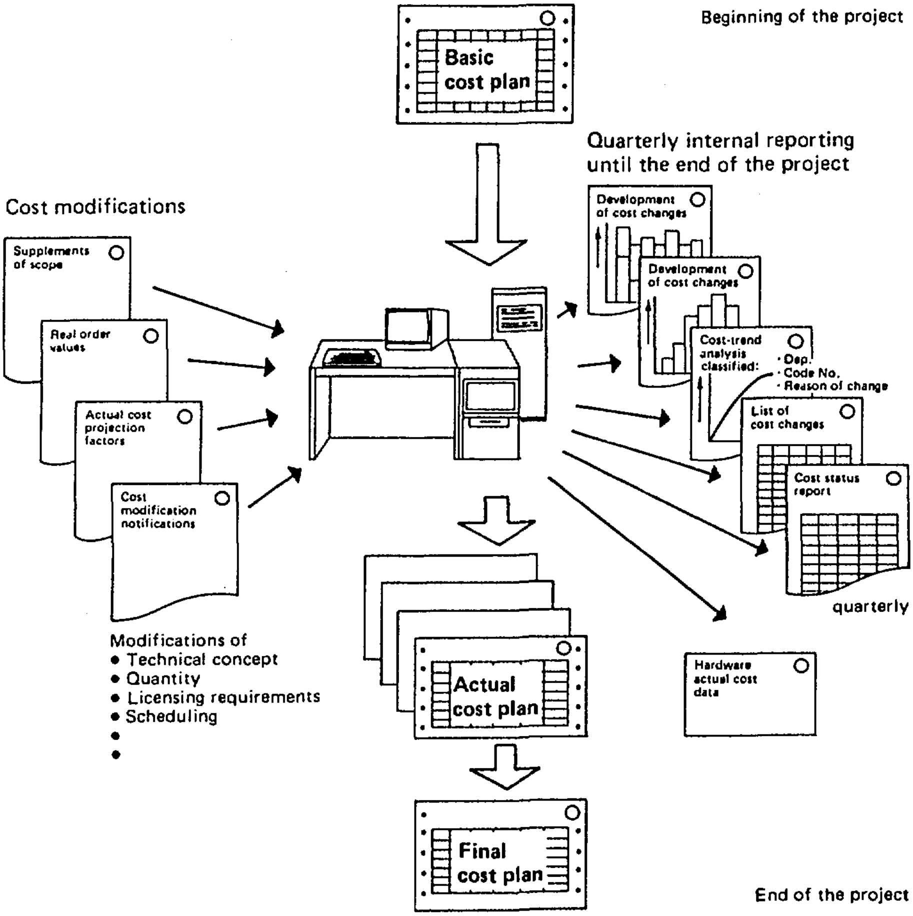

FIG. 17. Cost control concept.

Throughout the project these agreements should be enforced by checking actual expenditures against original allocations and requiring formal change control and reauthorization for any later budget increases or decreases. The numbering scheme of the work breakdown structure should be used for unique budget identification and corresponding charge numbers should be followed and reported by the accounting unit in support of the project and the line organization. Suspension of payments can be used as an effective tool to control contracts and subcontracts. Such measures show what power is involved in this project control tool; the project manager must have a share in this power to be effective.

To minimize future cost overruns, the managers of the project partners must co-operate and work towards the good project management practices explained in this Guidebook. In particular, reliable budget estimates depend on the choice of reliable project partners, the existence of a well defined and proven contractual set-up, extensive definition of the scopes of supply, a definition of the project coverage and a formal risk analysis approach to remaining uncertainties. Detailed estimates may be higher than those from preliminary or simpler analyses (which may have been more pleasing to some decision makers) but will be less subject to future surprises. Throughout the project it is a good management practice to reward project managers and cost controllers for foresighted and realistic assessment, rather than for lower but unrealistic figures. Realistic budgets are the best basis for monitoring and controlling the project.

Figure 17 illustrates the cost control concept in relation to the basic cost plan.

3.3.2.2. Specific control tasks

Utility project management is ultimately responsible for funding the project and must be aware of the overall budget and funding situation at all times. Careful and realistic planning, efficient execution and tight control are the means of keeping close to the projected budget. Once additional costs are inevitable, the project manager should promptly inform the utility general management and possibly the governmental bodies and financial institutions whether cost changes will affect the overall plant financing and cash flow requirements. To assist in this effort, the project managers of the partners will be obliged to monitor continuously the costs in their own area of responsibility and keep the utility project manager informed. For each major deviation from budgeted costs the utility project manager has to initiate corrective action together with the affected partners (preferably before and not after the costs have been incurred). Such action may involve solving a particular problem, demanding better contractor performance (possibly reporting to upper management), refusal or acceptance of additional charges (according to contract provisions) or ultimately renegotiated budgets. In a split package approach, the architect–engineer may be performing detailed cost control for the utility.

In view of the limited engineering experience and staff capacity that the utility might have in a first nuclear power project, contractors will usually perform the detailed project budgeting and control along with detailed engineering and construction. Depending on the type of contract, this may involve a main contractor, or an architect–engineer and one or more main contractors and subcontractors. Development of projected budget and incurred cost items have to be followed and checked in detail at individual task or shipment level. The figures in the work authorizations should be used as a basis.

Computer based detailed cost control systems can offer the project manager and his staff a large choice of information. Many computer systems are combined with computerized project schedule information and the results can be presented against the time schedule. In addition to carefully selected summary information, which gives the project manager an indication of overall trends, project assistants may require more detailed information sorted and listed by system or equipment numbers (work breakdown structure), by cost centres (organizational units) or by the magnitude of the anticipated cost deviation. Such detailed reports are routinely used by both specific task engineers or section managers as well as by project assistants in their respective areas of responsibility. To provide a certain amount of flexibility for corrective action, the cost reporting system should contain both the amount actually spent (sometimes closed accounts) as well as developments based on forecasts and degree of completion estimates. Many of the computer programs can automatically produce informative curves on the individual task or overall project level, including extrapolations and forecasts. However, the project manager or project assistant must apply a certain amount of critical judgement and interpretation to such curves.

Reaction to report deviations or to forecasts of increases should be immediate and extremely careful. The project manager should explore in detail the reasons for major deviations and find out whether productivity has slipped, or additional unauthorized work is being planned, or new requirements have to be met. Only when he knows the problem well enough can he propose or negotiate a solution with the departments and/or project partners affected, i.e. reducing or shifting expenses or appropriating extra funding.

3.3.2.3. Cost escalation

Every year wages and salaries go up, raw materials and components cost more and transport becomes more expensive. All of these increases imply a decrease in the real value of money (inflation). This decay appears to be largely inevitable and therefore predictable and it must not be overlooked for the long duration of a nuclear project. Methods and mathematical equations to anticipate such changes and correct for them are quite common in the economics of budgeting and cost control. They have also been used in many nuclear power plant contracts. Establishing a baseline for adjusted budgets and costs makes it easier to produce realistic forecasts and helps to improve awareness of cost increases due to inflation.

3.3.2.4. Contingencies

One common source of errors in overall project estimating is the failure to appreciate that additional costs are bound to arise as a result of design errors, manufacturing mistakes, logistic errors, material or component failures and the like.

The degree to which contingencies have to be added to estimated project costs will depend on many factors, including the soundness (or otherwise) of the engineering concepts, the reliability and experience of project partners, the contractual conditions, and so on. Performance in previous projects is a reliable pointer for deciding just how much to allow on each new project to cover unforeseen circumstances. For a proven product and contractual set-up, not entailing an inordinate degree of risk, the total contingency allowance might be set at 5% of the project scope of each partner; usually a higher percentage has to be foreseen. If the figure exceeds something like 15%, perhaps the utility should consider whether or not the offer and contractual conditions are acceptable. Additional costs in the overall nuclear power plant project are to a large extent a measure of the performance of all project partners and their incidence can be measured and used as a control.

It is probably better to set up a reserve fund to pay for statistical cost deviations rather than to re-examine the original estimates on an item by item basis. In the rarer cases where cost savings are achievable, these must be monitored equally carefully and added to the contingency or the profit of the contract. Costs and possibly contingencies can also be divided into categories, such as changes, planning and logistic errors, scrappage, rectification and so on. If a good accounting and cost control system exists with the production of biweekly or monthly sorted listings and trend curves, control can be concentrated in areas where unforeseen overruns are likely to be largest or most frequent and where corrective action will do the most good. A high modification cost rate, for instance, might show up from cost records, and the result could be used to tighten up control on the number of changes authorized. A systematic method of approaching contingencies associated with technical uncertainties is the use of risk management. Early discovery of trends and figures and corresponding early remedial action can help project management to stay within the budgeted contingencies. Good accountability and good housekeeping are important and the credibility of the project and its overall costs should be maintained by all means.

As the ultimate holder and controller of the project funds, the utility project manager has a particular responsibility in planning for, using and keeping within budgetary contingencies. In some nuclear utilities, the career advancement of project managers has depended on their overall performance and foresight with regard to the budget. Such performance, however, can only pertain to the parts of the project over which the project manager has real control, i.e. to the utility scope and to delegated contracts. In a turnkey situation, for example, with a fixed cost, a predictable licensing situation and, above all, a sound and stable contractor, the utility may not need much contingency. Most of the risk and contingency planning would go to the contractors.

Depending on the contracts in the project, the main contractors and/or the architect-engineer will take on large portions of the project scope and project budget and so the planning of project contingencies. Correspondingly, a firm pricing and costing policy with reasonable (say 5–10%) contingency over the project life should apply internally to the partner organizations. An open ended, unpredictable, cost-plus situation on any portion of the project should be avoided by all means.

3.3.2.5. Project interruptions

Work interruptions in nuclear power plant projects are generally even more of a cost problem than difficulties with scheduling. The timing of such interruptions greatly affects the degree and type of project cost changes. Project interruptions during the engineering, design and licensing phase can result in work inefficiencies and in price increases. Problems of continuity and consistency in the engineering and design effort can also result. In many cases, work might have to be redone as new personnel are brought into the project, replacing engineers and designers who have been reassigned during the delay. On the other hand, the temporary stoppage of certain manufacturing, construction and engineering activities for proper schedule sequencing and for firming up inputs and/or specifications can be less expensive than rushing a job with uncertain data.

During the construction phase, project interruptions result in work disruptions and increased interest costs for expenditures already incurred. With high interest rates, each month's delay in a project with 20 to 30% of the construction completed would increase project costs by several per cent. In addition, approximately three to six additional months would have to be added to the work interruption to compensate for demobilizing, remobilizing and possibly retraining of construction personnel.

A low level of project management activity, possibly including engineering and design effort, should be maintained during any unavoidable major work interruption. The small workforce would basically continue to work on tasks required to support site preparation, conservation measures and/or critical path items, depending on the project status and the contractual provisions.

Special care has to be taken during early project interruptions with regard to long lead time components, such as the reactor vessel or its major forgings. Failure to proceed with this work five to nine months prior to construction start could delay the entire project.

3.3.3. Quality assurance

The particular processes involved in the operation of a nuclear power plant and the need to protect all persons from undue radiological hazards impose strict requirements with regard to safety. This is the fundamental concern of the regulatory authority. For the utility, however, there are other priorities besides those related to safety. The nuclear plant is supposed to generate electricity with a risk to the public as low as reasonably achievable but also it has to attain the highest level of availability at a reasonable cost.

The effect of human and equipment failures on the operation of a nuclear power plant can be serious. An effective methodology for detecting, correcting and preventing failures is the implementation of an adequate quality assurance programme.

According to a generally accepted definition, quality assurance (QA) represents "all those planned and systematic actions necessary to provide adequate confidence that an item or facility will perform satisfactorily in service". In terms of this definition, QA represents a management control system that must be established and used in the attainment of the quality objectives in the construction and operation of the nuclear power plant.

As with any management control system, QA requires an organizational structure with defined responsibilities and functions, a documented programme with established goals and objectives, and prescribed procedures for performance evaluation. Feedback of information on performance monitoring should exist to allow corrective action to be taken and to ensure that the organization is pursuing its established objectives.

The achievement of quality in the construction and operation of a nuclear power plant depends on the ability of the project management to establish and effectively implement QA as a management control system. Quality assurance should not simply be regarded as a regulatory requirement but be considered as an essential management tool to ensure the accomplishment of safety and availability requirements at reasonable cost.

The success of QA is tied to the understanding, commitment and support of top management. Efforts have to be made to ensure that through education and training management personnel realize the importance of QA as a necessary and cost effective management tool.

Recommendations, guidance and examples for the establishment and implementation of QA functions are provided in the IAEA Code of Practice in Safety Series No. 50-C-QA with its related Safety Guides and supporting manuals. The main characteristics of the QA concept presented in those documents are:

— The focal point of the QA requirements is an overall responsibility for QA programme establishment and implementation. This responsibility, during the whole life cycle of a nuclear power plant, lies with the utility, i.e. the organization having overall legal, technical and financial responsibility for the plant. Although all partners involved in nuclear power project activities are obliged to implement QA requirements, the utility is the central point as far as the regulatory body is concerned and has the overall responsibility for QA. The utility must discharge this responsibility either by directly implementing all required QA functions itself or by delegating this work to other partners. Such delegation is purely contractual and does not decrease the responsibility of the utility for QA in respect of the regulatory body.

— Quality assurance requirements to be implemented by all partners in a nuclear power project are formulated in a set of basic QA principles, contained in the above-mentioned Code. They obligate the utility, main contractor, architect-engineer, constructors and subcontractors to plan, conduct and document their work in a systematic way. This allows the verification of all activities not only by physical inspection or testing of all hardware in the plant but also through indirect methods such as evaluation of the effectiveness of the respective QA programmes.

— Quality assurance includes both quality achievement and quality verification functions. Achievement means that the qualified personnel responsible for the work should perform it according to qualified procedures and instructions, using adequate tools, providing an appropriate environment and controlling all the factors having a direct or indirect influence on quality. Verification functions are performed by personnel with no direct responsibility for the work but with enough authority and organizational freedom to identify quality problems and initiate corrective action. In a nuclear power project the verification functions spread through a network of contractors and subcontractors with each partner performing direct or indirect verifications of all its own and its subcontractors' activities.

— The scope of the QA programme should include all equipment and activities in a nuclear power plant that are important for or related to safety. There should be in principle no items or activities having an influence on safety that are not subject to QA requirements. However, the QA concept can and should be extended to cover all items influencing not only safety but also the availability of the plant, so as to achieve an integral QA programme to ensure the availability, safety, economy and environmental acceptability of the nuclear power plant.

3.3.4. Measuring progress

If a project is to be cost controlled with any degree of success, three factors assume major significance. These are planned and contracted budgets, the costs actually incurred, and the work achieved in relation to those costs. A knowledge of the budgets and costs by themselves will be of no use unless the corresponding progress in software and hardware production can be gauged. All three basic factors must therefore be monitored during the active project life.

Budgets should be easy to follow throughout the project. They are derived from the departmental estimates and may be amended from time to time to allow for authorized modifications. Cost recording for man-hours, equipment and materials will be an established routine in any well run organization so that records of project costs at any time can be obtained from the cost administration and accounting offices. One possible difficulty in cost analysis is the time delay which must inevitably occur between the actual expenditure, its local recording (entry) and the corresponding appearance in the books. With modern computerized methods a two week trailing is achievable and acceptable.

Analysis of the progress achieved, however, has not always been part of the normal project control procedures and thus has often been a missing link in any attempt to follow the actual status of the project. The project managers in the different partner organizations have to look at three different areas for measurements of project performance, namely:

— Hardware installation and construction
— Preceding engineering design
— Accompanying project management effectiveness.

Evaluating project progress continuously is not only necessary to forecast potential deviations in cost or to schedule early remedial action, but is usually essential for the purposes of contractual progress payments. Specific plans for remuneration of the main or subcontractors by the utility are normally part of the contract — except for cost-plus contracts, where performance is essentially based on trust — and are tied to predefined progress milestones in the project schedule (which force an evaluation). Delivery of equipment such as heavy components, finishing and acceptance of major pieces of work in the manufacturing shop, and of finishing certain elevations of buildings are often used as payment milestones.

Since payment milestones are usually associated with the more obvious large items, they provide project management with a fairly good overview of progress, internally and externally, and with a means for detecting if schedules are not being met or budgets are being exceeded. Major problems in project progress, however, are often related to large numbers of smaller items such as ancillary systems, piping, electrical work and ventilation. Such problems normally originate already during the engineering phase, e.g. through a late start, undefined requirements, insufficient resources, bad co-ordination, inadequate methodology or plain incompetence. This is often because in a build-up phase of a nuclear power programme with scarce personnel resources, the seemingly less important, more conventional parts of the plant may be taken over by the less capable engineers, managers and organizations, not fully aware of the technical and quality standards associated with nuclear work and/or the complexity of the plant. Therefore an early measurement of progress and work quality in these areas is a vital part of project management control. Management information systems can provide data on the usage of material and equipment and thus provide the project manager with weekly information on metres of piping installed, elevation of concrete pouring, etc. Objective measuring of engineering progress can provide invaluable early diagnosis of performance problems or schedule and cost overruns of utmost importance to the entire project. The project manager should therefore make every effort to convince department managers to establish systems of performance measurement from the beginning of contract work; it will often involve reporting on items which some engineering managers feel concern only them. In the end, however, most managers and engineers working in a project will understand that detecting problems early, taking remedial action, adjusting manpower and renegotiating contracts, where necessary, helps everybody to do a better job.

The project manager himself should also try to measure his group's performance in leading the project. Intermediate and long term action plans for the project group can help to assess progress. Project management is often confronted with many parallel priorities, namely organizing itself, planning, executing and controlling, and certain items, initialy recognized as important (such as a risk programme), may be postponed and eventually forgotten in the day to day work. A long term action plan with assignments for each project assistant can promote a more balanced approach to priorities, and monthly status meetings on the plan could provide an important contribution to the measurement of project management.

The utility project manager will obviously need a realistic assessment of progress on large and critical schedule items, such as heavy components or the potentially troublesome piping work, for example. In addition, he must pay attention to the less obvious ancillary or electrical systems. If some of this work is engineered and installed under utility direction, the project manager would work directly with the appropriate line organization to obtain realistic status reports. Otherwise the utility project manager must ensure, via progress meetings and reports, that the project managers of the partners concerned establish an appropriate measuring system and present proper results in their progress reports to the utility.

Measuring progress in detail in the execution phase of the project is most important in organizations which have execution responsibilities, typically the main contractor or an architect-engineer and contractors. These organizations also have the most internally available information on which measurements could be based. For a progress assessment, many hundreds of different activities may have to be examined, some of them not started, others in progress and a few completely finished. Measurement is now not directed at the work of one man, or even one department, but at a whole range of project activities. Design tasks, production, testing, inspection, erection and commissioning are all possible fields of activity which might have to be taken into account. It is essential that the project manager of each partner obtains at least statistically significant statements of project progress for his contractual scope, based on a rather detailed breakdown of reporting according to appropriate measuring criteria. The cost centres used to establish the original project estimates and task orders will provide the most logical framework and will probably also contain a key to different types of costs such as labour, engineering, computer, and material and equipment.

However, an early and continuous measurement of progress in engineering usually presents problems. For example, let us consider a design engineer, engaged in one project activity, and suppose that his particular job has been scheduled to take ten weeks to complete. How can any sensible intermediate measurement of achievement be made on a possibly intangible task? One could perhaps attempt to use the passage of time as a rough guide, so that when three weeks have elapsed the job is considered to be 30% complete. Alternatively, the actual accounting charges to the job could be obtained and progress assessed from the man-hours expended; in both cases a true measure of performance is missing. Any reliance on measurements of this type could be dangerous for obvious reasons. The engineer may have been interrupted in his work through lack of design information or he may just be a slow worker. It is also more than possible that the original estimate was intrinsically wrong. A better method would be to ask the engineer, or his superior, for an opinion from time to time. "What percentage of this task has been achieved?", or, perhaps more provocatively: "How much longer will this job take?"

Where simple achievement measurements prove not to be sufficiently reliable, a combination of degree of completion estimates and departmental data collection on measurable items, such as completed documents, might be used, as shown in the following example. Let us suppose that a department of an architect–engineer has in its project scope 15 systems of safety significance and, associated with those systems, 100 equipment specifications for heat exchangers, tanks, valves, pipes, etc. These documents are normally submitted sequentially to the customer (utility), the regulatory body, and/or inspectorates. Let us assume 10 specifications have obtained final approval, on average, in their fifth revision (iteration). Twenty more specifications are at a stage between 2 and 3 revisions, 30 have been completely drafted, at revision 1. A rough, but quite acceptable and continuously adjustable, measure of the degree of completion of this entire lot of work would be:

$$100 \times \frac{10 \times 5 + 20 \times 2.5 + 30 \times 1}{115 \times 5} = 18\%$$

The department manager, recalling — for the same situation — that nearly 50 specifications have been worked on may say that at least 50% of his work is complete. The project manager may have to admit that his own estimate could be pessimistic, but should only accept demonstrated performance in terms of finished (software) products. If the department head is correct in his assessment, a simple monthly plot of the above measurement against budgeted engineering man-hours spent should indicate a strong upward trend within a few months. Both a more rapid first completion of specifications (as revision 1) and a smaller number of submissions (iterations) up to regulatory approval could work in favour of the department head's estimate. The project manager would be the first to accept the improvement, but only on the basis of demonstrated performance and not on the basis of loose optimistic thinking.

3.3.5. Change control

3.3.5.1. Changes in a project

Changes in a nuclear power project, in the form of modifications of a standard product, new requirements, late engineering changes, and changes in standard or approved documents, are usually detrimental to progress and cost control, and sometimes also to safety. Since there are many possible sources for change within the partners of the project, particularly at the individual engineering level, the project manager's basic attitude must be one of caution. On the other hand, it is almost certain that some new licensing requirements will be added during the planning and construction of a nuclear power plant as a result perhaps of feedback from operating plants or the discovery of oversights in engineering. This requires a flexible response by the project manager and sometimes early incorporation or even anticipation of the change to reduce the impact on cost and schedule. Because of the potentially large consequences, changes have to be decided on and controlled in a well organized manner. Three major steps must be considered:

— Clear identification, registration, documentation and communication of a change;
— Thorough evaluation of the justification and of the entire impact of the change, preferably by a committee or task force;
— Use of strict authorization procedures, requiring the project manager's signature after checking with all affected departments and project partners; ensuring that no changes are implemented before authorization.

The above principles apply more or less to project managers of all partners for their respective areas of responsibility though utility project management should finally approve any change. The work of evaluation and implementation of a change would typically be at contractor level, where size and impact of the change, contractual terms and the wish to make a profit will influence the situation.

Although the documentation requirements and amendments to contracts can serve as a logical interface between project partners with regard to changes, it is preferable that at least part of the change procedure is gone through jointly by the project partners affected, i.e. in joint meetings. Since a change in one part of a plant or a system can have consequences elsewhere which the originator might not have been able to foresee, it is prudent to ensure that every proposed change receives the attention of at least one key member of the responsible project group of each possibly affected partner. This would help ensure that an independent check on its need can be made and that the full effects have been predicted as reliably as possible. The total effects of any modification may be felt far beyond the confines of the actual area in which the change originated. This may relate to the technical, schedule, or cost aspects of the project. Moreover, the effects may even involve product certificate or licensing backfit aspects for a whole series of projects. Sometimes utilities with operating plants set up joint evaluation programmes with architect–engineers or main contractors (typically called plant follow programmes), which can result in backfit changes or product improvements.

An emphasis on minimizing changes and limiting them to the absolutely necessary has to be applied by the utility project management, where ultimately the costs for the changes will have to be borne. Utility control for changes is particularly important if the project contracts have cost-plus components and/or automatic coverage of extra licensing requirements. In addition, utility project management may have to control changes in tasks, where it has executing responsibility, in a similar way to the main contractor.

3.3.5.2. Change requests

Any engineer who is employed within the relevant project partner organization, regardless of seniority, could be allowed to put forward a change request, as an idea without authorization to be implemented and therefore, at first without risk to the project. The logging of this simply as an idea to be examined (by a committee) will establish the basic possibility of a beneficial change. In order to save the time of the examining committee and to ensure that all requests are properly controlled through the review cycle, it may be practical to use a standard request form. This form must be designed in such a way that the originator will be obliged to answer in advance some of the questions which must be asked in the review process. If possible, several project partners could agree on a common form and enter their comments whenever they are affected. The early involvement of the utility is particularly important. The request forms may typically carry titles such as 'Engineering Change Request' or 'Modification Request'. Project managers could at first examine the feasibility informally to avoid unnecessary work. Later at the change order stage matters have to become formal.

In practice, these requests will have to be registered into a log book in the contracts office, the project manager's office, the engineering department, or some other department. A unique serial number is allocated to every request, which provides each potential modification with its own identity. The log will be used as a progress check, to ensure that all requests are being properly reviewed within a reasonably short time. For changes which are approved, the log number provides a means of making the change on new issues of drawings and ascertain that they do, in fact, incorporate the change. A list of all approved change requests (change orders) must be kept by project management throughout the life of the project, and can be checked against the log book for requests. The request form would typically contain the following:

— A clear identification of the reason for the change, listing the new requirements.

— Indication of possible alternative solutions fulfilling the new requirements, their technical feasibility and provenness.
— Estimates of man-hours and computer-hours required in the technical department responsible for implementing the modifications.
— Impact on equipment manufacturing and erection costs for each affected section or subcontractor.
— Schedule consequences for engineering, equipment subcontractor, site works, erection and commissioning. A new task, system or plant network analysis may be necessary to clarify the overall effects on the plant completion date.
— A brief check of the feasibility of the change from a QA point of view, supplemented by estimated impacts on QA resources and schedule, as well as on costs, including engineering documentation and overheads.

3.3.5.3. Change review

Of the three major steps associated with changes indicated in Section 3.5.1, the first and last rest largely with the project management organization and require strict and systematic control, whereas the central one is more work intense, involving the engineering departments. It is therefore the most important step for the partner organizations with most of the execution responsibility in engineering, i.e. the main contractor or the architect–engineer. In these organizations a panel of experts is usually appointed to deal with changes in order to determine how they should be handled. Often the panel meets regularly on a formal basis and deals with modifications in a batch. Although change requests can also be circulated for comments, it is assumed for the purpose of this Guidebook that a formal change review procedure exists, with regular committee meetings, and that all affected project partners will participate in this review process through appropriate project management (and engineering) participation. The principal points which have to be considered are:

— Examining whether the change is really essential
— Checking the feasibility of the modification as described by the originator
— Defining technical and economic responsibility for the change
— Estimating cost and the additional price (if appropriate)
— Determining effect on specific delivery dates and master schedule
— Examining effects on the reliability and safety of the plant
— Updating all relevant documentation, including drawings, specifications and instruction manuals
— Deciding which sets of equipment are going to be affected by the proposed change if more than one set is being produced.

Although the technical review and evaluation of changes can be very much a question of conceptual engineering, it will usually also involve problem solving and, therefore, requires close attention by project management. Once the proposed solution, its impact, cost and schedule have been identified, the change can be approved, rejected or left pending. In the case of approval, instructions should be developed to permit engineering departments and project management to incorporate the changes into the regular path of project work and project control.

3.3.5.4. Change orders/authorizations

When a change has been formally approved and a communication from the project management of the affected partner issued, a number of steps have to be taken for formal implementation and introduction into the normal course of the project. This is illustrated in the following example.

(1) A 'Change Order' or 'Change Authorization' form is issued. This designates and defines the change and provides basic information on its authorization, budget schedule, etc. It is also possible to use the task order document or the change request with appropriate additional entries. The change order forms are received by the affected technical offices of engineering production, site, etc., and completed if necessary. The forms normally have been assigned unique numbers within the entire project by project management and could be further marked as follows, if such groups are affected:

C — Civil engineering group M — Mechanical engineering group E — Electrical engineering group P — Piping group X — Commissioning group	Plus Serial No. within the group

The form must contain all the information and instructions necessary for each group in sufficient detail and include the sketches necessary for a complete description of the changes decided. Implementation details would normally be worked out between the cognizant task engineer and/or section head and the project management assistant in charge, in a very similar way to the contents of original work packages.

(2) The forms filled in this way will be sent to the relevant Quality Assurance department to obtain additional authorization or certification, where appropriate.

(3) If site management is affected by the change described, its written consent must be sought.

(4) Affected engineering sections will incorporate the change into all relevant project documents.

(5) Utility project management will be informed and will monitor the approved actions taken in connection with the change order and follow-up.

The change authorization and implementation procedures must include the necessary approval from those project partners which ultimately provide the funds for the change (i.e. the utility).

3.4. INTERFACES WITH PROJECT MANAGEMENT

In planning, executing and controlling the project, the project manager of each partner organization not only has to co-operate with the project managers of other partners, but above all with the line organization and with the numerous staff personnel who sometimes perform project management tasks. In all this work proper interfacing and proper definition of roles for the main disciplines working with project management in a matrix type organization become very important.

3.4.1. Engineering

The interface with engineering is the one most frequently encountered by project management. It sometimes gives rise to the following problem. Since project management personnel for a nuclear power project should preferably have an engineering background, there is a considerable temptation to actually do engineering work instead of steering, planning, co-ordinating and controlling it. Conversely, engineers of the line organization may find themselves getting into communication co-ordination or even authorization work, which are project management tasks. Such cross-overs have to be watched constantly and should be minimized in order to avoid conflicts.

The main concern of project management with regard to engineering is to make sure the work is done on time, since delays in engineering have proved to be a common problem in nuclear projects.

3.4.2. Quality assurance

There are different approaches to quality assurance (QA) implementation, ranging from a product oriented approach, which verifies by direct independent and redundant test or inspection of each significant technical detail, to a systems oriented approach, which places emphasis on prescribed QA methodology and obligates the utility and other partners to plan, conduct, control and document their work in a systematic way.

The QA concept developed in IAEA Safety Series No. 50-C-QA is closer to the systems oriented approach. It is considered that this approach might be more responsive to the needs and possibilities of developing countries and more cost effective because of the lower expenditure in terms of both finance and manpower.

According to the IAEA recommendations, each partner organization participating in activities affecting the quality of the nuclear power plant shall establish a documented organizational structure where the functional responsibilities, levels of authority and lines of internal and external communication are clearly defined. The organizational structure shall recognize that execution of the QA programme involves both performers and verifiers and is not the responsibility of a single group.

The utility shall be responsible for the establishment and the implementation of an effective overall QA programme for the complete plant. This programme shall be established sufficiently well in advance of the commencement of the work to ensure its effective implementation. The utility may delegate to other partners the work of establishing and implementing all or part of the programme, but shall retain responsibility for the effectiveness of the overall QA programme, without prejudice to the contractor's obligations and/or legal responsibilities.

Each partner organization to which the work of establishing and implementing any portion of the overall QA programme is delegated is responsible for structuring itself and for assuring that each related partner organization structures itself in accordance with the requirements of the overall QA programme.

Measures shall be established and prescribed in the contracts to ensure that each partner organization obtains sufficient information and access to the work places, facilities and records so that it can fulfil its responsibilities.

IAEA Safety Series No. 50-SG-QA7 illustrates one technique by which quality assurance programme activities may be defined for implementation by the combined efforts of all partners.

In each partner organization a 'quality assurance unit' shall be identified and assigned the responsibility (a) of ensuring that an appropriate QA programme is established and effectively executed, and (b) of verifying that activities have been correctly performed. The quality assurance unit shall be located in the organizational structure at a level such that its ability to be effective is not obstructed by conflict of interest. At a minimum the level of the unit should be such that it reports upwards to a general management level position so that an interface with project management will exist. Because of the many variables involved, e.g. the number of personnel, the types of activity, and the locations where these activities are performed, the size and structure of the 'quality assurance unit' may vary widely. IAEA Safety Series No. 50-SG-QA7 provides illustrations of the functions, structuring and location of the quality assurance unit.

To ensure co-ordination at all interfaces, both horizontal and vertical, each partner organization that delegates any part of the QA programme to other partners shall establish the requirements for this co-ordination where necessary, and shall document them by policies and procedures.

The functions of the regulatory body in connection with QA shall be planned to be consistent with and complementary to the utility QA programme. A

QA programme based upon the IAEA recommendations establishes an effective management tool that can be used by the utility as well as by the regulatory body to obtain confidence that the plant will perform satisfactorily in service. The regulatory inspections must correlate with the established QA requirements and make use of the results obtained by the plant owner. They should serve as an effective way of corroborating that the QA programme is being performed correctly. However, this corroboration does not relieve the utility project management of the primary responsibility for the effectiveness of the QA programme.

3.4.3. Procurement

3.4.3.1. Purchasing

Purchasing may exist as a centralized speciality in any project partner organization involved with equipment subcontracting. It comprises a number of management and administrative activities. In fact, procurement of any item could be regarded as a small project in itself. The project manager is replaced in this analogy by the purchasing manager. A centralized purchasing department in the organization may handle other projects besides the nuclear power plant and represents a concentration of expertise in all types of procurement and subcontracting which is an important help to project management.

The purchasing is normally activated by an equipment specification and/or a project schedule milestone; sometimes entire lists of equipment are issued in advance by engineering departments with schedule requirement dates. Once the need has been recognized, a check is made to see whether items are already available on stock. If this is not the case, action will be started on a written requisition, possibly requiring some form of authorization by cost control, the responsible engineering department and project management to monitor the expenditure.

The first responsibility of the purchasing specialist will be to select a suitable source of supply. Occasionally, only one supplier can be chosen and may be specified on the requisition. Limitation of choice usually occurs when the goods are highly specialized. Even so, for goods which are only manufactured by one firm, there may be a choice between different stockists. Whenever possible, the supplier should be preselected from a number of competitive quotations. One would normally expect the selection of the lowest priced quotation consistent with the required delivery time and quality. Previous reliability as a business partner and qualifications in manufacturing to nuclear quality standards are additional considerations.

Several days of project time may be involved in getting the order to the supplier. Procurement lead times on the schedule network must always allow for such delays; in fact, unless emergency measures are contemplated, two weeks should always be regarded as a minimum purchase lead time.

When the chosen supplier has received the order, he will be expected to return an acknowledgement which includes details of delivery and possibly price. Naturally these details must be compared with the original quotation and with the stated requirements (specification). If agreement is reached, a period of waiting follows and a great deal of reliance will have to be placed on the ability of the supplier to meet his obligations. Interim progress reports, which should have been part of the subcontract with the supplier, should be received and carefully evaluated for any potential problems. Delays in such reports should not be accepted. Expediting, usually a part of the purchasing department, provides early warning of any difficulties which the supplier may encounter.

Equipment must be examined on receipt for any damage in transit and in more detail for conformance with QA requirements. There could also have been some mistake either in the quantity supplied or in the nature of the goods. If the articles are received according to specifications, the purchasing department or its warehousing counterpart will circulate copies of a certificate of receipt. One copy will go to the accounts department, who need it before they can allow payment of the supplier's invoice. Other copies will go to the technical department which is responsible for the specification of the part and possibly its installation and, depending on internal procedures, to quality assurance and to project management.

If the consignment is not received in a satisfactory condition for any reason and betterments cannot be made on site (where received), it should be sent back at once, accompanied by a reject note. Internal circulation of the reject note generally follows the same procedure as the acceptance certificates but it will produce the opposite reactions from the various recipients. The accounts department, for instance, would not allow payment of the invoice, whilst the expeditor would redouble his efforts instead of closing his books.

When the equipment has been accepted, it will be passed into stores, usually at the power plant construction site, to await actual installation. At the same time the stock (warehousing) records must be updated. If the consignment is for repeating production stocks, there will be a gradual depletion as usage takes place, and early warning procedures have to be established to notify purchasing and site management of the need for possible reorders.

As long as the delivered product conforms with project requirements and specifications, the project manager does not necessarily have to be involved in the terms and conditions or in the purchasing process. Engineering sections and departments or the task engineers in the project would be the direct partners with purchasing. It is, however, recommended in a project partner organization that purchasing personnel attend project meetings and consult with project management in regard to major orders (i.e. in the final awarding session) or strategies. The project manager or one of his assistants should maintain continuous liaison with purchasing to stay informed, help communications, assist expediting and check that change control, scheduling and budgeting procedures are not bypassed.

3.4.3.2. *Specifying the purchase order*

The three main ingredients of a purchase order are budgeted price, delivery date, and a complete technical description of the goods. Specifications of price and delivery are straightforward. The price limit can be set either by reference to the project budgets or by a knowledge of the market. The delivery date will be provided by the project schedule network. The full description of the goods may give rise to slightly more difficulty, but it is essential to define the requirements, scope, size, function, etc., of the equipment completely in order to avoid misunderstanding, incomplete delivery and/or contractual problems.

Parts or materials can usually be specified by reference to a manufacturer's catalogue number, part number or standard. This would appear to be a sufficiently rigid description of the goods. However, it must be remembered that some suppliers reserve the right to change their designs without notice or to use apparently equivalent materials. Although this may be acceptable in some cases, the terms and conditions should normally forbid such changes. Licensing and quality assurance certificates and records or future inspection provisions may all be invalidated and the long term behaviour of the new material under the plant operating conditions may be unknown.

A piece of equipment to be purchased, i.e. a component or even an entire system, should be completely specified in corresponding project documents, such as specifications and drawings, which would be under project management control in general and project change control in particular. Such documents should be made attachments to the purchase order, integral and unchanged, and be supplemented with standard and specific terms and conditions, negotiated by the purchasing department with the subcontractor. The terms of a purchase order would essentially represent a subcontract, including such matters as payment, warranty, penalty, schedule and delivery conditions.

3.4.3.3. *Material flow*

Shortages of materials and supplies or lack of interfacing pieces (locks, bolts, flanges) can prove serious in the course of a project. Apart from the effects on individual jobs, the presence of superfluous items or incorrect items which have to be replaced may result in considerable direct and indirect costs. Should jobs become delayed or stopped as a result of shortages or continued changes, this can be interpreted as a failure on the part of engineering and management. In some nuclear power plant projects, the productivity figures have dropped to as low as 20% of the rate for well managed ones. Moreover, good project management control in general with streamlined supply of parts and materials can contribute to good project performance. Well defined scopes within the work breakdown structure and well defined interfaces also help in this respect.

The importance of a good handling system for bulk materials, semi-finished products and finished equipment is underlined by the fact that more than half the total expenditure of a particular project partner may be related to equipment and materials. Competitive buying (purchasing), efficient transportation, warehousing and usage, therefore, are of major significance in the overall project performance. Another aspect of importance is capital investment. If the materials are bought before they are required, money is tied up in an unprofitable way. In addition, untimely delivery can cause substantial storage, handling or conservation problems and costs.

Effective material flow depends on the adoption of a common sense approach to the relative amount of money and time spent on special schemes for different products. A classification into items which require rigid control and those which do not will usually be made on the basis of volume, value and quality assurance requirements. Special control measures would normally be applied most rigorously to parts which involve the greatest investment of either storage space or money. In practice, the choice is difficult, although on most projects there will be one or two items which stand out as being particularly large or expensive, or both. There are also less obvious items (e.g. small valves, motors, etc.) whose enormous quantities (close to half a million separate shipments to the site) and rigorous quality assurance and record keeping requirements make them of special significance. Computerized material flow schemes can be very useful.

In general, software is available for monitoring and controlling material flow. This often includes assistance in defining the resources needed to do the work (i.e. personnel, money, material, facilities, equipment) and the documentation (drawings, specifications, invoices, contracts, etc.) involved. In short, the large volume of information for a major portion or all of the project can be entered, stored, arranged and manipulated quickly by the computer to produce information which has significance in terms of what has to be done, who will do it, how and when it will be done, and how much it will cost. Automatic production of typical forms, certificates, status reports and updates is also possible.

With a common database, one department may enter information into the file, while others can use the information in carrying out their responsibilities. For example, if the purchasing department places orders for equipment and material, then the accounting and cost engineering department can use the information to determine future commitments and cash flow requirements; correlation can also be provided to the appropriate level of the schedule networks.

Material flow information systems can and sometimes must provide the answer to the problems arising from the size and complexity of parts requirements for a nuclear power project. Systems are in operation today which can provide the project manager or the quality assurance department with the current status of every one of the up to one million shippable items in the plant. Where the item is, in what condition it is, which documents belong to it, etc., are questions which can be answered via terminals in the project headquarters, on the site and in the purchasing department. This wide range of possibilities goes beyond material flow and can form part of a large management information system within the project.

Establishing a material flow system can involve a major effort in which project management should be a participant. The day to day running may require only technician level support, which can be provided from purchasing or site management. The interface to project management is relatively simple and consists in the use of material flow data for monitoring project progress and enforcing associated procedures.

3.4.3.4. Special transports

The transport of heavy components, fuel and special materials usually requires specific expertise and the use of transportation equipment. Specialized companies have developed such services and are best qualified to carry them out. This task is therefore often contracted out directly by the utility. Project management has to see that this is done in a timely manner and carefully scheduled and budgeted.

The utility may handle international transport operations, including customs formalities, while delegating the management of internal transport operations to an architect-engineering company or main contractor.

3.4.4. Accounting

Unlike the practically exclusive authority exercised over planning and control of the project schedule by project management, planning, monitoring and authorizing costs for the contracted portions of the plant usually constitute a split or joint responsibility. While general management holds the ultimate responsibility for the profit and loss position of the project partner organization, the task of keeping within a project budget may be completely delegated to the project manager, while the organization's overall financial position would be monitored by accounting or (financial) controlling. Accountants will always play a major role in collecting, tabulating and analysing project expenditures and should form an organizationally separate group, even if they report to project management (which would be exceptional). Depending on the exact rôle of accounting in the organization, the degree of control afforded to the project manager will vary. The preferred arrangement is one where the project manager is responsible for keeping to the project budget, with accounting providing the necessary tools and data, and an additional monitoring and warning process set up for the project costs.

3.5. OTHER IMPORTANT ACTIVITIES OF PROJECT MANAGEMENT

The development of a nuclear power project involves other important activities to be performed by project management. Though different in nature, all of them require special consideration by the partners involved.

3.5.1. Licensing

Some licensing organizations use a project management approach to their work. The functions are different from those of the utility or main contractor project management. The regulatory project management has to plan for a thorough and well co-ordinated licensing review to ensure that the established regulatory criteria are met. This task must be scheduled with due regard to its own resources. In general, this approach avoids unnecessary haste and pressures in review and approval procedures.

A realistic project schedule and the early completion of much of the project engineering cannot be achieved without good communication and co-ordination between the licensing project manager and the project manager of the utility, and between the latter and other project partners.

To obtain this result, the project manager of the regulatory body or inspectorate will clearly define and communicate the relevant requirements to the utility project management, indicate the type of documentation needed, ensure timely availability of expert manpower resources for review and inspection within his organization and expedite the completion of reviews.

The utility is responsible for applying for, and obtaining from the licensing authority, the construction permit and operating licence for the plant. The tasks of utility project management are to co-ordinate the preparation of the Preliminary Safety Analysis Report, to start the licensing process, and to ensure compilation of the Final Safety Analysis Report when the project is near completion. During project implementation the utility project management must satisfy the requirements of the licensing authority by providing any necessary information or clarification. If the engineering for the plant is subcontracted, such information is more likely to be produced by the main contractor or the architect–engineer; the utility will then be responsible for passing it on and also be directly responsible for information related to its own scope.

In executing its portion of the overall project, each partner has important responsibilities in the licensing area which require internal organizational support. This internal licensing function usually includes:

— Developing company strategies in response to regulatory requirements
— Cataloguing all licensing requirements and the responses to them
— Archiving licensing documents
— Scheduling, updating and expediting licensing matters.

In the partner organizations, this function may be assigned to a separate section or to a group of the project management. However, it should be remembered that the overall responsibility for co-ordination of the licensing function of the entire project will remain with the utility project management.

3.5.2. Fuel supply

During contract negotiations for the construction of the plant the utility may already be dealing with a second project manager from the main contractor, namely the one responsible for the fuel. While some organizations hold the view that fuel and power plants should be separate business and profit centres, others see the fuel, particularly the first core, as an integral part of the plant. This latter approach is advisable for a first nuclear project. However, reload fuel will have to be supplied for the entire plant life and spent fuel has to be disposed of. Therefore the utility will eventually deal with different companies or organizational units for these matters. The project manager of a fuel contractor, i.e. a main contractor, will be more a salesman than a project manager and thus more interested in commercial problems than in co-ordination work.

On the utility side, fuel is at first taken care of by the power plant project management organization together with the cognizant technical department, which during the construction phase should supervise the design, manufacture and transport of the fuel. If according to the contract some part of fuel services (yellow cake, enrichment, etc.) is included in the utility scope of supply, the utility project management will be responsible for such provision. With the start of operation of the plant, that responsibility may be transferred to the plant superintendent, depending on the particular utility organization.

3.5.3. Documents management

3.5.3.1. Importance of documents

Since the main part of the project management effort is expended within organizations which deal entirely with software (i.e. engineering), the control of documents, their main product, is very important. In a properly timed engineering exercise the documents are a vehicle of information, interfacing and adjustment. A change on drawings costs much less than a change in concrete or steel. However, a strict change control procedure is necessary within the project.

Documents, namely drawings, specifications, procedures, etc., do not only serve to communicate information between the various engineering groups, but also to define the conditions on the manufacturing floor and on the construction site. Errors, inconsistencies or wrong versions of documents can be extremely costly and would violate licensing and quality assurance requirements. The completeness of the scope of all documents and the correctness and clarity of each document are major concerns for project management. The project managers of all partners in a nuclear power project must, as a minimum, exercise review and approval rights on documents and maintain a list of valid project documents even if special service departments within an organization or engineering departments may actually be

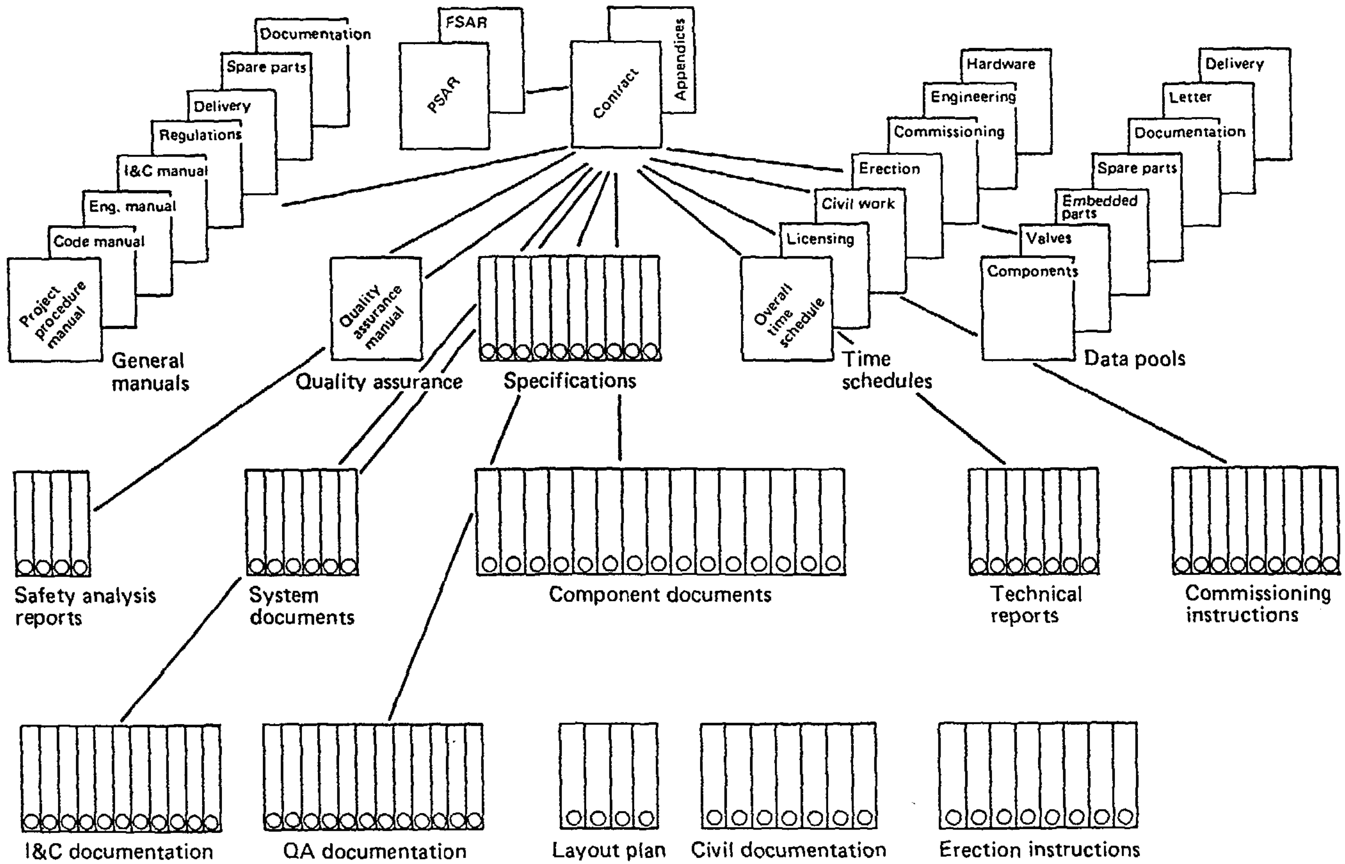

FIG. 18. Documents related to nuclear power plant construction.

performing document storage, retrieval, distribution and control. Documentation is, of course, also the primary tool for quality assurance and control. Well organized record keeping and document security (i.e. redundant sets in different locations) should be required by project management and should be set up for the lifetime of the plant. Since the volume of documentation on nuclear power plants is substantial, space is required and computerized methods for document distribution, record keeping and retrieval have become important.

Figure 18 shows the type of documents involved in a nuclear power plant project.

The utility project manager not only represents the ultimate owner responsibility in this area during the project execution, but also has to see that a complete set of correct and up to date documents describing the plant is left behind for the operating team. He therefore has to ensure from the very beginning of the project that document control is an integrated part of project management. A large part of this work may be delegated to project partners with major engineering activities, but the utility project manager should at least make spot checks on the system.

3.5.3.2. Validity of documents and resubmittal

Changes to or reissuance of documents can pose substantial problems, although less so than late hardware changes. Utility project management should exercise approval rights on main contractor or architect-engineer documentation, drawings, specifications, analysis reports, QA plans, etc., even if the utility has delegated most of document control to other project partners under contract. Spot checks can be very useful for keeping people up to date and preventing unnecessary changes. In general, project documents should be produced according to schedule requirements. There should be sufficient schedule contingency to allow for approval and the incorporation of the latest inputs and requirements, particularly those of the regulatory authority. The documents should then ideally stay unchanged, at least throughout the execution of the project. Where drawings or procedures have been approved on a previous contract and the identical documents apply to the present contract, the partner issuing the document should certify that to be the case. The certification, together with the previous approvals, should eliminate the need for approval on the present contract and reduce the manpower and cost requirements. The same applies to licensing documents such as standard safety analysis reports and their approval and resubmittal. Many licensing authorities are willing to grant a period of grace for the validity of their review and certification of between one and three years, a period for which state of the art changes might be considered minor. This gives project management a chance to obtain such commitments from the regulatory authority and use them in resubmittals, sometimes in conjunction with the management of a subsequent or parallel project.

Benefits from reuse or resubmittal of licensing, engineering and/or manufacturing documents would normally already be a subject of contract negotiations, project costing, scheduling and budget. If such benefits are discovered and/or organized later on, they might be used for schedule or cost reductions or for balancing out other unavoidable increases. All partners should therefore be aware of these opportunities in their own interest and that of good project management.

3.5.3.3. Document control system

While all project partners, in particular the utility (as the ultimate holder of most project documents), must be involved in document approval and storage and retrieval, document production control applies mainly to those project partners which have major engineering responsibility. A project document control system is one part of the overall management function of controlling engineering and manufacturing, and it must adhere to the same set of fundamental principles. Basically, the document control system must be up to date and leaktight (i.e. it must be complete and not allow unlisted documents), and must focus on deviations from plan rather than the mistakes of individuals. In general, a successful document control system will include the following major features:

— Identification. The documents to be produced must be identified at the outset, with the identification including, as a minimum, the type of document to be produced, the document title, the document identification number taken from the overall project identification system (work breakdown structure and task orders), and the organizational unit and/or person responsible for its production.
— Scheduling. The production of each document must be scheduled for the key steps such as start of draft, input from other groups, completion of first draft, review by other groups, final editing, internal approvals, regulatory approval, printing and issue. The project manager and the task engineer and/or the section head must select a manageable number of key steps for the schedule and for the monitoring of progress.
— Lists and schedules. The key dates of the production of documents will be included in the integrated project schedule. It is important that the data be made available in the most easily usable format for the responsible section and individuals. Usually this is in the form of (computer produced) lists of documents, indicating the responsibility and the key dates to be met for each document.
— Reports. Status reports on document production are usually compiled by computer and form part of the overall schedule updating procedure, but can be a separate or collateral effort and may be carried out more frequently than the updating if desired. Reports will go to the engineering sections involved,

to project management and to the licensing and quality assurance departments. A reporting system must accomplish three things:

(1) It must provide quick turnaround of the information so that the information is up to date and so that corrective action can be taken before any problems become serious.
(2) It must clearly identify deviations from the project plan so that management attention can be given to the problems rather than to those documents which are on schedule.
(3) It must get the information to the proper individuals so that they can take appropriate corrective action to get the document back on schedule or minimize the deviation. It must also alert the appropriate section head and project management assistant so that they can take whatever other corrective actions may be necessary to minimize the impact on the overall project.

3.5.4. Reports

3.5.4.1. Regular progress

Progress reports by the project managers of all partners will be addressed to their senior management and must inform on the technical, manufacturing and financial status of the project and compare the performance in each of these respects with the scheduled targets. These reports will be issued at regular intervals, typically monthly, and presentations by the project manager may sometimes be combined with the more frequent project meetings. Discussion of the facts presented might lead to decisions ranging beyond simple questions of progress. It is important that a differentiation is made between factual information and data relevant to the current condition of the project and predictions, trends or proposed changes in contract policy or reorganization. Resolutions and decisions must be clearly marked and followed up by specific project orders (such as change orders). Because of its detailed and sometimes strategic nature, the information will most likely not be suitable for distribution outside the company, and should normally be regarded as proprietory material.

The submission of formal progress reports by contractors to the utility could be a contractual condition. They can quite obviously be compiled from relevant portions of the internal reports and supplemented where needed. Utility project management's own internal progress reports can be to some extent edited versions of reports from project partners.

In editing reports for use outside the particular project partner organization, possibly to remove proprietory information, project managers should pay attention to clarity and truthfulness. It is always important to keep the other partners, particularly the utility, informed of the true progress position, especially when slippages have occurred which cannot possibly be contained within the available schedule contingency. Any attempt to put off the truth by placating upper management or the utility with unfounded optimistic forecasts must lead to unwelcome repercussions later.

3.5.4.2. Exception reports

There is another type of management report in addition to the detailed progress reports just described. These are the reports of exceptions, i.e. they deal with those project factors which give rise to acute concern and which must receive immediate attention if the project is to be held on course. Exception reports can range from selective computer printouts to oral intervention at the executive level by a departmental manager or project manager. Such reports can also form a separate, easily recognizable portion of the regular monthly progress report. Before the project manager allows any communication about an exception to be passed on to senior management, he must always assure himself that no remedy within his own control can be found. Once he has established that events are beyond his control, however, the project manager has a very clear duty to appraise senior management and other project partners affected of the facts without delay. This helps to ensure that executive effort is employed to the best advantage.

3.5.5. Preparing operations

3.5.5.1. Training of operating personnel

One main responsibility of the utility is the training of operating personnel.

This responsibility may be shared with other partners involved in the project and in such a case the assignment of tasks is already established in the contractual arrangements.

The utility project management should provide the personnel to be trained well in advance (3 to 4 years before the start of operation) and in accordance with contractual obligations regarding qualifications; this entails selection and recruitment. The future plant superintendent, who should be designated as early as possible, will play an important role in these early activities in co-operation with the project management.

Depending on the utility's capabilities, it may take part in the training implementation or it may delegate all these activities to the main contractor or the architect-engineer. However, in both cases, the utility project management should ensure that the training is appropriate and follows the plans and schedules.

The personnel under training should participate in the commissioning of the plant and be involved in the preparation of the manuals and procedures for operation and maintenance, which should be drafted during this period.

Further information can be found in the guidebook on Qualifications of Nuclear Power Plant Operations Personnel (IAEA Technical Reports Series No. 242), in which the subject of training is covered in detail.

3.5.5.2. Outage management

Outage management is the planning and execution of all work which must be performed on a completed plant during those periods when the plant is shut down for maintenance, repair, modification or refuelling. This subject may seem to be more appropriate to a guidebook on nuclear power plant operation. However, operating experience with existing plants has demonstrated the need to consider outage management as early as possible in the project. Outage management relates to project management in three principal areas:

— Designing for improved future outage management — a task often overlooked in plant engineering and possibly a contractual item
— Actual outage management, as management of a small project
— Fuel supply projects.

The problem of outage management is seldom considered in sufficient depth by either the utility or its contractors at the proposal or early design stages. Plant designs have rarely given sufficient attention to component accessibility for maintenance, lay-down areas, rigging facilities, locker and change room facilities or design aspects that limit radiation exposure to maintenance personnel. Nevertheless, design features necessary for good maintainability and rapid refuelling should already be incorporated into early planning, bid specifications and proposals. Maintainability of the plant should be integrated into the initial design and monitored closely during final design and plant construction.

In general, a service organization is used to assist the operating utility in maintenance, spare parts administration, implementation of backfittings for safety or reliability improvements, special operations such as refuelling, steam generator tube plugging, steam generator sludge lancing, in-service inspection, etc. All these activities normally start after plant commissioning, and may be handled and co-ordinated by a special service unit within the utility organization centrally located at utility headquarters or wholly or in part attached to the plant operating staff. Depending on the magnitude of the work, the service unit manager may become or may specially appoint a project manager for the particular job at hand.

It is usual for NSSS suppliers, architect–engineers and other contractors to offer utilities various services for operating plants. This question is normally handled by a different organizational unit (or profit centre) on the contractor side — who may or may not have been a partner during construction of the project — and is established in different contracts and controlled by separate project management. The project management organization will depend on the magnitude of these jobs, but will be very similar to that of the main contractor or the subcontractor for a construction project. The bidding process and the selection of competent contractors and subcontractors, the overall co-ordination by project management and the quality assurance programme are also similar, while scheduling requirements are generally even tighter.

There is one major connection between outage project management and plant construction project management, within the same contractor or via the utility; that is plant information. The outage project manager should have at his disposal complete files categorized by systems and/or components, with final construction drawings, field change notices, as-built drawings, specifications, instruction books and manuals for all equipment, equipment alignment data, instrument calibration data, control set points, etc. These files should, in general, contain all the information necessary to define the condition of the plant at the time the outage begins.

Project management for services during an outage requires a sharper understanding of the importance of time and priorities than that for plant construction. The project manager for the construction of a new nuclear plant begins his work towards a goal that is many years away, while the project manager of a refuelling outage must complete his work in approximately sixty days. In co-ordinating thousands of tasks, the outage project manager is faced with many more sensitive decisions than his construction counterpart. An additional dimension of service work on an operating plant is the problem of the radiation environment. Although radiation protection specialists may do most of the relevant planning, this aspect becomes an important and integral part of project management for outages.

To obtain good performance during an outage, integrated management and co-ordination of all the work, which may involve many contractors, are essential. If the utility does not provide this lead itself, a main contractor should perform the function. This could be an NSSS supplier or a special service company, with experience from other plants, providing a lead project manager for the job and numerous software and computerized planning tools to facilitate the work. A split package approach to this work with the lead co-ordination also under contract is a common practice.

Utilities have historically targeted nuclear plant availabilities in the range of 86 to 90%, which allows for a 30 day annual refuelling outage. Since most refuelling outages actually have longer average times, considerable attention is being given to ways of getting reductions. It is the outage project manager, through his ability to plan, organize and co-ordinate the complex evaluation, who is the key to shortening outage length. Reviews of outage experience have shown the following methods/tools to have a significant impact on reducing outage length:

— A dedicated outage project manager, responsible full time for the planning and scheduling of the next outage. This planning work may begin immediately after the end of the previous outage.

— Computerized scheduling, capable of rapid accommodation of changes and based on the allocation of time, personnel and spare parts.
— A well established regular maintenance management programme during operation based on task priorities and matched with the planning of major outages.
— A plant-follow programme based on feedback of operating experience aimed at improving maintenance and repair.
— A programme of personnel training including the use of full scale models to practise key operations and of video recording of complex maintenance operations.
— Detailed scheduling and assignment of tasks within a refuelling outage.
— An established communication chain, including possibly daily meetings during the outage.
— Hiring of highly specialized service contractors to perform special maintenance and inspection tasks.

Appendix I

SAMPLE OUTLINE OF PROJECT MANUAL[1]

I-1. General project manual

General

— Description of the participating organization
— Description of the Manual's purpose
— Compulsory nature of adherence stressed
— Validity and scope
— Reasons and general procedure for proposing and performing modifications to the Manual.

Particular functions

— Descriptions of the different functions being performed within the project; assignment of responsibility for development
— Planning (master plan, engineering, system supplier, planning, etc.)
— Correspondence
— Meetings
— Progress reports
— Issuance of reports, specifications and drawings
— Handling of manufacturers' documents
— Plant data and reference book
— Quality assurance.

Organization

— Structure of the project, indicating the functional, communications, contractual and co-ordination relations between the different organizations
— Organization of every main partner in the project
— Functions of the project manager of every partner. A suggested breakdown can be as follows:

(a) Scheduling
(b) Communication
(c) Co-ordination
(d) Licensing
(e) Quality assurance
(f) Implementation
(g) Control.

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[1] See also specific example attached to CARETTI, A., Adapted Project Manual of Empresarios Agrupados, Madrid (1982).

Procedures

Detailed description of the procedures to be followed for the following suggested activities:

Scheduling

(a) Description of the different programmes being used
(b) Responsibilities and content of the periodic schedule reports
(c) Distribution of programmes and reports.

Communications

(a) Correspondence
— Identification of correspondence
— Distribution of correspondence
— General instructions to be followed (i.e. language, addresses, mailing procedures, etc.)

(b) Meetings
— Procedures for calling a meeting
— Responsibilities for the preparation of minutes
— Identification of the minutes
— General content of minutes
— Distribution of minutes

(c) Telephone conversations
— Cases requiring written confirmation
— Distribution of written confirmation

(d) Project documents (project requirements, specifications, drawings, etc.)
— Definition of the types of document
— Identification of documents
— Required formalities for the approval of a document
— Issuance of documents
— Change procedures
— Symbol definition
— Language
— Distribution

(e) Manufacturing documents
— Conceptual description of documents
— Distribution of documents for comments and record of comments
— Responsibility for comments and the issuance of commented documents
— Criteria for comments and/or approval
— Handling of delays

— Standardized stamps
— Identification of documents

(f) Filing
— General file index
— General criteria for official files, dead files and duplicated files

(g) Quality assurance
— Applicable standards
— Procedures to be followed to comply with the applicable standards requirements referring to external interface

(h) Progress reports
— Inputs to be supplied by each organization
— Specific progress reports and minimum contents to be prepared by every organization
— Identification.

I-2. Specific project manual

This includes the following general information of an administrative nature useful to any staff of a company participating in the project (in particular, an architect–engineer or main contractor):

General information

— Brief technical description of the project
— Description of the organizations participating and their scope
— Project milestones

Project organization

— General company chart for the project
— When required, specific organization charts for other project partners involved
— Functions and responsibilities of the different positions within the project organization

Scope

— Detailed description of the scope of the company for the project
— Detailed description of the interface with other organizations participating in the project
— When applicable, a list of project documents to be issued, as agreed with the utility at the bidding and contracting phase. (Reference can be made to the proposal or the contract.)

Scheduling

— Master plan
— Requirements for detailed project scheduling

Quality assurance

— Company's quality assurance and design review responsibilities for the project
— Reference to the quality assurance programme for the project

Document distribution control

— Documents produced internally
— Documents produced externally

Filing

— Project file index
— Project filing information

Contract administration

— General information as required (e.g. time information code, invoices, subcontracting)
— Particular information of administrative nature as agreed with the utility in the contract.

Appendix II

MANPOWER FOR UTILITY PROJECT MANAGEMENT

TABLE II.1. MANPOWER FOR UTILITY PROJECT MANAGEMENT

Function/Task	Number (range)	Qualifications		
		Education	Experience	Specialized training
Project manager				
Responsibility for entire nuclear power project: engineering, design, licensing, purchasing, construction, installation, preoperational tests and startup. Co-ordination of all project activities to ensure meeting schedules, cost and quality requirements.	1	M.S. in engineering (nuclear, mechanical or electrical).	10–15 years in profession; at least 5 years in power plant project management. Experience in planning and operation of thermal power plants; demonstrated managerial ability.	Nuclear power technology (1 year); on-the-job training in nuclear power projects (6 months).
Deputy project manager				
Sharing of project manager's tasks and replacing him when necessary.	1	M.S. in engineering (nuclear, mechanical or electrical).	8–10 years in profession; at least 2 years in power plant design and management, fossil fired thermal or preferably nuclear.	Nuclear power technology (1 year); 6 months on-the-job training in nuclear power projects.
Legal adviser				
Project legal support.	1	Degree in law.	5–10 years in profession; at least 2 years in contract administration of major industrial projects, preferably power plants; previous involvement in contracting highly desirable.	Basic course on nuclear power; legal aspects of nuclear power.

Planning and scheduling				
Project planning and schedule control, including supervision of the engineering planning and cost control.	1	B.S. in engineering.	5–8 years in profession, at least 3 years in project planning and scheduling;	Basic course in nuclear power; scheduling techniques; on-the-job training in nuclear projects (6 months).
	3–5	B.S. in engineering.	3–5 years in profession, 2 years in planning and scheduling.	Basic course in nuclear power; scheduling techniques.
Engineering manager				
Management and supervision of project engineering group, plant design and technical specifications. Engineering review and approval. Promotion of national industrial participation.	1	M.S. in engineering (nuclear, mechanical or electrical).	8–10 years in profession; 4 years power plant design, preferably nuclear. Experience in power related industries in engineering and planning. Demonstrated managerial ability.	Nuclear power technology (1 year); on-the-job training (6 months).
ENGINEERING SUPERVISORS				
Responsible for supervision of relevant project engineering aspects.				
Nuclear engineering supervisor	1	B.S. in nuclear engineering or physics.	3–5 years in profession; at least 2 years in power plant design.	Nuclear power technology (1 year); on-the-job training (6 months) in nuclear power projects.

TABLE II.1. (cont.)

Function/Task	Number (range)	Qualifications		
		Education	Experience	Specialized training
Mechanical engineering supervisor	1	B.S. in mechanical engineering.	3–5 years in profession; 2 years in power plant design; experience in power related industries.	Basic course in nuclear power; 3–6 months on-the-job training.
Electrical engineering supervisor	1	B.S. in electrical engineering.	3–5 years in profession; 2 years in power plant design.	Basic course in nuclear power; 3–6 months on-the-job training.
Control and instrumentation supervisor	1	B.S. in engineering (electronics).	3–5 years in profession; 2–3 years in power plant design.	Nuclear power technology (1 year) oriented towards control and instrumentation; 6 months on-the-job training.
Civil engineering supervisor	1	B.S. in civil engineering.	3–5 years in profession; construction experience in large projects, preferably power plants.	Basic course in nuclear power.
Fuel management supervisor	1	B.S. in mechanical engineering or metallurgist.	5–8 years in profession; at least 1 year in nuclear fuel cycle activities.	Basic course in nuclear power; nuclear fuel cycle; QA/QC and NDE courses.
Site supervisor	1	B.S. in engineering, preferably civil.	3–5 years in profession; at least 2 years on construction and erection of major projects.	Basic course in nuclear power.

Engineering staff	15–20	B.S. in engineering (mechanical, electrical, electronics, civil or chemical); Metallurgist; Physicist.	2–3 years in profession, some experience in power plant design and engineering, preferably nuclear.	Basic course in nuclear power; specialized courses according to subject area.
Technician staff	5–7	Draftsmen.	2–3 years practical experience in power projects.	
Safety and licensing group				
Responsibility for ensuring safe design and licensability of the plant. Co-ordination of activities concerning the licensing procedures. Liaison with regulatory body. Responsibility for environmental studies and programmes.	1	M.S. in nuclear engineering or physics.	8–10 years in profession, at least 2–3 years in nuclear safety related work.	Basic course in nuclear power; courses in nuclear safety, health physics, regulatory and legal aspects; 6 months on-the-job training.
	3–5	B.S. in engineering (nuclear physics, chemistry).	3–5 years in profession; 1–2 years in nuclear safety, health physics, regulatory work or nuclear engineering.	Basic course in nuclear power; safety-oriented specialization courses; 3–6 months on-the-job training.
Quality assurance group				
Responsibility for introducing and co-ordinating QA and QC programmes in the design, engineering, procurement, construction, erection, testing and operation of the project.	1	M.S. in mechanical engineering.	8–10 years in profession; 3–5 years in QA/QC in position of senior responsibility.	Basic course in nuclear power; QA courses; 3–6 months on-the-job training in nuclear power project.

TABLE II.1. (cont.)

Function/Task	Number (range)	Qualifications		
		Education	Experience	Specialized training
Quality assurance group (cont.)	3–4	B.S. in engineering (mechanical, electrical or civil).	3–5 years in profession; 2 years in QA/QC work.	Basic course in nuclear power; QA courses; 3 months on-the-job training in power projects.
Training and personnel management				
Responsibility for developing, co-ordinating and supervising training programmes for all project personnel, in particular the O&M staff; responsibility for personnel management including recruitment.	1	M.S. in engineering.	10–15 years in profession; 3–5 years in power projects; 5–10 years in teaching, experience in nuclear power projects.	Nuclear power technology (1–2 years) including on-the-job training in nuclear power plant construction and operations; nuclear manpower development course.
	2–3	B.S. in engineering.	3–5 years in profession; experience in power plants and in training.	Basic course in nuclear power; courses on training and education, psychology, management.
Finance and commercial				
Responsibility for accounting, cost control, budgeting, finance and payments.	1	M.A. in economics or business administration.	10–15 years in profession; at least 5 years in senior responsibility position involving large projects, preferably power plants.	Basic course in nuclear power; nuclear power economics.

	3–5	B.A. in economics, business administration, B.S. in engineering.	3–5 years in profession; 1–2 years in major projects.	Basic course in nuclear power; cost control methodology.
	3–4	Accountants.	2–3 years in profession.	
Administration and public relations				
Responsible for administration support of project management, auxiliary services, filing, records management, public information and relations.	1	B.A. in business administration or equivalent.	8–10 years in profession, preferably involved in large industrial or power projects.	Basic course in nuclear power.
	1–2	B.S. in engineering.	3–5 years in profession, familiar with project work.	Basic course in nuclear power.
	1–2	B.A. in journalism.	2–3 years in public information and public relations.	Basic courses in nuclear power; safety and environmental aspects; public acceptance.
Total	48–63 8–11	Professionals Technicians		
	56–74			

Appendix III

MANPOWER FOR MAIN CONTRACTOR PROJECT MANAGEMENT

TABLE III.1. MANPOWER FOR MAIN CONTRACTOR PROJECT MANAGEMENT

Function/Task	Number (range)	Qualifications		
		Education	Experience	Specialized training
Project manager				
Overall responsibility for execution of the project; planning co-ordination, direction and control of all activities involved.	1	M.S. in engineering (mechanical, electrical or nuclear).	10–15 years in profession; 3–5 years in nuclear power projects. Demonstrated project management ability; background also in economics, legal aspects.	Course in nuclear technology (1–2 years).
Planning and scheduling				
Overall project planning scheduling and schedule control.	1	B.S. in engineering.	8–10 years in profession; 3–5 years in project scheduling; involved in large industrial projects, preferably power plants.	Basic course on nuclear power. Course on scheduling techniques.
Group supervisors				
Responsibility for overall co-ordination of the project management tasks assigned to their specific groups; maintaining contract and communication with other organizational units, reporting directly to the project manager. – Nuclear group	5–7	M.S. in engineering (nuclear, mechanical, electrical); B.A. in business administration.	8–10 years in profession; at least 3–5 years in power projects, preferably nuclear, experience in specific field of activity and interdisciplinary work.	Basic courses on nuclear power. Course in nuclear technology (1 year) and on-the-job training (6 months) for nuclear, control and instrumentation and licensing supervisors, specialized training in QA, safety and regulatory aspects etc. according to tasks.

– Conventional group – Electrical, control and instrumentation group – Licensing group – Commercial group				
ENGINEERING STAFF				
Nuclear group	3–4	B.S. in engineering (nuclear, mechanical, electronics).	5–8 years in profession; 3–5 years in project management or engineering of power plants, preferably nuclear.	Course in nuclear technology (1 year) and on-the-job training (3–6 months), QA, safety aspects.
Conventional group	7–9	B.S. in engineering (civil, mechanical, chemical).	5–8 years in profession; 3–5 years in thermal power plant projects.	Basic course in nuclear power; QA overview course.
Electrical and instrumentation and control group	4–5	B.S. in engineering (electrical, electronics).	5–8 years in profession; 3–5 years in power projects, preferably nuclear.	Basic course in nuclear power; QA, systems analysis, control and instrumentation courses.
Licensing group	4–6	B.S. in engineering, (nuclear, mechanical, civil, electrical).	5–8 years in profession; 3–5 years in power projects, at least 1–2 years in nuclear activity.	Course in nuclear technology (1 year); on-the-job training (3–6 months) in regulatory activity; safety analysis, health physics, systems analysis.
Commercial group	2–3	B.A. in business administration or economics; B.S. in engineering.	5–8 years in profession; 3–5 years in project management, commercial aspects.	Basic course in nuclear power; cost control methodology.
	3–4	Accountants.	3–5 years in industry undertakings.	
Total	27–36 3–4 30–40	Professionals Technicians		

Appendix IV

COMPUTERIZED TREATMENT OF PROJECT SCHEDULES

Incorrect use of computers can create unnecessary overheads, excess administrative work and a sense of demotivation. A computer cannot replace a project manager or good project management. This should be kept in mind when setting up computerized systems. On the other hand, nuclear power plants are so large and complex, with millions of parts, that computerization of schedules, material flow and document control — to name a few examples — can be of great help.

As with any tool, effective use of a computer requires a clear understanding of its purpose, its mode of operation, its strengths and limitations. The primary function of a computer system (a system consists of the computer or hardware and the instructions to the computer, the programs or software) is to receive, store, and process data in order to produce new data or information. The primary advantages of the computer are its speed, and the size and accuracy of its memory. It can manipulate large volumes of data quickly, and thus can handle large, repetitive and tedious tasks economically. However, the computer cannot think. It can only make decisions or control functions in accordance with rules or instructions predefined by the user; in essence, it can only be as clever as the instructions given to it.

Schedules are essential to the systematic execution of all but the very smallest projects. There are many computerized systems now available which can assist with scheduling and carry out tasks associated with estimating, accounting, material control, payroll, personnel and purchasing. If small computer systems do not have sufficient scheduling capability, suitable large systems can be remotely accessed from almost any geographical location.

Computers and codes with sufficient capacity to handle project network analysis and resource scheduling can be expensive cost items if not already available from other projects or administrative work. In addition to the hardware and the running costs, there are requirements for supporting staff and the provision of essential air conditioned accommodation. Quite obviously, not every organization can justify the installation of its own computer for project control work, even though the projects themselves may be very large. Fortunately, there are several ways in which a project manager can arrange for the hiring of effective computer facilities without having to commit his company to any capital expenditure.

Most real life scheduling problems evolve from the consideration of a number of conflicting factors. To solve problems with many variables, the accepted practice is to work in a logical sequence to eliminate one variable at a time. In scheduling, this is done in several specific steps, the first being to identify, name, time and interconnect reasonably independent and detailed activities.

Independence means that an activity can be pursued without interference from other tasks during its course; activities should be chosen in such a way that major

TABLE IV-1. SCHEDULING BY COMPUTER

Item	Program/Bureau capabilities
Skeletonization	— Can the computer program carry out any network summary techniques such as skeletonization or hammock activity reports? (These are techniques where reports are simplified by gathering and reporting data on one line for groups of activities which fall between key events specified by the planner)
Cost schedules	— Can the computer accept cost data for an activity? — Is it possible also to specify costs for resources? — What types of reports can be generated?
Resources	— Can the program carry out resource allocation? Check that claimed capability for resource allocation is not simply resource aggregation. What priority rules are available for allocation of resources from the common pool? — How many different types of resource can be specified? — How many units can be included within each resource type? — Must resources be rate-constant (continuous for an activity) or can complex patterns be specified? — What is the maximum number of resource type and resource units which can be specified for one activity?
Output	— Can the computer print out activity lists, bar charts, cost curves, resource usage tables, resource usage histograms? Can a network plotter be attached? Does the planner have the option to specify report page layouts? (See also the next item)
Editing and sorting	— What are the factors for determining editing and sorting? (Some programs are able to edit or sort according to departmental codes, preceding event numbers, succeeding event numbers, specified parts of activity descriptions, earliest or latest finish dates, float, scheduled start of finish dates, remaining float, key or milestone events, etc.)
Error detection	— How effective are the error search routines in the program? — Can loops be specified? Are the error reports easily understood by non-computer staff?
Bureau performance	— What is the expected turn-round time between presentation of input data and production of completed output reports? — Is the bureau staff familiar with the program to be used? — Is the bureau prepared to give the names of other users, who can give testimonials?

TABLE IV-1. (cont.)

Item	Program/Bureau capabilities
	— What are the expected bureau charges? Ask for quotations for providing processing and specified output reports from (a) Time analysis only for 100 activities (b) Resource allocation for 100 activities (c) Time analysis only for 1000 activities (d) Resource allocation for 1000 activities These results will help to formalize comparisons between different bureaux.
Bureau performance (continued)	— Are minimum usage rates demanded according to a rigid contract? (It is not much good finding a bureau which is charging only half as much as the competition if the contract is going to specify a minimum charge per annum that is too high) — Is the bureau willing to carry out a 'free sample' test run?
Type of network	— Capable of activity on arrow (CPM), or precedence, or both. (Remainder of this checklist relates to CPM networks)
Events	— Method of numbering — maximum number of characters allowed and whether alpha-numeric or numeric only — Maximum number of events possible in the computer file — Can events be classified as key events or milestones for separate reporting? If so, are different levels of reporting possible, and how many characters may be used for event descriptions?
Activities	— How many activities can the computer accommodate as a maximum? — Can activities be interrupted ('split') if required to assist in resource allocation? — How many characters may be used for each activity description? — How many punched cards are necessary per activity for data input? (if more than one, card punching costs may become excessive)
Target dates	— These are sometimes called scheduled dates or imposed dates. Can they be imposed as earliest or latest permissible dates on events? Or, can dates be imposed on the starts or finishes of individual activities? If these dates are used anywhere, how will the computer regard them in relation to dates obtained from time analysis? (There are programs which cause

TABLE IV-1. (cont.)

Item	Program/Bureau capabilities
	nonsense to be printed out when scheduled dates generate negative float)
Subprojects	— Can the computer accept more than one subproject at a time? If so, how does each subproject claim priority for common resources? Can event numbering for different subprojects be completely independent (so that if the same number happens to occur in different subprojects, nor error will result)? — How many subprojects can be accepted, and how many activities in each?
Data input	— How simple are the instructions for input? Can the bureau carry out card punching? Will the bureau accept responsibility for control cards? How easy is it to input instructions for updating schedules?

interfaces occur only at the beginning or the end. Interconnections are communications of data and information as input and output from or to other (usually several) activities.

The next step is to draw up a logic flow diagram of these activities in the form of an overall schedule network. Trial and error may be used to eliminate obvious errors and identify prohibitive interconnections, which may have to be put into a different work sequence to comply with contractual targets. Ultimately, a debugged schedule will become a working tool which can be routinely (e.g. every two weeks) updated, to indicate overall times for the project and critical paths of activities which need particular attention to prevent delays. Various printout options are usually available in the form of bar charts and listings of activities by due date, by starting date, by criticality, by department, etc.

When a computer is used to draw up a schedule, the following points deserve particular attention:

— Events have to be numbered, so that they can be uniquely identified in the computer.
— Activities in parallel should be avoided, i.e. those which would share exactly the same start and finish events. The computer may not be able to distinguish one from the other. The solution is to insert a dummy along one of the parallel paths.

When computerized programs and services are being hired, the check-list given in Table IV-I can prove very useful (CLELAND, D.I., KING, W.R., System Analysis and Project Management, McGraw Hill, New York (1983)).

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GLOSSARY

To facilitate the discussions and the understanding of the project management role in nuclear power the following explanations of important terms are provided:

Architect–engineer. Engineering firm with a very similar engineering scope to that of the main contractor and acting for the utility or the contractor under a contractual arrangement.

Change order. Formal authorization (on task order or special form) by project management of a well specified change, examined for all its consequences, to be introduced into the project.

Change request. Formal request by memorandum or standard form for an engineering, organizational or documentation change in a project; addressed to a designated recipient (usually a committee) for examination. The request produces no other action.

Integration. Combining diverse portions of an organization or of a product into a system with overall objectives or functions.

Main contractor. A contractor for the whole or a major portion of the plant with essentially fixed price and turnkey responsibility towards the utility and financial accountability internally.

Management information system. A comprehensive system of usually computerized data in an organization, including most or all of accounting, manpower, scheduling, etc., which can be sorted, analysed and used for forecasts of many different types; useful to project as well as line management.

Material flow information system. Information system tracing materials and equipment from the point of ordering through production, delivery and warehousing to installation, indicating location, quantity and status.

Matrix approach. Management approach in which project management fulfils its function by horizontal co-ordination of many different engineering and production functions, which report normally in a technically oriented line organization (vertical).

Partners. Organizational entities having contractual relationships in a nuclear power plant project.

Procurement. Project supporting activities (centralized function in most large organizations) relating to materials and equipment, including purchasing, transportation and warehousing.

Project. A complete nuclear power plant project, which in turn is a part of a national nuclear power programme.

Project assistant. Staff member in charge of a major system or major aspect of the project, reporting to the project manager in both a functional and disciplinary way, with responsibilities as described for the project manager.

Project engineer. A lead engineer for a large or smaller portion of the plant or discipline (such as project engineer structural) charged with engineering management, co-ordination and/or system integration; possibly performing some project management tasks (as described above) in close co-operation with the project manager or within an expanded project management team.

Project group. A group of project management assistants and other personnel (such as schedulers, where applicable), headed by the project manager, to whom they report in a disciplinary (line) relationship.

Project management. Technique for the efficient expenditure of resources to achieve a desired result. Project management defines the work to be done, estimates the resources that will be required to accomplish that work, controls the quality of the work and the expenditure of the resources, monitors the progress towards the final objectives, and makes corrections in all the foregoing as may be required to achieve the ultimate goal.

Project manager. The lead project function in any one of the contractually independent project partners, in charge of the planning, execution and control of the project in all technical, schedule and cost matters; also key representative of project in relation to partners and the public.

Project team. The overall formal or informal group of people which make up the entire staff (project management, engineering, production and support) working on a project and co-ordinated by project management.

Resident engineer. Local, knowledgeable representative of one project partner at the other project partner's offices or at the site, representing essentially project management there and communicating up to date information in both directions.

Site manager. Production oriented (executing) manager on the power plant site, usually reporting to engineering or general management and taking project directives from project management.

Subcontractor. System or equipment supplier, or construction firm, in charge of manufacturing and/or erection of small or larger portions of the plant, under contract to the utility directly or to a main contractor.

Task engineer. Engineer in charge (and signatory) of a work package or task (via a task order) in the project, representing an intersection in the organizational management matrix. Unlike the project engineer the task engineer would normally not carry out project co-ordination tasks.

Task order. Formal authorization on a special form of a well defined project task, also called a work package, requiring authorizing signature by project management and consenting and accepting signature by the affected engineering section. The task order also contains schedule and budgetary information.

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