CONSIDERATIONS AND MILESTONES INFRASTRUCTURE FOR A RESEARCH REACTOR PROJECT

A.M. SHOKR, H. ABOU YEHIA
Department of Nuclear Safety and Security,
International Atomic Energy Agency (IAEA),
Vienna,
Austria

P. ADELFANG, K. ALLDRED
Department of Nuclear Energy,
International Atomic Energy Agency,
Vienna,
Austria

D. RIDIKAS
Department of Nuclear Science and Applications,
International Atomic Energy Agency,
Vienna,
Austria

Abstract

Establishment of a research reactor is a major project requiring careful planning, preparation, implementation, and investment in time and human resources. The implementation of such a project requires establishment of sustainable infrastructures, including legal and regulatory, safety, technical, and economic. This paper discusses the scope of these infrastructures and the major stages in their development; starting with a robust pre-project justification for the research reactor and moving through three milestones in the establishment of the infrastructure itself. The paper discusses also the main elements of the feasibility study for a new research reactor project and specific safety and technical considerations in different phases of the project as well as the major activities to be performed along with the project phases, including progressive involvement of the main organizations in the project, and application of the IAEA Code of Conduct on the Safety of Research Reactors and IAEA Safety Standards.

1. INTRODUCTION

For more than 60 years, research reactors (RRs) have been a corner stone in the development and application of nuclear science and technology. The multi-disciplinary research that RRs can support has led to the development of numerous capacities in a wide variety of areas including nuclear power, radioisotope production for medical and industrial applications, neutron beam research, material development, and personnel training. In addition, recently a number of countries have started planning to build their first RR as a tool to develop the necessary national infrastructure in the view of embarking on a nuclear power programme.

Establishing a first RR in a country requires establishment of national sustainable infrastructures which cover a wide range of areas. These infrastructures are not a minor undertaking and their cost may exceed the cost of the reactor itself. They cover legal and regulatory framework, siting, transport of equipment and supplies to the site, facilities for fuel handling and radioactive waste management, emergency preparedness, and facilities associated with the reactor applications as well as the human and financial resources necessary to implement the project and to ensure sustainable safe, secure, and efficient operation. The IAEA therefore recommends adaption of a systematic approach for decision making for the RR project, and for establishment of the supporting infrastructures in phases that are matched to the needs of the project. The main characteristics of these phases are discussed in the following sections together with the elements of the technical and safety infrastructures, and major activities that should be completed in different phases of a new RR project.

2. RESEARCH REACTOR PROJECT PHASES

The milestones (step-wise) approach for developing a national nuclear power programme is provided by the IAEA publication NG-G-3.1 [1]. A similar approach (Fig. 1) was developed for establishing the technical and safety infrastructures for new RR projects, tacking into considerations the differences between RRs and nuclear power reactors [2]. This approach cover the period from the point of initial consideration for establishing a new RR to the point at which a country is ready to commission and operate the RR. According to the IAEA Code of Conduct on the Safety of Research Reactors, it should be also noted that the development of technical and safety infrastructures should continue throughout the RR operation and utilization, and decommissioning phases [3]. Infrastructure development during operation, utilization and commissioning phases are not discussed in this paper.

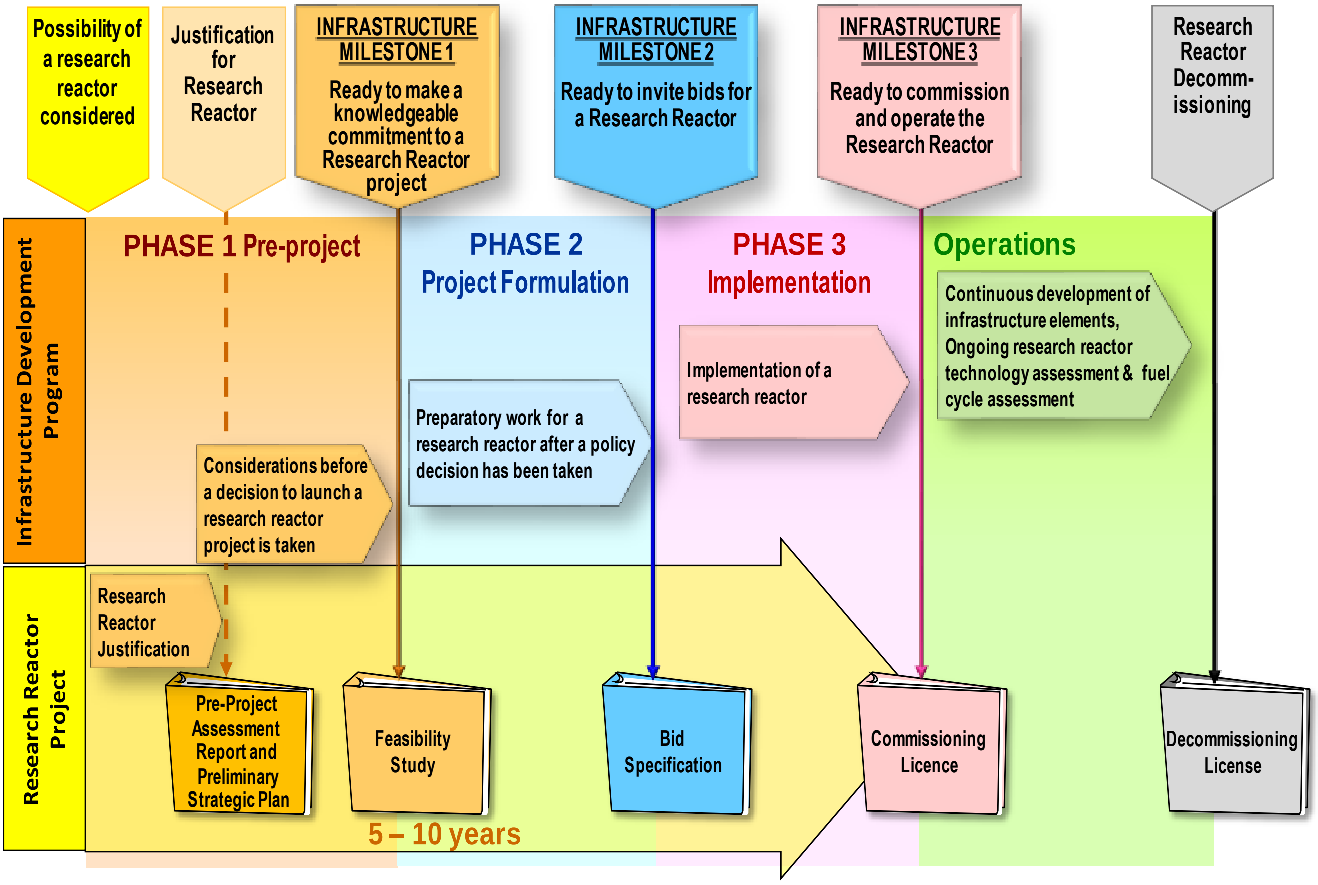

FIG.1. Phases of implementation of the first RR project.

Phase 1 is related to the pre-project activities which cover all considerations before a decision to lunch a RR programme is taken. These considerations are consolidated in a form of a feasibility study showing the needs (or not) for a RR. Such a study is the main deliverable of this phase and based on its results, a country should be ready to make a knowledgeable commitment to proceed (or not) with the new RR project (Milestone 1). The activities of Phase 2 cover the preparatory work for the reactor construction, including the establishment of the legal framework, regulatory body, and operating organization which should be able to select the preferred site for the reactor, develop the bid technical specifications, and be ready at the end of this phase to invite bids (Milestone 2). During Phase 3 the activities for implementing the RR project should be completed, including finalization of the design and construction stages with the relevant licensing activities. By the end of Phase 3 the RR should be ready for commissioning (Milestone 3).

Experience has shown that the duration of implementing the activities corresponding to these three phases may be up to approximately ten years, depending upon the existing infrastructure at the beginning of the project and resources available for the project. The duration also depends on the reactor type, size, intended utilization programme, and contract methodology (i.e. turn-key or contracts with different levels of national participation), and may be reduced significantly in the case of low power RRs dedicated to education and training. Similarly, a graded approach may be used in the implementation of the activities of different phases. While all the safety requirements associated with these activities should be considered, their application may be graded based on the potential hazard of the reactor.

3. ISSUES OF THE INFRASTRUCTURE MILESTONES

Reference [2] defines the “infrastructure milestone” as the set of conditions that demonstrates that the preceding phase of a new RR project has been successfully completed. For each milestone, there are nineteen “milestone issues” that need to be considered (as indicated in Table 1). Although nuclear safety is considered as one of the "milestone issues", it should be noted that most of these issues have also safety components and security considerations. As it can be seen in TABLE I the “milestone issues” are organized differently from the twenty elements for safety infrastructure which are established by the INSAG-22 publication [4] in accordance with the structure of the IAEA Safety Standards. Table 1 provides the cross reference between the “milestone issues” and the IAEA Safety Standards. In addition, the INSAG-22 elements transport safety and interface between safety and security are not separately identified within the “milestone issues”, but the associated conditions are addressed within several milestone issues as indicated in TABLE I.

The provisions of the Code of Conduct on the Safety of Research Reactors should be integrated into the programme from the early beginning by making full use of the IAEA Safety Standards [5-14]. The organizations responsible for establishing the required infrastructure through progressive application of the IAEA Safety Standards are the government, regulatory body, and operating organization. The level of involvement of these organizations normally increases during the phases of developing a RR project. While all the activities of Phase 1 are performed by the government, the operating organization and regulatory body (being established at the beginning of Phase 2) are responsible to implement the activities corresponding to this phase. Involvement of these organizations will increase gradually along Phase 2. However, the level of involvement of the regulatory body will be relatively higher due to its responsibility for establishing the safety requirements for different activities beforehand. The involvement of the operating organization, which has the prime responsibility on safety, will increase along Phase 3. The involvement of the government will be reduced significantly during Phases 2 and 3, and will include mainly support of maintenance and improvement of some infrastructure elements such as national policy and strategy, global nuclear safety regime, legal and regulatory framework, funding and financing, safety management, emergency preparedness and radioactive waste management including decommissioning.

4. SPECIFIC CONSIDERATIONS IN DIFFERENT PHASES OF A NEW RESEARCH REACTOR PROJECT

The major activities in the different phases of a new RR project are presented in FIG. 2, with indication of the required level of application of the IAEA Safety Standards (i.e. Awareness of the requirements, requirements under implementation, and requirements fully implemented). Detailed discussions of these activities are presented in the following sections.

TABLE 1: MILESTONE ISSUES AND THE MAIN SUPPORTING IAEA SAFETY STANDARDS WITH THE RELEVANT ELEMENTS OF THE SAFETY INFRASTRUCTURE AS DEFINED BY THE INSAG-22 REPORT

Milestone issues	**Main supporting current IAEA Safety Standards**	**Relevant Safety Standards according to the IAEA long-term structure**	**Relevant safety infrastructure elements as defined by INSAG-22**
National position	GSR-Part 1	GSR-Part 1	National policy and strategy; Global Nuclear Safety Regime
Nuclear Safety	NS-R-4, GSR-Part 4, TS-R-1	SSR 3	Global Nuclear Safety Regime; Safety Assessment; Design Safety; Preparation for Commissioning; Transport Safety
Management	GS-R-3, NS-R-4	GSR-Part 2, SSR 3	Leadership and Management of Safety; Transparency and Openness; External Support Organizations and Contractors
Funding and Financing	GSR-Part 1, NS-R-4	GSR-Part 1	Funding and Financing
Legislative Framework	GSR-Part 1, NS-R-4, TS-R-1	GSR-Part 1, SSR 3	Legal Framework
Regulatory Framework	GSR-Part 1, NS-R-4, TS-R-1	GSR-Part 1, SSR 3	Regulatory Framework
Safeguards	Not covered by Safety Standards		
Radiation Protection	NS-R-4	GSR-Part 3	Radiation Protection
Application, Utilization and Facilities	NS-R-4	SSR 3	Not Applicable
Human Resources Development	NS-R-4	SSR-3	Human Resources Development
Stakeholder Involvement	GS-R-3	GSR-Part 2	Leadership and Management of Safety; Transparency and Openness
Site Survey, Site Selection and Evaluation	NS-R-3, NS-R-4	SSR-1	Site Survey, Site Selection and Evaluation
Environmental Protection	GSR-Part5	SSR-3, GSR-Part 5	Radiation Protection; Safety of radioactive waste, spent fuel management and decommissioning; Transport Safety
Emergency Preparedness and Response	GS-R-2	SSR-3, GSR-Part 7	Emergency Preparedness and Response
Nuclear Security	NS-R-4	SSR-3	Interfaces with Nuclear Security
Nuclear Fuel Management	NS-R-4, TS-R-1	SSR-3, SSR-5	Safety of radioactive waste, spent fuel management and decommissioning;
Radioactive Waste	NS-R-4, WS-R-2	SSR-3, SSR-5, GSR-Part 5	Safety of radioactive waste, spent fuel management and decommissioning;
Industrial Involvement	GSR-Part1	GRS-Part 1	External Support Organizations and Contractors
Procurement	GS-R-3, NS-R-4	GSR-Part 2, SSR 3	Funding and Financing; External Support Organizations and Contractors

GSR: Generic Safety Requirements; SSR: Specific Safety Requirements

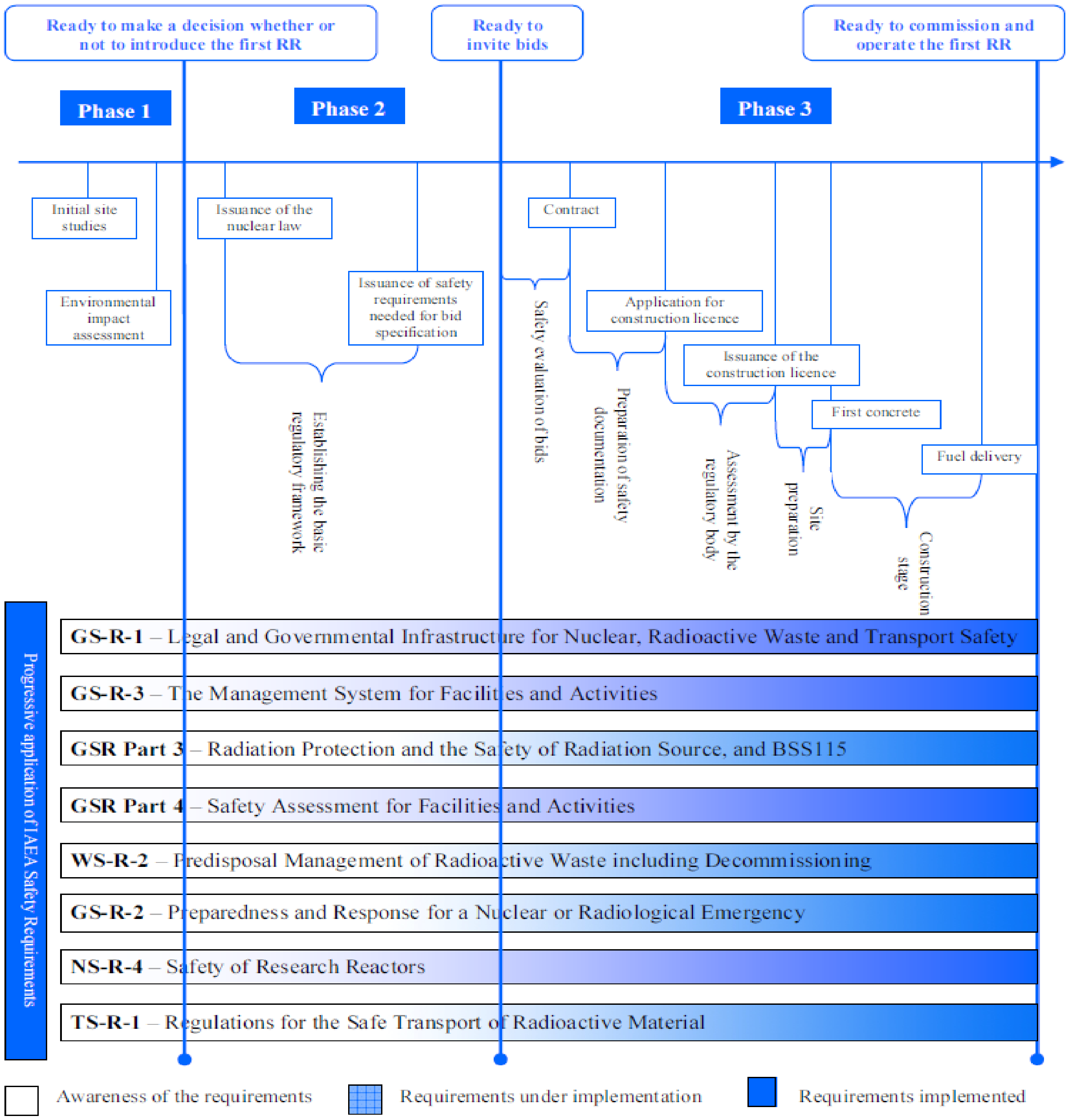

FIG. 2. Major activities in different phases of a RR project and illustration of progressive application of the IAEA Safety Standards.

4.1. Specific considerations in Phase 1

Experience has shown that a robust utilization plan was not always a part of the decision making process for determining whether a RR should be built, or should continue to operate, in a long-term run. It is therefore essential at the initial stage to perform a feasibility study justifying the need for a RR in accordance with Principle 4 (Justification of Facilities and Activities) of the Fundamental Safety Principles [5]. It is also necessary to have a clear definition of the reactor purpose, utilization, and users as well as pre-selection of the reactor type and size including experimental facilities. The feasibility study should consider the advantages and disadvantages of utilizing alternative technologies (e.g. spallation neutron source and cyclotrons), and possible use of the RRs existing in the region.

The feasibility study should also address the government commitment to adhere to the international obligations and to apply the provisions of the IAEA Code of Conduct on the Safety of Research Reactors, including the need to:

- Consider various safety principles that are applied to the development of the RR;
- Establish an effective legal and regulatory framework for safety, including an independent regulatory body, and an operating organization with prime responsibility on safety;
- Establish a sustainable financing system for all activities related to safety for operating organization and regulatory body;
- Establish an effective management system and provide for a strong leadership capabilities and foster safety culture within the involved organizations;
- Provide for adequate arrangements for building the technical competence of the involved organizations;
- Develop and implement a national strategy for long-term radioactive waste and spent fuel management and decommissioning of the facility;
- Provide for adequate arrangements for emergency preparedness and response.

In addition, an initial site survey should be an essential part of the feasibility study. The initial site survey includes identification of potential and preferred candidate site(s) according to established criteria and on the basis of the existing data. Identification of the preferred candidate site(s) should be supported by a radiological impact assessment, which should also be a part of the feasibility study.

4.2. Specific considerations in Phase 2

Once the decision to build the RR has been made, the activities to establish the necessary technical and safety infrastructures should proceed during Phases 2 and 3. The highest priority is given to enacting the essential elements of the legal framework including establishment of an effective and independent regulatory body and the operating organization. During this phase the regulatory body should establish a licensing process for the RR. Establishment of a suitable working relationship between the regulatory body and operating organization, and early involvement of the regulatory body in the process, including specification of the safety requirements needed for the bidding process, are essential for successful implementation of the project.

The decisions that need to be made by the operating organization typically include the type, size, and safety features of the RR to be built as well as the associated experimental facilities. The operating organization should also proceed with the reactor site evaluation and selection. The site parameters which are needed for the reactor design and operation should be identified and included in the technical specifications of the bid. Attention should be given to the availability of expertise in site selection, bidding, and evaluation of the technical offers from different vendors.

Development of human resources is a high priority task in this phase. The regulatory body should start developing the competences needed for establishing regulations and performing regulatory review, licensing and inspection. It is also essential that the operating organization starts developing the required knowledge and skills through specialized training. These include project management, performance of safety assessment, reactor commissioning, operation, maintenance, and utilization. In addition to these topics, specialized training is also needed in reactor physics, thermal-hydraulic, radiation protection, core management and fuel handling, quality assurance, and safety culture. Such training requirements could be obtained from the reactor vendor in accordance with the requirements of the bid.

4.3. Specific considerations in Phase 3

This phase consists of intensive activities to build the RR. One of the first activities in this phase is the technical evaluation of the bids. In this regard, the operating organization should ensure adequate safety review of the design proposed by the vendors in the submitted bids. Adherence of the design to the IAEA Safety Standards should be one of the criteria established for the selection of the winning bid. The project execution schedule should include hold points for regulatory review and verification that the activities of safety significance are properly implemented.

This phase requires significant development and training for all levels of staff. Recruitment of the operation and maintenance personnel should begin early in this phase. The participation of reactor staff in different activities of this phase including design review, construction activities, and development of operating documents will have a positive impact on safety and effective utilization of the reactor. It will also help development of a safety culture and acceptance of the responsibilities for the transferred systems at the end of Phase 3. It is beneficial to include in the project organization chart a group (or individual) responsible for human resources development, whose duties will include establishing links with the vendor to ensure knowledge transfer to the operating organization and adequate training of the reactor staff.

Preparation of the Safety Analysis Report (SAR) should start as early as possible in the design stage. The operating organization should ensure proper interaction with the reactor designer in the preparation of the safety documents. The SAR, including a comprehensive safety assessment, Operational Limits and Conditions (OLCs) and specification of the codes and standards which provide acceptable reference for design and construction, is the main safety document for the licensing process. The regulatory body, prior to issuing the construction license, should assess the SAR and verify that the relevant safety requirements can be met.

During the construction stage, the operating organization should ensure adequate involvement in the construction process to ensure that the safety systems and components are constructed according to the approved design. A process should be in place, in accordance with the management system, to address changes in the design during the construction, and maintain the knowledge on the design and construction during the lifetime of the reactor. These items should also be verified by the regulatory body.

In addition to the commissioning programme, the management programmes for operation should be developed during this phase. These include the operating procedures, maintenance, periodic testing, and inspection programmes. The operational radiation protection programme and the emergency plan should be fully implemented at the time the nuclear fuel is received at the reactor building. The corresponding chapters of the SAR should be prepared by the operating organziation and assessed by the regulatory body during preparation for commissioning.

5. CONCLUSIONS

The decision to build a RR should be based on a study showing the feasibility of the reactor. The study should evaluate the real needs, utilization programme, and availability of a suitable site. It should also show the commitment to establish the necessary safety and technical infrastructures. Establishment of such infrastructures should start early in the process and should be achieved progressively during the different phases of the project through effective application of the IAEA Code of Conduct on the Safety of Research Reactors and the supporting IAEA Safety Standards. To be ready to invite bids for a RR, the commitments required at all stages of the project should be fully understood and mechanisms to meet those commitments should be developed. The plans and funding mechanisms for operation, regulation, decommissioning, spent fuel and waste management, should be in place before a RR bid request is issued. Through the lifetime of the RR, periodic safety reviews aiming at ensuring high level of safety should be performed to deal with cumulative effects of reactor ageing, modifications, changes in utilization programme or installation of new experimental devices, operating experience feedback, and changes in safety requirements, as well as site-related aspects.

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