NUREG/CR-3959
PNL-5769

Transition to an Operating Reactor Environment -- Implications for NRC Quality Assurance Programs Based on Nuclear Power Industry and Regulatory Projections Through 1995

Prepared by J. A. Christensen, C. R. Schuller, H. Harty, M. G. Patrick

Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory Commission

NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W.
   Washington, DC 20555
2. The Superintendent of Documents, U.S. Government Printing Office, Post Office Box 37082, Washington, DC 20013-7082
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

NUREG/CR-3959
PNL-5769

Transition to an Operating Reactor Environment -- Implications for NRC Quality Assurance Programs Based on Nuclear Power Industry and Regulatory Projections Through 1995

Manuscript Completed: March 1986
Date Published: March 1986

Prepared by
J. A. Christensen, C. R. Schuller, H. Harty, M. G. Patrick

Pacific Northwest Laboratory
Richland, WA 99352

Prepared for
Division of Quality Assurance, Vendor, and Technical Training Center Programs
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN P2003

ABSTRACT

This report develops projections for nuclear power plant regulatory needs in general, and those relating to quality assurance in particular, for the time period 1985 to 1995. This required an assessment of future prospects for the nuclear power industry and its primary segments. Electric power demand projections and their relationship to estimated schedules for nuclear plant construction and operations were evaluated, and estimates of anticipated business volume and long term economic viability were made for each of the major segments of the U.S. nuclear industry (utilities, NSSS vendors, AEs, constructors, component suppliers, and service vendors). These estimates were made for two, five and ten year intervals through 1995. Other significant factors that are not specific to any one industry segment were also reviewed. These included: 1) the expanding foreign presence in U.S. markets; 2) pending legislations; 3) trends in personnel availability; 4) new institutional arrangements for nuclear power generation; 5) nuclear plant aging, life extension, and decommissioning; 6) reactivation of mothballed projects; 7) advanced and standardized plant designs; and 8) likely technological development in computer applications and inspection methods. The trends revealed by these analyses imply a number of significant challenges for nuclear power regulation in the U.S. Many projected changes have implications for NRC QA policies and practices. These issues were divided into functional elements, each of which was analyzed in terms of its significance and kinetics of emergence for each of the overall industry projections. Finally, NRC options for dealing with each QA-related issue were assessed.

CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

Credit is due B. K. Grimes and G. T. Ankrum, USNRC, for their extensive and perceptive critiques of earlier drafts of this report. The contributions of W. B. Menczer, USNRC Project Manager in guiding the project and reviewing work products have been particularly helpful.

INTRODUCTION

Over the next ten years, the character of the commercial nuclear power industry will change dramatically. Construction projects currently under way will be complete around the turn of the decade after which the power generating segment of the industry will enter an "all-operating-plant" phase which is expected to persist until at least 1995. This transition has major implications for all segments of the nuclear industry and for the NRC. As the plants presently being built are completed, the NRC will have progressively less regulatory concern with large, complex construction activities and relatively more involvement with plant operations, maintenance, life extension, foreign imports, etc. The nature of the NRC quality assurance (QA) program is expected to evolve to conform to the changing mix of safety issues which the industry transition will bring. The purpose of this study is to anticipate these changes and to guide the NRC in developing QA policies and programs which will effectively deal with them.

To arrive at specific conclusions and recommendations pertinent to evolving NRC QA policies, it was necessary to begin with a global assessment of nuclear power and its overall prospects. Capacity demand projections and their relationship to best estimate schedules for nuclear plant construction and operations were evaluated. In addition to nominal power-time projections for plants currently in operation or under construction, most credible upper and lower bounds for nuclear generating capacity over the next decade were developed. More detailed estimates were made for the effects of each of the three projections on anticipated business volume and long term economic viability for each of the major segments of the U.S. nuclear industry (utilities, NSSS vendors, architect engineers/constructors, component suppliers, and service vendors). These estimates were made for two, five, and ten year intervals (1987, 1990, and 1995).

Other factors that are not specific to any one industry segment but which will significantly affect overall industry and regulatory futures were also reviewed. These included: 1) the expanding foreign presence in U.S. markets; 2) pending legislation; 3) trends in qualified personnel availability; 4) possible new institutional arrangements for nuclear power generation; 5) nuclear plant aging, life extension, and decommissioning; 6) reactivation of mothballed construction projects; 7) advanced and standardized plant designs; and 8) likely technological developments in computer applications and inspection methods.

The trends revealed by analyzing the above factors imply a number of significant, new and emerging challenges to nuclear power regulation in the U.S. Many of these projected problems have implications for NRC QA policies and practices. These issues were broken into tractable, functional elements each of which was analyzed in terms of its significance and kinetics of emergence for each of the overall industry projections. Finally, an assessment of NRC options for dealing with each QA-related issue was performed. Chapter 4, (particularly Tables 10, 11, and 12) forms a possible planning basis for NRC QA activities for the next ten years.

Limited resources did not permit original research to establish industry trends. This was not a handicap since several, well founded, detailed studies of nuclear industry future prospects have been performed by others. The approach taken was to review and integrate results of other studies and to extrapolate these to the capacity and time bounds selected for this study. The resulting, composite perspective of the nuclear industry, while not detailed, was adequate for displaying the likely new quality-related regulatory issues to be confronted over the next ten years.

CONCLUSIONS AND RECOMMENDATIONS

Over the next decade all new construction of nuclear power plants currently in progress in the U.S. should be completed. By the mid-1990s nominally 120 plants will be operational, except for a few possibly restarted projects none are expected to be under construction, and it is reasonably likely that no new orders will have been placed and none foreseen. These trends will have major effects upon what has been the traditional nuclear industry and the regulatory climate in which it exists.

INDUSTRY TRENDS

The nuclear industry, although a somewhat diffuse collection of many companies and company divisions of all sizes, can be characterized as consisting of five major segments. These are 1) the utilities; 2) steam supply system vendors; 3) architects-engineers and constructors; 4) component suppliers; and 5) service vendors. Each of these segments will respond differently to anticipated trends in nuclear generating capacity and future demand over the next ten years.

The Utilities

The situation for most utilities should not change markedly over the next two years. Pressures from state regulatory bodies for higher capacity factors and less latitude in recovery of construction costs are likely to increase. Any serious, off-normal incidents, the cause of which can be associated with utility staff inadequacies, would pose potentially major economic threats. Some of the more exposed utilities may need to consider default and/or bankruptcy proceedings. Generating and distributing facilities will continue to function in one form or another, however, and the economic prognosis for the utility industry is generally favorable in the near term. By mid 1987, approximately ten plants will remain under construction, and several utilities will be involved in operating license hearings. Serious interest in forming new licensee arrangements for future nuclear construction seems likely. The presence of nuclear utilities in the nuclear services business is expected to increase. Transmission systems will be expanding to accommodate larger interregional and international power transfer, which can compensate regional capacity shortages. By 1990, essentially all plant construction will be complete and most of the long, costly procedures associated with obtaining operating licenses should be over. The frequency of allegations should have diminished sharply; but intervenor activities, rather than declining, will likely be refocused on operating plants, radioactive materials transport, and waste isolation. Pressures by state regulators for disallowance of some construction costs will continue and may have intensified; however, there should be no remaining nuclear-construction-related questions concerning the solvency of individual utilities. Utility involvement in the services segment should have grown and probably stabilized. Some parts of the country may be experiencing power shortages (the south, middle south, far west and northeast). To some extent, these will be accommodated by expanded transmission systems, but a clear need will exist to construct new generating facilities. The most widespread current belief is that these will probably use fossil fuels; however, under some circumstances, nuclear plants could be an option. These may be of a standardized, advanced design that provides even greater safety assurance than do contemporary plants or may be custom designs in an advanced stage of design completion. By 1995, rate base and licensing hearings will be concluded and the nuclear generating industry should have achieved a stable, relatively low profile condition. The physical and financial debacles of the 1970s and 1980s should be over. Utilities should, in general, have resumed their traditional, fiscally conservative role with a stable presence in the nuclear services business. Transmission systems should be optimized as should operations and maintenance practices at operating nuclear plants. Substantial new generating capacity, some of which may be nuclear plant restarts or, less likely, new starts, will be under construction.

Nuclear Steam Supply System Vendors (NSSS)

Within two years, steam supply system fabrication for all domestic plants should be complete and the associated personnel and facilities either shifted to other activities or terminated. Many key personnel will likely gravitate to service organizations or to the utilities. Some manufacturing and engineering capabilities will be retained to serve a limited foreign trade and to build replacement fuel for existing reactors. The NSSS manufacturers are expected to continue forging partnerships with overseas concerns in efforts to further penetrate the foreign market and with AEs and other domestic firms to establish stronger positions in the services business. Reactor vendors will continue to promote advanced concepts, including standard designs and turnkey projects, and will be involved in the planning and promotion for new institutional configurations and regulatory reform. By 1990 or earlier, manufacturing and engineering will probably be reduced to the minimum needed to support fuel reload requirements and foreign commitments. Reactor vendors will be party to more alliances with both foreign and domestic firms and may be experiencing some expansion in service-related business and in foreign orders. A shortage of parts and component suppliers may force the NSSS vendors to do more specialized manufacturing in-house or to order from abroad. Either eventuality would pose new problems in terms of supplier qualification and inspection. Standard and advanced plants will be actively promoted and marketed, and the NSSS vendors are likely to be key participants in emerging new institutional configurations. Possibly one or two of the four major vendors will have abandoned the NSSS business. Through 1995, the reload business will continue at a stable, profitable level and service and foreign business should grow moderately. An advanced plant demonstration or commercial unit may be under construction. The NSSS vendors will be increasingly involved with decommissioning, waste storage, and life extension. They are also likely to be lead actors in new institutional arrangements. Increased in house fabrication and/or foreign procurement of components and equipment will continue.

Architect-Engineers and Constructors (AE/Cs)

A continuing general decline in AE and construction business is expected. The growth in other projects will fail to compensate the larger massive personnel needs characteristic of nuclear construction, and general force reductions will occur. Fluctuations of this sort are common in the construction business and are thus likely to be relatively easy for the AE/C firms to accommodate. Many key personnel will join the ranks of the utilities or service organizations. Over the next two years, most of the basic construction of plants in progress will be completed. Backfit-related work and plant modifications will continue but at a combined, reduced level. The AE/Cs will be participating with the NSSS vendors and others in exploring new institutional configurations in which they are likely to be major participants. Major involvement in the services business and foreign nuclear projects should continue for the AE/Cs. By 1990, AE/C nuclear staffs should be stabilized at minimum levels. Plant construction and most backfitting will be complete. Continued, stable business in the services sector and in plant modification is expected. Planning for new projects involving new institutional configurations should be well along. These are likely to include partnerships with NSSS vendors in advanced, standard, or turnkey plant proposals. In ten years, new capacity needs, fossil, nuclear, or other, will have created new business for the AE/C firms with a resulting growth in staff and capabilities. There will be a growing involvement in decommissioning, life extension, and waste isolation. By 1995, the AE/Cs are likely to have a major role in new institutional arrangements involved in advanced, standard, and/or turnkey projects.

Component Suppliers

Business for the component suppliers will continue its rapid decline. Over the next two years, as many as 50% of the firms currently listed as qualified suppliers may have left the business. Some suppliers may attempt to penetrate foreign markets but it is likely that the reverse process--foreign entry into the domestic market--will predominate. By 1990, the nuclear grade component and equipment supply sector, as traditionally constituted, will be greatly reduced. Surviving firms will provide replacement parts and equipment. Components which must be replaced periodically to maintain their environmentally qualified status will constitute a major portion of the market. Prices and delivery lead times will have increased appreciably. Utilities will be required to "engineer around" parts and components or to buy from foreign firms. This may create new problems in evaluating design changes and foreign qualifications. The market in ten years will continue to be minimal. Many new and replacement parts may be purchased from abroad. Some new business potential may develop in connection with life extension and waste isolation programs, but foreign suppliers may have the advantage here also.

Service Vendors

The well being of the service industry in some respects is inversely related to that of the nuclear industry as a whole. This reflects the fact that regulatory, financial, and technical factors that created burdens for the utilities also established the need for many of the services which they now procure. Over the next two years, the service industry in general will expand significantly as more plants come on line. The balance of service needs will change but the net business volume will increase. Because services represent the only expansive industry segment, competition from all segments with relevant capabilities will become more intense. The NSSS suppliers, AEs, and some utilities will seek to enlarge their market share, often as composite entities. In self defense, some of the smaller, traditional service firms can be expected to consolidate to offer broader capabilities. This trend should be balanced somewhat by the competitive advantage inherent in the higher efficiency characteristic of small firms. Continuing, successful efforts by foreign firms to acquire a share in the U.S. services market are expected. These will be partly through acquisitions of and agreements with domestic firms but will also involve direct marketing by foreign companies. By 1990, the services market should have stabilized. Much of the business will have been acquired by NSSS suppliers, AEs, utilities and combinations thereof. The successful traditional services firms will, in many cases, have found it necessary to align themselves with former competitors to meet the challenge of larger newcomers. There is likely to be a sizeable, minority foreign presence in the business that will inhibit new domestic startups, and the work force and business base should be stable in a highly competitive environment. Business should continue strong and fairly stable through 1995 with approximately the same mix of participants as in 1990. Some decline in business volume could result as reactor operations become more routine and non-continuous activities associated with construction and startup are completed. This should be compensated by new work in life extension, decommissioning, waste isolation, and advanced plant planning and design.

CHALLENGES FOR THE NRC

As the character of the nuclear industry changes, the nature of and potential for regulatory problems in general and for quality assurance problems specifically will change as well. Anticipated trends for individual industry segments project quite different futures for the five major components of the current nuclear industry. Most are expected to contract--some severely; but for others, e.g., the services business, considerable expansion is in store. Some activities that currently require NRC concern over QA will decline or cease, e.g., basic plant design and construction, while other areas such as foreign imports, life extension, computerization, plant maintenance, and waste handling and storage will gain more prominence. A number of issues that are expected to require future attention from the NRC were surfaced by this study.

Of primary interest are quality concerns which are expected to arise as a natural and predictable consequence of the decline and termination of plant construction and the accompanying increase in the number of operating plants. Findings that relate to this trend represent the basic results of this study. There are also general trends not directly associated with the transition to an all operating plant environment which have significant future quality implications for the NRC. These include technological developments, possible changes in overall regulatory policies, and the expanding presence of foreign suppliers in the domestic market.

Issues Arising from the Transition to an All-Operating Reactor Environment

The general effects of the industry transition on NRC quality assurance responsibilities will be to shift technical emphasis to plant operations and to develop new regulatory bases to deal with changes in a timely way. Barring some dramatic and inherently unpredictable event (such as TMI-2), the need for revisions in NRC QA policies and practices should evolve in an orderly way. Over the next 10 years, the nature of NRC regulation can be expected to change gradually in a manner consistent with industry trends. The net effect of these changes will probably be substantial. A proactive posture on the part of NRC to anticipate these changes will lend to the effectiveness of the Agency in fulfilling its mission.

Needs for qualified NRC inspectors, including QA inspectors, will increase. Operating plants now require a greater inspection presence than the NRC has provided for at plants under construction. There is also likely to be more competition from industry for capable personnel and fewer new graduates in nuclear-related disciplines are expected over the next few years. Transfer of inspectors from completed construction projects to operating plants will ease the shortage, but not all construction inspectors will have the skills or the inclination to make the transition. The NRC may need to hire more inspectors and provide more incentives to attract and retain staff. More emphasis on training programs and more selective, prioritized, coordinated inspection procedures may allow the job to be done with fewer personnel. The use of licensee staff or contractors to supplement the inspection corps is another option.

If new plant starts are deferred much beyond 1990, there is a risk of losing the knowledge and experience base which would be needed when construction does resume. Deliberate efforts to preserve the "lessons learned" should be implemented. In addition to conventional archiving, possible approaches might include imaginative, user friendly video tapes which capture the perspectives of seasoned inspectors and other staff and, perhaps, development of a simple expert system.

Inspection personnel qualifications will require upgrading because of staff turnover and the introduction of new inspection technology. The NRC training programs can be supplemented to meet these needs. A training team consisting of individuals with expertise in inspection techniques, NDE in particular, may be useful in providing timely, consistent guidance to field personnel.

Plant aging and life extension issues may create needs for more and different types of inspections. Continued aging studies and timely communication of results and information on associated changes in inspection requirements to appropriate inspection staff are important. Guidance on requirements for plant license extension will be needed in the near term.

Further evaluation of maintenance program effectiveness and the adequacy of QA as applied to outage management and activities is needed. NRC programs addressing these needs are in progress or planned.

Shortages of original parts and certified parts in general and the potential for violating plant design bases, which could occur if unavailability of parts requires re-engineering, will need to be addressed. Possibly certification requirements can be relaxed or equivalencies established between nuclear and certain non-nuclear certification standards. More QA oversight may be necessary if shortages become more general.

Restart of mothballed plants would raise questions concerning adequacy of documentation and earlier regulatory requirements and possible in-storage deterioration. A study of deterioration mechanisms, including review of experiences with long term storage at TMI-1 and Diablo Canyon, would be useful. Guidance on plant preservation and regulatory standards to which restarted plants will be held may be needed. Serious proposals for new institutional arrangements or for construction of new generation plants (standardized designs or advanced reactors) will require review by NRC QA staff and may lead to time-consuming recasting of regulations. Resources required for this and the timing of their commission may require NRC resolution.

Proliferation of computer usage in reactor operations will require near term response by NRC. There are growing interests in employing computers in reactor control and in developing expert systems to guide maintenance, inspection, trouble shooting, and other activities. Needed regulatory guidance on software QA is being developed. The NRC may have to strengthen its staff in computer awareness through training, recruitment of personnel with strong computer backgrounds, or both. Required training could itself be facilitated through the use of expert systems and other modern computerized methods.

The economic difficulties which several utilities are and will continue to be experiencing pose special problems for the NRC. Whether, in the interest of cost savings, pressures on licensees might lead to the reality or the perception of possible safety or quality compromise, the NRC will have to exercise heightened concern. This may take the form of more intense scrutiny during plant operation and maintenance.

The growing involvement of foreign firms in all segments of the U.S. nuclear supply market creates new problems of legitimate concern to the NRC. Products from abroad are produced to standards which may deviate from NRC requirements. Whether or not these meet the intent of U.S. standard practices for nuclear grade products needs to be determined. The extent to which U.S. and foreign QA programs and practices are equivalent or interchangeable will have to be established. It may also be necessary to provide for NRC inspection in foreign plants. Foreign firms often enter the U.S. market through acquisition of or cooperative agreements with domestic firms. Possible effects of these developments on the quality practices of traditional, U.S. suppliers may require study.

The general implication of the alternative projections developed in Chapters 2.0 and 3.0 and the resultant policy issues and options discussed in Chapter 4.0 is that the nature of NRC quality-related responsibilities and work load will change substantially over the next ten years. Neither significant, sudden increases nor declines in overall personnel or other resource requirements can be foreseen. Anticipated changes should be evolutionary in nature and can be effected in an orderly way without serious disruption in staff or resource allocation if the agency recognizes and prepares for change in a timely, efficient manner. Training and staff development are important elements in dealing with many of the expected trends. These activities are under the direct control of the NRC and can be quickly and economically supplemented to meet new needs. Some near term needs for new regulatory guidance exist, e.g., in the areas of nuclear waste isolation, plant life extension, computer software, maintenance, mothballing of partially complete plants, and determination of equivalencies between NRC and foreign and non-nuclear quality programs.

The question of issue prioritization has been avoided in this study for two reasons:

1. The trends from which issues derive are predictions which include significant uncertainty. Tangible indications that a trend is materializing are required to justify substantive action by the NRC.

2. The NRC must contend with organizational and political exigencies which must be considered in conjunction with technical issues in determining priorities. Resolution of these composite factors can be accomplished only internally, i.e., within the Agency by NRC staff.

Finally, the fact that an issue is cited in the foregoing should not be construed to suggest that the NRC has not been aware of or has been unresponsive to that particular problem. Many of the issues noted are of current (and some of long term) concern to the NRC, and in a number of cases, initiatives to resolve cited issues are in progress.

NUCLEAR INDUSTRY PROJECTIONS - 1985 TO 1995

1.0 NEW CAPACITY NEEDS

Between 1945 and 1972, electricity use in the U.S. grew at an annual average rate of 8.1% and the share of total energy supplies represented by electricity more than doubled to 26% in 1972. With this rapid growth in demand, utilities were forced to expand their construction activities increasing generating capacity from 50,000 MW in 1945 to 400,000 MW in 1972. In the late 1970s, inflation and interest rates increased and moves towards environmental protection eroded cost advantages of larger generating units. These factors, which increased utility costs and rates, were intensified by the oil embargo in 1973 which, together with the oil price shock following the Iranian Revolution in 1978, forced substantial rate increases. The need to increase rates began to meet with resistance in state regulatory proceedings. Between 1973 and 1981, electricity rates increased by 179% in current dollars and 37% after adjustment for inflation.[1] During this same period, construction costs increased to the point where the addition of new capacity increased rather than decreased electric rates. As a result, since 1974, although 220,000 MW of new capacity have been completed, 148,000 MW of capacity on order have been cancelled. Since 1979, the pace of cancellations has accelerated and new capacity under development has been reduced by 72,000 MW. Since 1973, 109 nuclear projects with a total generating capacity of 119,000 MW have been cancelled, and since 1978 no new orders have been placed.[1]

The present electric generating capacity of U.S. utilities is approximately 600,000 MWe. This includes an average capacity margin of 25% which is adequate to compensate routine maintenance, breakdowns, and other problems that limit generating units to less than their maximum capacities. With the present rate of plant construction, capacity margins will increase slightly until 1986 after which it will decline. Annual additions in new generating capacity will drop from approximately 20,000 MW a year presently to less than 6,000 MW in 1988 and to virtually zero by 1991.[2]

Current circumstances in the U.S. provide disincentives for utilities to invest in new capacity. Some regions have substantial excess capacity, and it is common for utilities to earn less on new investment than the cost of the capital that is financing it. As a consequence, to finance large construction projects, most utilities would currently be required, for example, to sell stock at less than book value thereby diluting the investment of existing stockholders. As demonstrated by several recent projects, efforts to finance nuclear construction can severely stress a utility's finances.[3]

In the 1960s nuclear units were constructed for from $100 to $300 per kW of generating capacity. By the late 1970s, installed capital costs of nuclear units had risen by nearly a factor of 10 to about $1,300 per kW. Even at this figure, nuclear power, in most instances, represented an attractive means of generating additional electricity. For nuclear plants being built in the 1980s, capital costs are highly variable ranging from as little as $900 per kW to more than $5,000 per kW. Over its brief history, nuclear power thus has increased in capital cost by as much as 1,500%. Only one-tenth of this increase is attributable to inflation and the increase in cost of plant construction and components. The principal part of the increase is attributed to increased financing costs, construction delays, quality assurance deficiencies, and increased regulatory requirements.[4]

Nuclear regulatory requirements began to expand significantly in the early-to-mid 1970s following the Calvert Cliffs decision and increased rapidly in reaction to the Three Mile Island (TMI) incident in 1979. By the early 1980s, the Nuclear Regulatory Commission (NRC) had issued approximately 2,000 regulatory guides, letters, bulletins, orders, notices, and standards governing the nuclear industry.[5] Roughly 80% of these were generated following the creation of the NRC as an independent agency in 1974. Since 1983, relatively few regulatory changes have been forthcoming-due largely to the implementation by the NRC of mechanisms for checking regulatory growth, e.g., creation of the Committee to Review Generic Requirements (CRGR).

Regulatory changes, especially when they required backfitting and reworking of existing construction, resulted in major construction cost increases and were mainly responsible for the sizeable increases in quantities of materials and manpower required for nuclear units. (As an example, craft labor requirements increased from 3.5 work hours per kW in early plants to more than 21 work hours per kW for units currently under construction.) Potential construction delays represent one of the most formidable impediments to new nuclear construction. The uncertainty in power demand projections plus concerns over delays introduced by financial limitations, new regulations, and the activities of antinuclear activists are of particular concern to a utility. Delay, from whatever source, can increase costs for a nuclear construction project by hundreds of thousands of dollars per day. The practice of accommodating cumulative interest costs in the capitalized value of the plant leads to extremely expensive projects that produce substantial rate shock when and if state regulating agencies allow the costs to be entered into the rate base. Given a 13 year lead-time for construction, which is currently not uncommon, carrying costs on the necessary capital for a nuclear project can represent 60% of the cost of the plant. In comparison, for a construction time of 5 years, carrying costs represent only about 30% of the plant cost.[6]

These factors plus concern over the regulatory climate (the consequences of serious non-compliance can extend to not being allowed to earn a return on the entire construction investment) have resulted in a situation in which no nuclear construction starts can be foreseen.

Eventually, new generating capacity will be required in all parts of the country. The magnitude and timing of this requirement depends upon a) the rate of demand growth, b) the rate of retirement of existing capacity, c) the utilities' ability to increase capacity factors, and d) the effectiveness of conservation and load management. The combinations of these trends defy accurate prediction; however, assuming completion of current construction projects and considering retirement of obsolete plants, the total U.S. utility generating capacity by 1995 should be approximately 640,000 MW--equivalent to an average annual growth rate of 2.5%.[a] This is a nominal growth rate which presumes no substantial change in unit generating costs. Demand for electricity is quite flexible depending upon unit costs thus developments that yield significant cost reductions would result in increased rate of growth in generating capacity. To achieve a 2.5% annual growth rate while retaining a capacity margin of 20%, additional capacity will be needed by 1992 and a total of approximately 40,000 MW additional will be required by 1995.[3]

(a) The Department of Energy predicts an annual increase in electricity demand of 2.49% over the balance of the century.[8] The Office of Technology Assessment made a similar prediction as did an assessment by the Library of Congress Congressional Research Service.[9] The DOE Energy Administration projects a growth in electric usage of 3.5% between 1983 and 1990 and 2.8% from 1990 to 1995.[10] Both lower and higher estimates have been made. The Committee on Nuclear and Alternative Energy Systems predicts a demand growth rate generally less than 2% and the Audubon Society a negative growth rate of -0.8%. The differences between these and other higher predictions lie in the assumptions made concerning growth in GNP, conservation, and customer response to the increasing price of electricity. On the other end of the spectrum, an analysis by Siegel and Sillin forecast annual growth rates in electricity demand of 4.5% through 1990.[11] These projections are based on the assumption of a relatively high increase in GNP of 3.5% and relatively low increases in the price of electricity.

2.0 NUCLEAR GENERATION PROJECTION

2.1 CURRENTLY OPERABLE PLANTS

As of mid-1985, 93 commercial reactors with a cumulative maximum power producing capacity of 84 GWe were operable in the United States. These provide approximately 14% of the total U.S. electric generating capability on the average and more than 50% in parts of the Northeast. With the exception of one, small HTGR, these are all LWRs of which most have net design generating capacities in the vicinity of 1000 MWe. Table 1 lists operable plants and cites plant type, supplier, and capacity; the responsible utility; and the date on which the operating license was issued.[11,12] Some perspective on the development of the current industry is provided by Figure 1. Most of the contemporary plants came on-line in the 1970s and early 1980s, with the greatest rate of increase in nuclear generating capacity occurring in the early-to-mid 1970s. Toward the end of the 1970s, increasing interest rates and decreasing demand projections resulted in curtailment of new plant orders and delays in construction projects which were in progress. As a result of the special and more stringent licensing requirements that were imposed by the NRC following the 1979 TMI accident, a further slow-down in introducing new nuclear capacity occurred in the late 1970s and early 1980s. Plants that were in the construction pipeline in that time frame have more recently been coming on-line at an increased rate which is expected to persist into the late 1980s. Plant commitments as reflected by new orders (Curve II, Figure 1) peaked in the mid 1970s and then declined rapidly in response to reduced demand forecasts and increased financing costs. Cancellations were further stimulated by the aftermath of TMI. Since 1978, no new plant orders have been placed and over sixty orders have been cancelled. The last plant on which construction actually began was Marble Hill which was ordered in 1974 and cancelled in 1984 after construction was approximately 50% complete.

2.2 PLANTS UNDER CONSTRUCTION[13,15,16,17,18]

Presently, 25 plants are under active construction. Of these, it seems likely that from two to four projects will be cancelled--primarily because of licensee financial problems. Details on plants under construction are provided by Table 2 which lists plant type, supplier and capacity; responsible utility; expected operation date as projected by the utility; and percent completion as of mid-1985. Table 2 also cites estimated total costs and completion costs for each reactor.

The rate at which the backlog of plants under construction is expected to enter commercial operations is shown in Figure 2.[6] Two projections are given: one which reflects the industry position and is probably somewhat optimistic and a second, more conservative projection generated by the investment community. Both curves show that by 1988, the bulk of construction will be complete with only "mop-up" and testing to be accomplished before the final

TABLE 1. Operable Nuclear Power Plants - July 1985[7,12,13]

Operating License Issuances

1985				
March	Fermi 2	1130 MWe	BWR/GE	Detroit Edison (MI)
April	Diablo Canyon 2	1106 MWe	PWR/W	Pacific Gas and Electric (CA)
June	Wolf Creek	1150 MWe	PWR/W	Kansas Gas and Electric
Total (7/16/85): 3 reactors = 3356 MWe				
1984				
Mar	Susquehanna 2	1050 MWe	BWR/GE	Pennsylvania P&L (PA)
June	Callaway 1	1150 MWe	PWR/W	Union Electric (MO)
Oct.	Limerick 1	1055 MWe	BWR/GE	Philadelphia Electric (PA)
Oct.	Byron 1	1120 MWe	PWR/W	Commonwealth Edison Co. (IL)
Dec	Catawba 1	1145 MWe	PWR/W	Duke Power (SC)
Dec.	Palo Verde 1	1270 MWe	PWR/CE	Arizona Public Service
Dec.	Shoreham	809 MWe	BWR/GE	Long Island Lighting (NY)
Dec.	Waterford 3	1104 MWe	PWR/CE	Louisiana P&L (LA)
Total: 8 reactors = 8703 MWe				
1983				
Dec.	LaSalle 2	1078 MWe	BWR/GE	Commonwealth Edison Co. (IL)
March	William McGuire 2	1180 MWe	PWR/W	Duke Power Co. (NC)
April	St. Lucie 2	786 MWe	PWR/CE	Florida Power and Light Co.
Dec.	WPPSS 2	1100 MWe	BWR/GE	Washington Public Power Supply System
Total: 4 reactors = 4144 MWe				
1982				
June	Grand Gulf 1	1250 MWe	BWR/GE	Mississippi Power and Light Co.
April	LaSalle 1	1078 MWe	BWR/GE	Commonwealth Edison Co. (IL)
Feb.	San Onofre 2	1100 MWe	PWR/CE	Southern California Edison Co.
Nov.	San Onofre 3	1100 MWe	PWR/CE	Southern California Edison Co.
Aug.	Summer 1	900 MWe	PWR/W	South Carolina Electric and Gas Co.
July	Susquehanna 1	1050 MWe	BWR/GE	Pennsylvania Power and Light Co.
Total: 6 reactors = 6478 MWe				
1981				
Sept.	Diablo Canyon 1[a]	1084 MWe	PWR/W	Pacific Gas and Electric Co. (CA)
Jan.	William McGuire 1	1180 MWe	PWR/W	Duke Power Co. (NC)
June	Sequoyah 2	1148 MWe	PWR/W	Tennessee Valley Authority
Total: 3 reactors 3412 MWe				

TABLE 1. (contd)

1980				
Oct.	Joseph M. Farley 2	860 MWe	PWR/W	Alabama Power Co.
April	North Anna 2	850 MWe	PWR/W	Virginia Electric and Power Co.
April	Salem 2	1115 MWe	PWR/W	Public Service Electric and Gas Co. (NJ)
Feb.	Sequoyah 1	1148 MWe	PWR/W	Tennessee Valley Authority
Total: 4 reactors = 4013 MWe				
1979				
None.				
1978				
Sept.	Arkansas Nuclear One-2	912 MWe	PWR/CE	Arkansas Power and Light Co.
June	Edwin I. Hatch 2	790 MWe	BWR/GE	Georgia Power Co.
Feb.	Three Mile Island 2[b]	906 MWe	PWR/B&W	Metropolitan Edison Co. (PA)
Total: 3 reactors = 2608 MWe				
1977				
Dec.	Donald C. Cook 2	1100 MWe	PWR/W	Indiana and Michigan Electric Co. (MI)
April	Davis-Besse 1	890 MWe	PWR/B&W	Toledo Edison Co. (OH)
June	Joseph M. Farley 1	860 MWe	PWR/W	Alabama Power Co.
Nov.	North Anna 1	877 MWe	PWR/W	Virginia Electric and Power Co.
Total: 4 reactors = 3927 MWe				
1976				
Jan.	Beaver Valley 1	833 MWe	PWR/W	Duquesne Light Co. (PA)
July	Browns Ferry 3	1067 MWe	BWR/GE	Tennessee Valley Authority (AL)
Sept.	Brunswick 1	790 MWe	BWR/GE	Carolina Power and Light Co. (NC)
Aug.	Calvert Cliffs 2	845 MWe	PWR/CE	Baltimore Gas and Electric Co. (MD)
Dec.	Crystal River 3	880 MWe	PWR/B&W	Florida Power Corp.
March	St. Lucie 1	822 MWe	PWR/CE	Florida Power and Light Co.
Aug.	Salem 1	1090 MWe	PWR/W	Public Service Electric and Gas Co. (NJ)
Total: 7 reactors = 6327 MWe				
1975				
Dec.	Indian Point 3	965 MWe	PWR/W	Power Authority of the State of New York
Sept.	Millstone 2	869 MWe	PWR/CE	Northeast Utilities (CT)
Nov.	Trojan	1130 MWe	PWR/W	Portland General Electric Co. (OR)
Total: 3 reactors = 2964 MWe				

TABLE 1. (contd)

1974

May	Arkansas Nuclear One-1	850 MWe	PWR/B&W	Arkansas Power and Light Co.
June	Browns Ferry 2	1067 MWe	BWR/GE	Tennessee Valley Authority (AL)
Dec.	Brunswick 2	790 MWe	BWR/GE	Carolina Power and Light Co. (NC)
July	Calvert Cliffs 1	845 MWe	PWR/CE	Baltimore Gas and Electric Co. (MD)
Oct.	Donald C. Cook 1	1030 MWe	PWR/W	Indiana and Michigan Electric Co. (MI)
Jan.	Cooper	778 MWe	BWR/GE	Nebraska Public Power District
Feb.	Duane Arnold	538 MWe	BWR/GE	Iowa Electric Light and Power Co.
Oct.	James A. Fitzpatrick	821 MWe	BWR/GE	Power Authority of the State of New York
Aug.	Edwin I. Hatch 1	786 MWe	BWR/GE	Georgia Power Co.
July	Oconee 3	860 MWe	PWR/B&W	Duke Power Co. (SC)
Oct.	Prairie Island 2	530 MWe	PWR/W	Northern States Power Co. (MN)
July	Peach Bottom 3	1065 MWe	BWR/GE	Philadelphia Electric Co. (PA)
Aug.	Rancho Seco 1	918 MWe	PWR/B&W	Sacramento Municipal Utility District (CA)
April	Three Mile Island 1[(c)]	819 MWe	PWR/B&W	Metropolitan Edison Co. (PA)

Total " 14 reactors = 11,697 MWe

1973

June	Browns Ferry 1	1067 MWe	PWR/GE	Tennessee Valley Authority (AL)
May	Fort Calhoun 1	486 MWe	PWR/CE	Omaha Public Power District (NB)
Dec.	Fort St. Vrain	330 MWe	HTGR/GA	Public Service Co. of Colorado
Dec.	Kewaunee	535 MWe	PWR/W	Wisconsin Public Service Corp.
Feb.	Oconee 1	860 MWe	PWR/B&W	Duke Power Co. (SC)
Oct.	Oconee 2	860 MWe	PWR/B&W	Duke Power Co. (SC)
Aug.	Peach Bottom 2	1065 MWe	BWR/GE	Philadelphia Electric Co. (PA)
Aug.	Prairie Island 1	530 MWe	PWR/W	Northern States Power Co. (MN)
Jan.	Surry 2	775 MWe	PWR/W	Virginia Electric and Power Co.
April	Turkey Point 4	666 MWe	PWR/W	Florida Power and Light Co.
April	Zion 1	1040 MWe	PWR/W	Commonwealth Edison Co. (IL)
Nov.	Zion 2	1040 MWe	PWR/W	Commonwealth Edison Co. (IL)

Total: 12 reactors 9254 MWe

1972

Sept.	Maine Yankee	825 MWe	PWR/CE	Maine Yankee Atomic Power Co.
June	Pilgrim 1	670 MWe	BWR/GE	Boston Edison Co. (MA)
March	Quad Cities 2	789 MWe	BWR/GE	Commonwealth Edison Co. (IL)
May	Surry 1	775 MWe	PWR/W	Virginia Electric and Power Co.
July	Turkey Point 3	666 MWe	PWR/W	Florida Power and Light Co.
March	Vermont Yankee	514 MWe	BWR/GE	Vermont Yankee Nuclear Power Corp.

Total: 6 reactors = 4239 MWe

TABLE 1. (contd)

		1971		
Jan.	Dresden 3	794 MWe	BWR/GE	Commonwealth Edison Co. (IL)
Oct.	Indian Point 2	873 MWe	PWR/W	Consolidated Edison Co. of New York, Inc.
March	Palisades	757 MWe	PWR/CE	Consumers Power Co. (MI)
Nov.	Point Beach 2	497 MWe	PWR/W	Wisconsin Electric Power Co. (WI)
Sept.	Quad Cities 1	665 MWe	BWR/GE	Commonwealth Edison Co. (IL)
Total:	5 reactors = 3710 MWe			
		1970		
Oct.	Millstone 1	660 MWe	BWR/GE	Northeast Utilities (CT)
Sept.	Monticello	545 MWe	BWR/GE	Northern States Power Co. (MN)
Oct.	Point Beach 1	497 MWe	PWR/W	Wisconsin Electric Power Co. (WI)
Aug.	H. B. Robinson 2	665 MWe	PWR/W	Carolina Power and Light Co. (SC)
Total:	4 reactors = 2367 MWe			
		1969		
Dec.	Dresden 2	794 MWe	BWR/GE	Commonwealth Edison Co. (IL)
Sept.	Robert E. Ginna	470 MWe	PWR/W	Rochester Gas and Electric Corp. (NY)
Aug.	Nine Mile Point 1	620 MWe	BWR/GE	Niagara Mohawk Power Corp. (NY)
April	Oyster Creek	650 MWe	BWR/GE	Jersey Central Power and Light Co. (NJ)
Total:	4 reactors = 2534 MWe			
		1968		
None.				
		1967		
June	Haddam Neck	582 MWe	PWR/W	Connecticut Yankee Atomic Power Co.
July	LaCrosse	50 MWe	BWR/AC	Dairyland Power Corp. (WI)
March	San Onofre 1	436 MWe	PWR/W	Southern California Edison Co.
Total:	3 reactors = 1068 MWe			
		1966		
	Hanford-N	860 MWe	LGR/GE	DOE and Washington Public Power Supply System
Total:	1 reactor = 860 MWe			
		1962		
Aug.	Big Rock Point	63 MWe	BWR/GE	Consumers Power Co. (MI)
Total:	1 reactor = 63 MWe			

TABLE 1. (contd)

1960				
July	Yankee Rowe	175 MWe	PWR/W	Yankee Atomic Electric Co. (MA)
Total: 1 reactor = 175 MWe				

(a) Suspended until 1984.
(b) Shut down since 3/28/79 accident.
(c) Shut down 3/28/79 by NRC order pending completion of re-start proceedings.

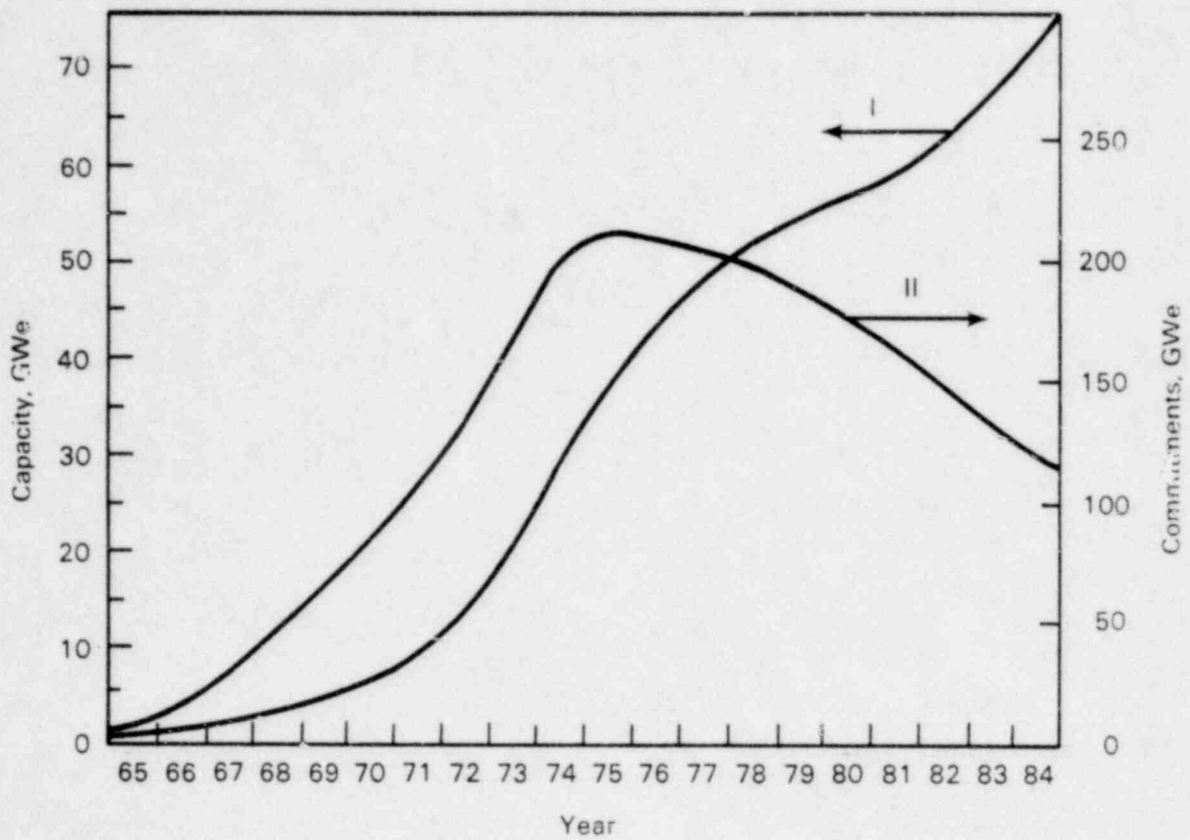

FIGURE 1. Nuclear Power Industry Historic Trends in Generating Capacity and Plant Orders(13,14)

plants go on-line. Except for plant modifications, by the end of 1991 all construction-related activities at commercial nuclear power plants should be completed. Assuming no new orders over the next 10 years, this situation is expected to persist until at least the mid-1990s.

2.2.1 Economic Implications of Current Construction Activities(18)

Even though all of the 39 plants ordered since 1973 have been cancelled, the residual projected construction activity represents a very substantial capital investment over the next few years. Figure 3 plots cumulative estimated completion costs for plants under construction versus time (these data are listed in the final column of Table 2). Assuming that all plants listed in Table 2 will be completed, Figure 3 shows that approximately $14 billion in new capital investment would be required between 1985 and 1991. Discounting these projections for some plant cancellations leads to an estimate of approximately $10 billion over the same time span (Curve II, Figure 3). Costs of these magnitudes represent massive investments for the utilities involved. This is

TABLE 2. Commercial Nuclear Power Plants Under Active Construction - July, 1985[14,15,16,17,18]

Facility	Utility	MWe	Type/ NSSS	Expected Commercial Operation[a]	% Complete	Est. Cost of Reactor ($ x 10^{-9})	Cost Per Installed kW ($ x 10^{-3})	Cost to Complete ($ x 10^{-6})
Comanche Peak 1	Tex. Ut	1150	PWR/W	1/86	99	2.8	2.4	28
Palo Verde 2	APS	1270	PWR/CE	7/86	99	2.3	1.8	23
Watts Bar 1	TVA	1177	PWR/W	10/85	99	1.7	1.5	17
Perry 1	Clev. Elec.	1205	BWR/GE	12/85	99	3.9	3.2	117
River Bend	Gulf St.	940	BWR/GE	12/85	98	4.0	4.3	280
Harris 1	Car. P&L	900	PWR/W	9/86	91	3.1	3.4	310
Millstone 3	NE Ut.	1150	PWR/W	5/86	96	3.9	3.4	312
Seabrook 1	PS of NH	1150	PWR/W	8/86	85	4.5	3.8	900
Braidwood 1	Com. Ed	1120	PWR/W	10/86	84	2.5	2.2	500
Bryon 2	Com. Ed	1120	PWR/W	10/86	72	1.7	1.5	561
Nine Mile Point 2	Niag. Mo.	1085	BWR/GE	10/86	92	5.4	5.0	810
Watts Bar 2	TVA	1177	PWR/W	4/88	68	1.8	1.6	580
Clinton 1	Ill. P	933	BWR/GE	11/86	94	3.1	3.3	279
Hope Creek 1	PSE&G	1070	BWR/GE	12/86	99	3.8	3.6	228
Beaver Valley 2	Duq L	833	PWR/W	10/87	87	3.9	4.6	663
Comanche Peak 2	Tex. Ut	1150	PWR/W	6/87	74	1.8	1.6	630
Palo Verde 3	APS	1270	PWR/CE	6/87	96	3.2	2.6	128
Vogtle 1	Ga. P	1100	PWR/W	3/87	79	4.3	3.6	1075
Braidwood 2	Com. Ed	1120	PWR/W	12/87	56	1.6	1.5	736
Catawba 2	Duke	1145	PWR/W	6/87	96	2.0	1.8	320
South Texas 1	HL&P	1250	PWR/W	6/87	80	4.5	3.6	1080
Vogtle 2	Ga. P	1100	PWR/W	9/88	50	2.9	2.4	1450
Bellefonte 1	TVA	1213	PWR/BW	4/89	81	2.8	2.3	530
South Texas 2	HL&P	1250	PWR/W	6/89	54	3.0	2.4	1410
Bellefonte 2	TVA	1213	PWR/BW	4/91	54	2.8	2.3	1290

(a) Utility Projections.

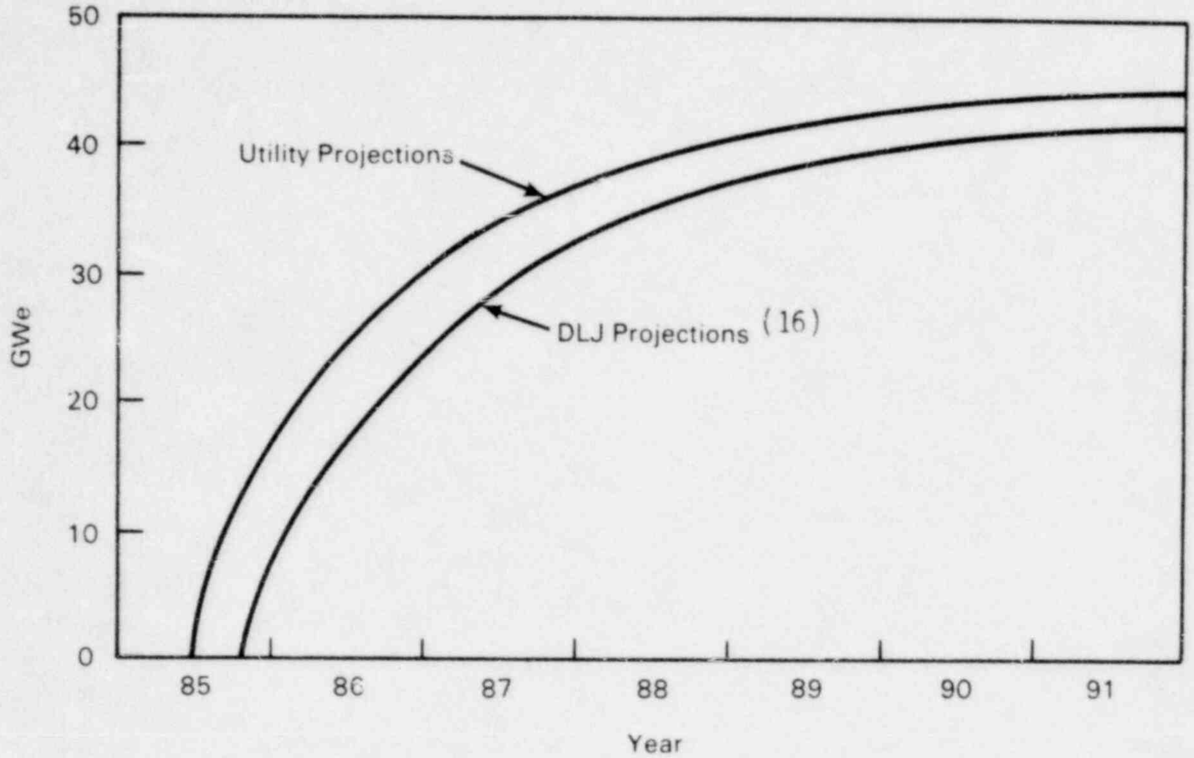

FIGURE 2. Anticipated Increase in Nuclear Generating Capacity as Plant Construction Phases Out

illustrated by Table 3 which gives nuclear construction investments as a percentage of common equity for utilities with current construction projects. For more than half of these utilities, nuclear construction investment exceeds common equity, and in the most extreme case, is three times the common equity.

2.3 NOMINAL CAPACITY PROJECTIONS THROUGH 1995

Combining current operating plant expectations (Section 2.1) with construction projections (Section 2.2) leads to the overall projection for domestic nuclear power capacity shown in Figure 4. This is a best-estimate prediction in that it discounts likely plant cancellations. The rate of change in capacity between 1985 and 1991 may be somewhat over stated in that utility estimated completion schedules, which may be optimistic, were used. Beyond 1991, total U.S. nuclear generating capacity is shown constant at approximately 120 GWe through 1995. In actuality, some increase in capacity during this period is anticipated because of expected increases in capacity factors. This is a second order effect, however, expected to contribute less than 7% to total generating capacity over the next 10 years. To some extent, these increases in capacity factor may be countered by a deterioration in on-line efficiency as plants age.

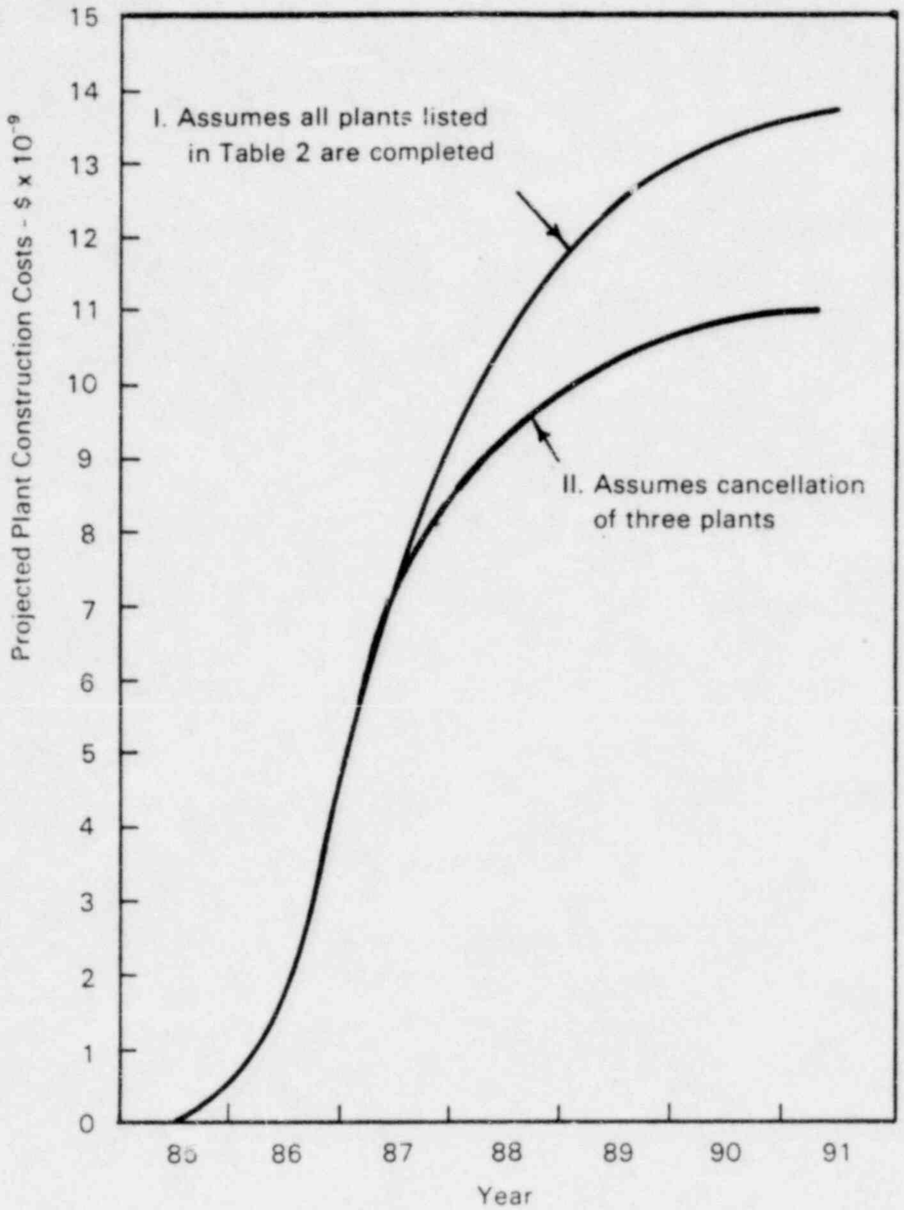

FIGURE 3. Costs to Complete Plants Under Construction

TABLE 3. Current Investment in Nuclear Construction as a Percentage of Common Equity[16]

	9/30/84	12/21/83
Louisiana Power and Light Co.	288%	282%
Middle South Energy Inc.	250	267
El Paso Electric Co.	199	209
Public Service Co., New Hampshire	187	188
United Illuminating Co.	173	159
Union Electric Co.	168	150
Consumers Power Co.	168	152
Illinois Power Co.	167	158
Kansas City Power and Light Co.	164	233
Toledo Edison Co.	161	146
Kansas Gas and Electric Co.	160	144
Long Island Lighting Co.	157	159
Philadelphia Electric Co.	140	128
Gulf States Utilities Co.	133	127
Cleveland Electric Illuminating Co.	123	109
Connecticut Light and Power Co.	122	104
New England Power Co.	120	114
Central Power and Light Co.	118	113
Arizona Public Service Co.	117	108
Ohio Edison Co.	115	117
Detroit Edison Co.	112	99
Commonwealth Edison Co.	108	98
Carolina Power and Light Co.	100	91
Central Hudson Gas and Electric Corp.	100	92
Pennsylvania Power and Light Co.	96	95
Central Maine Power Co.	93	92
Public Service Electric and Gas Co.	90	85
Georgia Power Co.	90	73
Texas Utilities	88	85
Duquesne Light Co.	88	79
Pacific Gas and Electric Co.	85	77
Rochester Gas and Electric Corp.	82	69
Public Service Co. New Mexico	73	77
Niagara Mohawk Power Co.	65	57
New York State Electric and Gas Corp.	51	43
Houston Lighting and Power Co.	47	42
Atlantic City Electric Co.	35	30
Portland General Electric Co.	32	34
Washington Water Power Co.	32	29
Southern California Edison Co.	24	25
Puget Sound Power and Light Co.	17	16
Duke Power Co.	16	25
Pacific Power and Light Co.	3	25

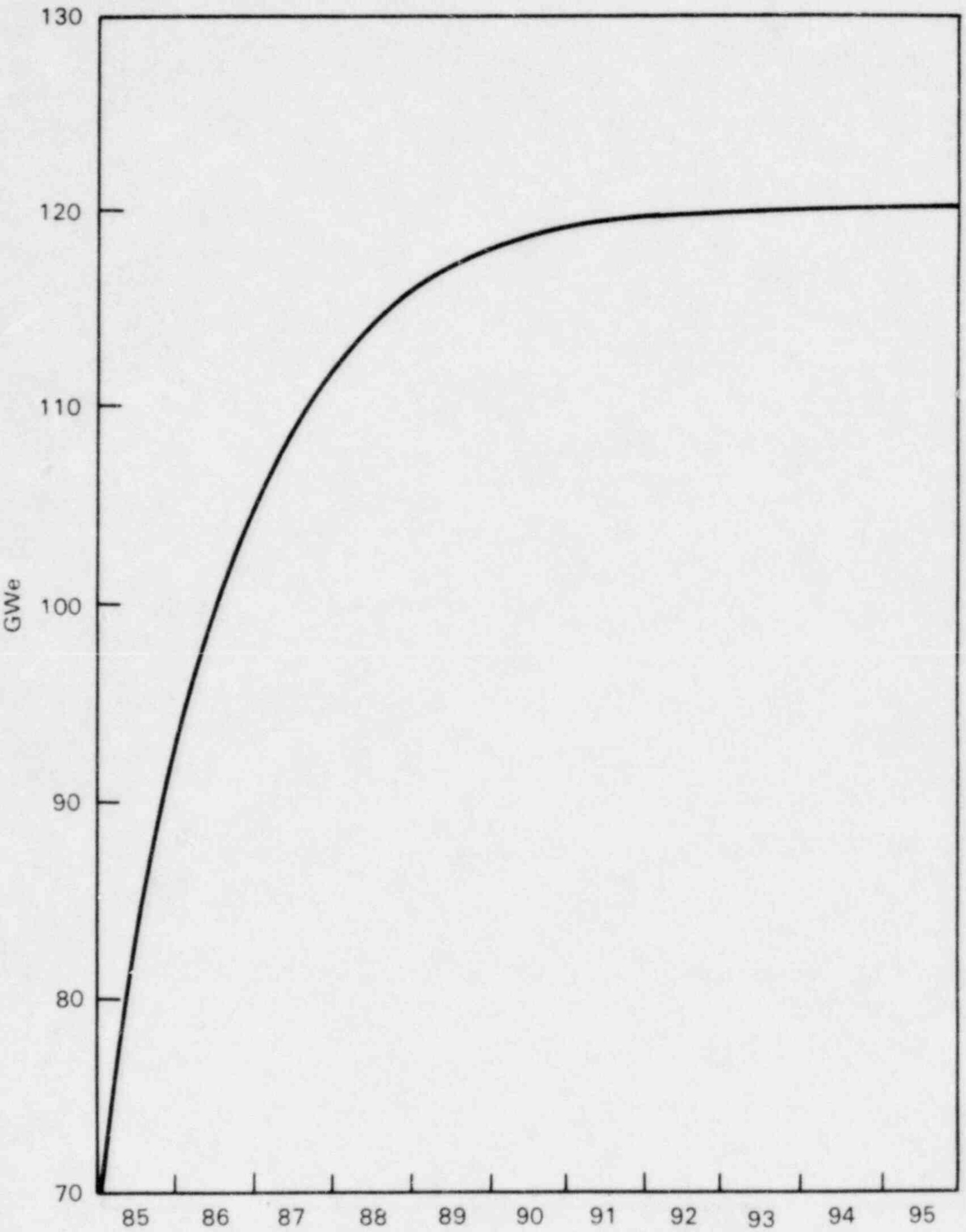

FIGURE 4. Anticipated Trend in Total U.S. Nuclear Generating Capacity - 1985-1995; Nominal Values Discounted for Expected Plant Cancellations

Nominal estimates for nuclear generating capacity over the next 10 years are broken down by NRC region in Figure 5 to provide an indication of where changes in the need for NRC inspection resources might be anticipated.

2.4 CAPACITY PROJECTION LIMITS

A variety of plausible but non-foreseeable events could arise to invalidate the nominal projections, made on the basis of current information in Section 1.0.

Postulated catastrophic events are beyond the scope of this consideration; however less severe upper and lower bounds can be posed. These could be selected arbitrarily; however it seems more meaningful to define boundaries in the context of potential real response to postulated, generic events that can be related either to historic precedent or to realistic, defensible predictions.

2.4.1 Low Projections

Barring major international events and severe domestic economic decline, the most likely non-catastrophic type of event that would negatively impact the nuclear power industry would seem to be an accident of severe economic proportions but not one in which public casualties occur, e.g., equivalent to the 1979 TMI-2 accident. A severe accident resulting, for example, in gross contamination and/or extensive loss of life was viewed as falling into the catastrophic category with the potential for impacting the industry in a manner beyond the useful scope of this study.

Using TMI-2 as a guide, the effect of another accident of similar consequences should be felt mainly in the licensing area. Other credible consequences could include more drastic effects such as state action to shut down operating plants or federal efforts to nationalize nuclear generation. If such an accident occurred and could be attributed to a major, previously unrecognized safety issue or to some fundamental deficiency in the licensing process, the consequence is estimated to be analogous to that which resulted from the TMI 2 accident. The net effects probably would be to delay the operational licensing process for approximately 2 years, to impose retrofitting requirements on some or all operating plants, and to introduce additional regulations for plants under construction. It is presumed that these added requirements would be manifest as increased costs and construction delays that would force cancellation of some projects. Since two-thirds of the plants under construction are more than 80% complete, it was presumed that most current projects would survive. The low estimate projection shown in Figure 6 - Curve A presumes the occurance of an accident that would delay issuance of operating licenses by two years and that would indirectly force cancellation of all plant construction projects that are not now greater than 80% complete. This represents a 10% decrease in long-term steady-state capacity as compared with the nominal projection (Curve B, Figure 6).

Anticipated Generating Capacity* in NRC Region

	I	II	III	IV	V	Total
12/31/84						76,000
12/31/85	20,330	27,870	18,250	6510	11,700	84,700
12/31/90	27,800	38,200	26,500	11,100	15,500	119,100
13/31/95	27,800	40,600	26,500	11,100	15,500	121,500

*MWe

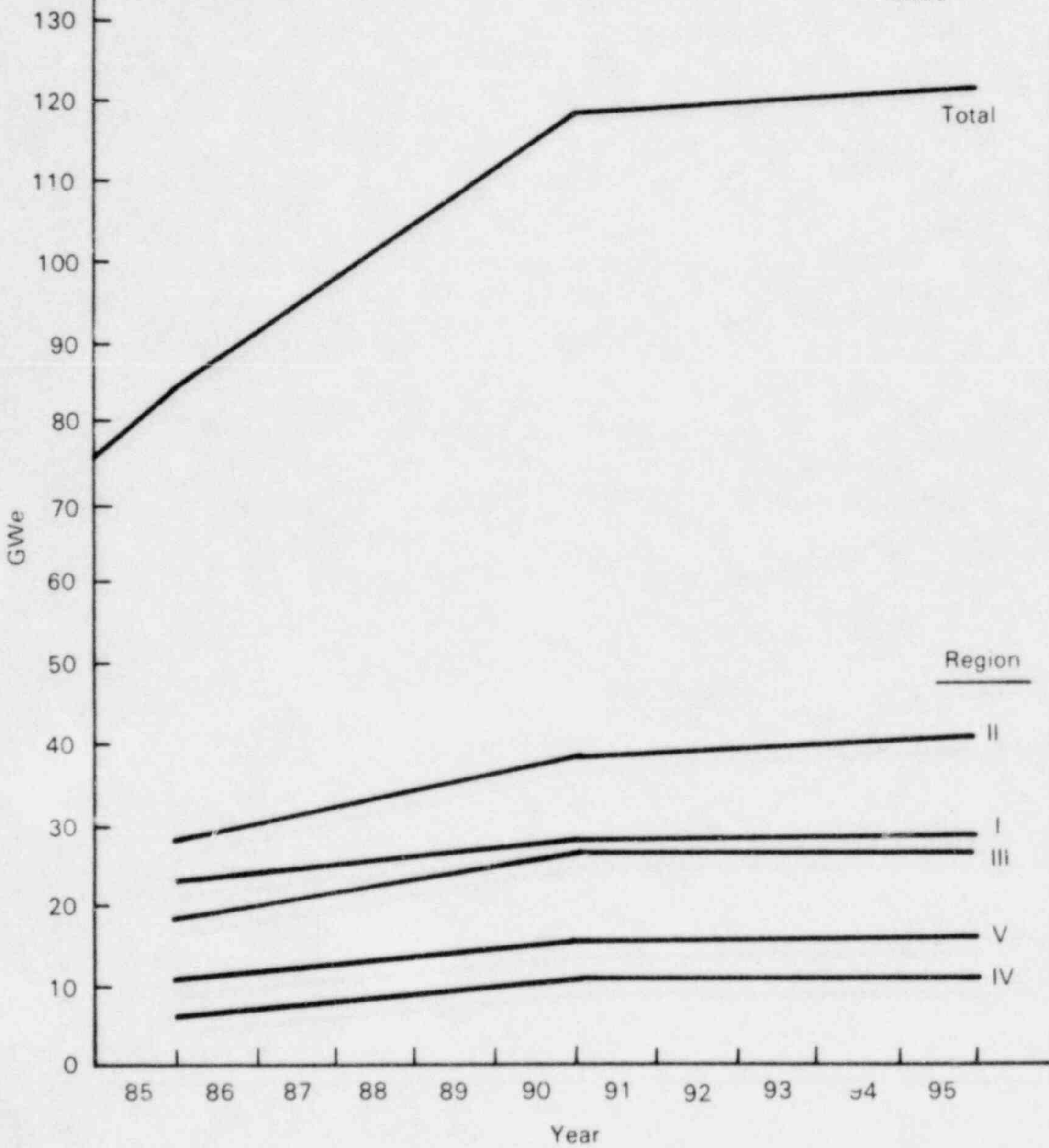

FIGURE 5. Ten Year Trend in Nominal Anticipated Nuclear Generating Capacity by NRC Region

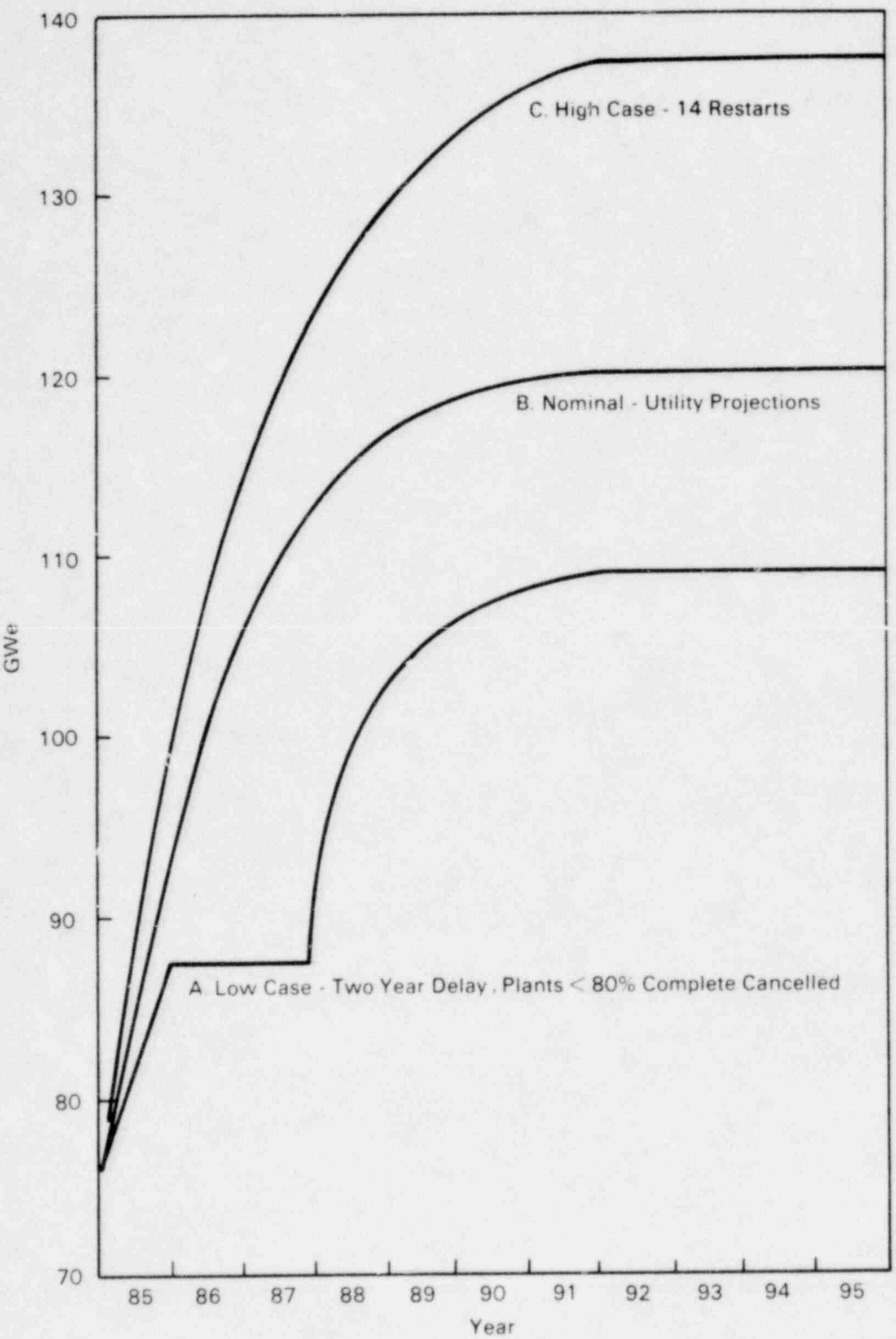

FIGURE 6. Postulated High and Low Extremes in Nuclear Generating Capacity - 1985-1995

2.4.2 High Projections

A resurgence of interest in nuclear power, from whatever source, could be accommodated by new plant orders, by reviving cancelled or faltering construction projects, or by a combination of the two.

Because of the long lead time for and lack of current interest in construction, new orders would not come on line in the 1985 through 1995 time frame. There exists, however, a substantial pool of terminated or insecure projects for which construction is well advanced. In principle, these projects (or some of them) could be revived and, given priority status, could yield usable power in a more timely and cost effective way than could new construction. Table 4 lists plants which might be considered in this context.[18] The thirteen plants listed represent 17.8 GWe which is a 15% increase in generating capacity over the nominal projections (Curve C, Figure 6). This seems an ample margin to accommodate any reasonable, arbitrary projection of a renewed need for nuclear power over the next 10 years. New construction need not be postulated as part of the high case projection; however, if it were, QA problems should not be more severe than those that would derive from restarting cancelled projects.

TABLE 4. Plants Recently Cancelled or Candidates for Cancellation[18]

Plant	Utility	MWe	Type/ NSSS	Date Ordered	Date Cancelled	% Complete	Cost to Complete ($ × 10^{-6})
Grand Gulf 2	Miss. P&L	1250	BWR/GE	72	(a)	33	2550
Limerick 2	Phil. Elec.	1055	BWR/GE	67	(a)	31	2620
Midland 1 & 2	Con. Pow.	1233	PWR/B&W	68	85	85	
Perry 2	Clev. Elec.	1205	BWR/GE	72	(a)	57	1460
Seabrook 2	PS of NH	1150	PWR/W	72	(a)	23	2160
STP 2	HL+P	1250	PWR/W	73	(a)	54	1410
WNP 3	WPPSS	1240	PWR/CE	73	(a)	75	1500
WNP 1	WPPSS	1250	PWR/B&W	72	(a)	63	1500
Zimmer	Cinn G&E	810	BWR/GE	69	84	97	1500
Marble Hill 1 & 2	PS of Ind.	2260	PWR/W	74	84	56/34	630
Yellow Cr. 1 & 2	TVA	2570	PWR/CE	74	84	35/3	
Hartsville A1	TVA	1287	BWR/GE	72	84	44	
Hartsville A2	TVA	1287	BWR/GE	72	84	34	

(a) Not yet.

3.0 PROJECTED CHANGES WITHIN THE NUCLEAR INDUSTRY - 1985 TO 1995

The domestic nuclear power community, although generally portrayed as a unified industry is, in fact, a diffuse collection of hundreds of large and small businesses. Activities in which these engage include: 1) power production and distribution (the utilities); 2) reactor vendors (the nuclear steam supply system manufacturers); 3) plant design and construction (the large architect-engineering-construction companies and some utilities and smaller firms); 4) component and equipment suppliers (many firms of all sizes--some specializing in nuclear components but most with significant markets elsewhere); and 5) nuclear services (virtually all industry segments plus many specialized firms). The nuclear power business has been characterized by change--expansion from its origins in the early 1960s to the mid 1970s followed by contraction from the mid 1970s onward. There has been no extended period of market stability. As a consequence, the individual industry segments have led a highly varied existence also. A further influence responsible for market variability has been the changing regulatory scene.

In some aspects, today's contracting market, relative stability of the regulatory base, and lack of prospects for new nuclear construction in the foreseeable future probably allow more reliable prediction for industry segments than have been possible in the past. Each segment has substantial capital- and personnel-related investments in nuclear power. It is only the smaller, more specialized firms, however, whose basic future is tied to nuclear power. Larger, more diversified companies, e.g., Westinghouse, General Electric, the major AEs, have only minority interests in nuclear power and will survive with or without further nuclear development. In this respect, the U.S. nuclear industry differs markedly from that in other countries in which large industry segments have majority commitments to development of nuclear power.

In the interest of protecting their investments, all industry segments have become increasingly competitive for a share of the declining market. In a general sense, this competition may have beneficial effects through a "survival of the fittest" process or may lead to a decline in vital capabilities. The balance will depend on a variety of complex and interrelated factors including the length of the nuclear construction hiatus; the availability and growth of similar business areas, e.g., defense-related work; foreign entry into the domestic market; the ability of U.S. firms to develop foreign markets; the perception of prospects for nuclear power; and changes in regulatory approaches.

The following discusses each of the five major industry segments listed above with emphasis on the makeup and business base of each segment. Likely responses of business activities and revenues to the projections developed in Section 1.2 are also developed. The purpose in this is to provide as realistic a base as possible for NRC QA policy and planning guidance. Large uncertainties are associated with conclusions drawn from this exercise. Each industry segment and each individual firm within each segment face somewhat different sets of problems. In addition, each segment interacts with every other segment in both contributory and competitive modes in a rapidly changing business climate. These complications are likely to lead to realities that vary significantly from today's projections; however, the following outlines a reasonable "snapshot" of industry segment prospects from a current perspective.

This section also analyzes several aspects of the "nuclear power future" that are not specific to any one segment of the industry. These include 1) foreign influence on the U.S. markets; 2) pertinent, pending federal legislation; 3) projected personnel needs; 4) power plant life extension and decommissioning; and 5) advanced technological concepts. These issues are included in this study because the nature of their resolution will influence the U.S. nuclear power industry as a whole and every segment that comprises it.

3.1 THE UTILITIES

There are presently fifty-nine private and public utilities in the U.S. which are principal owners of 120 nuclear power plants in operation or under construction. Among these, commitments to nuclear generation range from a single plant, e.g. Portland Gas and Electric, Nebraska Public Power District, to Commonwealth Edison's fifteen plants. While no U.S. utility would likely consider a new nuclear project construction start in the foreseeable future, the 93 plants currently operable and 27 units under construction will constitute a substantial part of the domestic generating capacity until well into the next century. Nearly half of the 90,000 people in the nuclear industry are employed by utilities.[19] No appreciable decrease in this number will accompany the wind-down of construction activities. In fact, the trend among utilities to increase the use of their staff for in-house work, e.g., plant modifications, outages, etc., may lead to further staffing. Some of the larger utilities are pursuing contract nuclear service work for their peers in direct competition with architect-engineer and service firms who, until recently, had the market to themselves.[20]

There exists a growing tendency among state regulating bodies to resist the rate increases necessary to pay for nuclear construction currently coming on line. A common ground cited for such action involves allegations of "imprudency" on the part of the utility in committing or allocating construction funds. Several such cases are in progress or pending, and the potential loss to utility shareholders is in the billions of dollars.[a] Such cost penalties

---

(a) As examples: The staff of the Kansas Corporation Committee has recommended that the two principal utilities responsible for the Wolf Creek Nuclear Plant be disallowed more than half of their investment in the plant. The cost to the utilities of this action, if it prevails, will be $1.5 billion.[21]

In a June, 1985 decision, the New York Public Services Commission disallowed Long Island Lighting Co. from including in the rate base $1.35 billion which was spent in constructing the Shoreham plant. The ruling, based on allegations of mismanagement is the largest of its kind ever imposed on a U.S. utility.[22]

In another June 1985 action, consultants hired by the Mississippi Public Service Commission to investigate allegations of imprudency at Grand Gulf found the utility blameless for a 300%, $2.5 billion overrun and concluded that the NRC was responsible for 15% of these cost increases.[21a]

plus the unprecedented increase in plant construction costs since 1980 have severely impaired the economic well being of several major utilities. It remains possible that some of these will be forced to seek protection under the bankruptcy laws. The power needs of their customers will assure survival of these utilities as generating and distributing entities in one form or another, however. In spite of the economic setbacks of the recent past, most of the large, mature utilities remain economically viable, and some are enjoying unprecedented prosperity, e.g., Pacific Gas and Electric, the Diablo Canyon project notwithstanding, has had record earnings in the recent past.

Several basic changes in the financial climate are frequently cited by the utilities as prerequisite to new nuclear construction. These include a stable, predictable regulatory process; provisions for including construction-work-in-progress in the ratebase; provisions for guaranteed, adequate financing at reasonable interest rates; multiple ownership of plants; and a reduction in capital and construction costs.(23) A mechanism by which the latter might be achieved involves plant standardization and licensing reform to provide for more stability and predictability in regulatory requirements. Joint ventures are receiving increased attention as a means of spreading the risk of nuclear projects. In addition to reducing the risk to individual members, multiple ownership has the further postulated advantages of providing the ability to match the capacity to which a utility commits to its projected needs, concentrating the participants' best construction and operations managers on the project, and an increased influence of a group of owners acting together to overcome problems. Disadvantages include a loss of individual independence, the need to compromise on design and other plant characteristics, initial difficulties in integrating a project team drawn from multiple sources, and the possible involvement of more than one state regulatory body. Difficulties in obtaining financing are likely to pose major barriers to joint ventures which are perceived as high risk ventures because of recent events at WPPSS, Seabrook, and elsewhere. If joint venture financing is available at all, it may be at prohibitively high interest rates. An alternative consolidation scheme might involve formation of an independent corporation to license, finance, construct, and operate new plants. Principal shareholders are envisioned to be equipment suppliers, architect-engineers, constructors, utilities, and/or other investors. Power produced from such a venture could be pre-sold to utilities under contracts that would serve as security for the project.(24)

The NRC has recently endorsed a policy of support for advanced reactors with certain design characteristics.(53) Early licensing or standardized design approval with minimal regulatory burden may be extended to plants that: 1) require fewer supplemental safety features; 2) provide more time from the onset of an emergency to critical consequences; 3) have safety systems that require fewer operator actions and less equipment; 4) feature components designed for easy maintainability; 5) increase standardization in shop fabrication to minimize potential for field construction error; and 6) require fewer components to maintain safe shutdown conditions. Designs with these characteristics should reduce the potential for severe accidents and their consequences by providing inherent safety, reliability, redundancy, and independence in the safety systems.

3.1.1 Utility Future Prospects

3.1.1.1 Nominal Projection

Assuming the nominal projection discussed in section 2.3, the situation for most utilities should not change markedly over the next two years. Pressures from state regulatory bodies for higher capacity factors and less latitude in recovery of construction costs are likely to increase. This may create some concern that financially strapped licensees might compromise quality in maintenance and operations. Some of the more exposed utilities may need to consider default and/or bankruptcy proceedings. Generating and distributing facilities will continue to function in one form or another, however, and the economic prognosis for the utility industry is generally favorable in the near term. By mid 1987, approximately ten plants will remain under construction requiring a continuing high level of NRC oversight. Several utilities will be involved in lengthy operating license hearings that will command significant NRC resources as well. Serious interest including, perhaps, concrete proposals in forming new licensee arrangements for future nuclear construction seems likely. These new arrangements (discussed in Section 3.1) in principle should not create qualitatively new problems from a regulatory perspective.

It seems likely that the presence of nuclear utilities in the nuclear services business will continue to increase. In some instances, this may lead to situations in which the same utility component is performing a function under the purview of more than one NRC group. This situation should be examined for any inconsistencies in regulatory practices. Transmission systems will be expanding to accommodate larger inter-regional and international power transfer. Improvement in the grid system can compensate regional capacity shortages. There has been a trend, which is likely to continue, for utilities to diversify into non-power related businesses.

By 1990, essentially all plant construction will be complete and most of the long, costly procedures associated with obtaining operating licenses should be over for both the licensees and the NRC. The frequency of construction-related allegations should have diminished sharply; but intervenor activities, rather than declining, will likely be refocused on operating plants, radioactive materials transport, and waste isolation. Pressures by state regulators for disallowance of some construction costs will continue and may have intensified; however, there should be no remaining questions concerning the solvency of individual utilities. Licensee involvement in the services segment should have grown some and probably stabilized. Some parts of the country may be experiencing power shortages (the south, middle south, far west and northeast). To some extent, these will be accommodated by expanded transmission systems, but a clear need will exist to construct new generating facilities. The most widespread current belief is that these will probably use fossil fuels; however, under some circumstances, nuclear plants may be an option. These may be of a standardized, advanced design that provides greater safety assurance than do contemporary plants or may be custom designs in an advanced stage of design completion. The NRC presence in design and construction of these plants is likely to be more intense in the early stages because of quality problems which arose, in part, because of too little NRC oversight. It will be important that a cadre of personnel, inspectors and others with design and construction experience be retained and that the lessons learned from the QA problem plants of the 1970s not be lost.

A growing problem for plant operations is lack of availability of replacement parts and components that are identical to the originals. In some cases, the original supplier is out of business or no longer produces the part in question. Frequently, the original component has become obsolete because of advances in the state-of-the-art. A licensee may find it desirable or necessary to replace with items the use of which requires redesign and modification of plant systems. This re-engineering should be of concern to the NRC to the extent that it may impact safety systems or original plant design bases or may introduce heretofore unanalyzed safety questions.

By 1995, rate base and licensing hearings will be concluded and the nuclear generating industry should have achieved a stable, relatively low profile condition. The physical and financial debacles of the 1970s and 1980s will be over. Utilities should, in general, have resumed their traditional, financially stable role with a stable presence in the nuclear services business and more diversified business bases. Transmission systems should be optimized as should operations and maintenance practices at operating nuclear plants. Substantial new generating capacity, some of which may be nuclear, will be under construction. It seems likely that, over the next ten years, public attitudes toward nuclear power will become more positive. Historically, resistance to new technology has been the norm, e.g., electricity, automobiles, air travel, and steam boilers. A similarly evolving perception of nuclear power may lead to a more favorable climate for new nuclear construction by 1995 provided a safe, economical operating record is compiled in the interim.

3.1.1.2 High Projection

A resurgence in demand for nuclear power resulting in reactivating mothballed plants and/or new construction starts should, in general, have positive consequences for the utilities. Sunk costs in presently stalled projects would be recovered, all or in part, and the economic picture for licensees with investments in these plants should brighten considerably. Improved economic prospects for the utilities may afford them greater latitude in refinancing bonded indebtedness at lower interest rates. An unknown, but potentially significant, dampening factor will be the extent to which state regulators resist inclusion of construction costs in the rate base.

A scenario that includes construction restarts presents the greatest near-term challenges to the NRC. The incentives for restart as opposed to new construction are: 1) to obtain new capacity more quickly and 2) to obtain new capacity more economically by using the structures, components, and systems that have already been purchased and assembled. In many cases, existing construction and components may not conform to contemporary regulatory requirements or documentation confirming that they do may either not exist or be very difficult to reconstruct. In addition; effects of long term deactivation and storage will have to be assessed. As an example of deterioration in storage, during the recent (August 1985) startup of Diablo Canyon 2, source range equipment failed repeatedly from inexplicable causes (dust accumulation was one suspected culprit). Although this equipment is "new" in the sense of never having been used, it has been in storage for eleven years. It will be particularly beneficial in structuring quality programs for standby projects to have current guidance on storage, records, and requalification requirements. NRC policy definition, quality requirements and perhaps some continuing inspection presence at mothballed plants will be necessary to achieve the level of quality assurance required to permit their reactivation.

With a near-term revitalization of the nuclear industry, the financial status of affected utilities would improve over the next two years. In fact, any expansion beyond the nominal projection presumes more favorable treatment from the money markets and state regulators. A more active interest in new types of licensees or institutional configurations would likely develop as would greater interest in standardized and advanced plant design. Small plants, both nuclear and fossil, which perturb the rate base relatively little would receive more attention.

Within five years, construction on restarted plants would be in full swing with utility and NRC inspection staffs at full complement. New institutional configurations may be realities, and planning and possibly orders for standard and advanced nuclear plants would be in progress. Utility involvement in the service business would probably expand.

By 1995, all restarted plants would be in operation and construction of a new generation of advanced and/or standard plants should be underway.

3.1.1.3 Low Projection

Another TMI 2-equivalent incident would severely impact the utilities. Such an event would be expected to precipitate a new round of hearings, rule making, and anti-nuclear reaction. These would probably result in costly delays, backfits, construction project terminations, and possibly some plant closures. Some of the more vulnerable utilities would probably not survive in their present form. Conversely, if TMI 2 is representative, a second, similar incident could create a need for increased NRC resources. Over the time period immediately preceding and following the TMI 2 incident, the NRC budget grew from $281 M (1978) to $448 M (1981) and the staff increased from 2960 to 3350. Increased regulatory activity would, of course, be necessitated by and focused upon whatever new generic safety issues were revealed by the incident. While these cannot be specifically anticipated, quality concerns would likely be involved.

Over the next two years, assuming a new incident, the licensing process would probably be effectively suspended as new regulations aimed at preventing recurrences are developed and implemented. The costs associated with this delay and likely resulting backfitting requirements may devastate some licensees. Possible mandated closure of selected plants (most likely older units where upgrading has been resisted) could be similarly damaging to others. Resulting cost increases would set the stage for increased resistance from

State Utility Regulating Agencies (SURAs) to rate increases. It is likely that any hope or plans for future new nuclear construction would be abandoned.

By 1990, construction on surviving projects should be nearing completion. Unit costs of these plants would be higher than ever before placing pressure on SURAs to disallow many of them from inclusion in the rate base. This would further economically damage the utilities involved encouraging them to save money wherever possible. Should this happen, quality, and perhaps safety, could be compromised--especially in the balance of plant. The NRC should remain alert to these possibilities.

By 1990, the industry would have stabilized with approximately 110 operating plants. These would continue to operate for the duration of their useful lives including, perhaps, some life extension after which they would be replaced by non-nuclear generating facilities.

3.2 NUCLEAR STEAM SUPPLY SYSTEM VENDORS

The Westinghouse Electric Corporation and the General Electric Corporation share most of the credit for the development and growth of commercial nuclear power in the U.S. and throughout the world. These companies perceived the economic promise of nuclear power and, through their involvement in early nuclear defense efforts, infusion of government funding, and aggressive marketing to utilities during the 1950s and 1960s, provided the main thrust for commercial nuclear power development. Through agreements with foreign licensees, Westinghouse and General Electric technology formed the basis for most nuclear power programs in the world. Several other firms launched early NSSS ventures. Two of these, Combustion Engineering and Babcock and Wilcox, established and maintain viable presences in the market place. They, together with GE and Westinghouse comprise the group of four NSSS manufacturers that has supplied virtually all of the commercial reactors sold in the U.S. and many of those built abroad.

As previously noted, all new plant construction is expected to be complete by 1991. The steam supply systems for remaining plants under construction have been completed, and all that remains to be done is some onsite assembly work. Table 5 lists the number of plants under construction grouped according to NSSS supplier and Table 6 shows all plants-both complete and under construction.[12,13,14]

Westinghouse has now and has had the major share of the market with General Electric in a strong second place. Construction-related activities for the NSSS vendor peak early in a project and begin to decline markedly when the plant is about 50% complete. Business volume for all four vendors is, thus, already much reduced from what it was a few years ago and is rapidly converging to zero around the end of the decade.

The high projection discussed earlier postulates restart of construction on fifteen plants that have been or may be terminated before completion. If

TABLE 5 NSSS Vendors and Anticipated Completion Dates for Plants Under Construction Which are Expected to be Completed

1. Westinghouse
   - Total under construction: 15
   - Expected completion 1986: 6
   - Expected completion 1987: 6
   - Expected completion 1988: 2
   - Expected completion 1989: 1

2. General Electric
   - Total under construction: 5
   - Expected completion 1986: 3
   - Expected completion 1988: 1
   - Expected completion 1991: 1

3. Combustion Engineering
   - Total under construction: 2
   - Expected completion 1986: 1
   - Expected completion 1987: 1

4. Babcock and Wilcox
   - Total under construction: 2
   - Expected completion 1989: 1
   - Expected completion 1991: 1

TABLE 6. NSSS Vendors Plants in Operation and Under Construction in the United States (greater than 100 MWe)

	In Operation	Under Construction
Westinghouse	42	15
General Electric	33	5
Babcock and Wilcox	9	2
Combustion Engineering	12	2
	96	24

this were to occur, the reactor vendor's business may be revitalized to some extent (see Section 3.2.1). The terminated plants include four Westinghouse units, six General Electric units, two Combustion Engineering units, and three Babcock and Wilcox units ranging in degree of completion from 31% to 97%.

The low projection involves only a delay in current construction projects and would not have a direct, negative impact upon NSSS vendors. If the assumed accident that triggered the delay resulted in a flurry of backfit and other plant modifications similar to those precipitated by the TMI-2 accident, substantial new business might accrue to the reactor vendors (see Section 3.2.1).

The need for engineering talent in reactor design and manufacturing is dropping sharply and is expected to continue to fall at the rate of approximately 10% per year over the next several years. This decline is somewhat offset (but not reversed) by personnel needs in fuel design and production and in providing service to operating plants.[25] The latter two business areas represent the main hope for NSSS vendors to maintain a cadre of skilled technical people for the foreseeable future. The need for reactor fuel reloads will increase as more plants come on line here and abroad thus providing an expanded market for former reactor vendors. NSSS suppliers are also competing more actively for a share of the nuclear service business once left to smaller, more specialized firms.[20] Remaining and anticipated plant backfits and rework will also provide markets for the reactor vendors--perhaps requiring the services of 3000 to 6000 technical personnel for several years.[25]

A significant casualty of the decline in NSSS business volume has been their R&D efforts. Technology development is needed for both product improvement and for status in the market place. The loss in technical reputation suffered by the U.S. vendors because of their reduced R&D programs has damaged some of their sales prospects--particularly overseas. This trend has been countered to some extent by nuclear development work and research for the Navy, DOE, and EPRI.[25]

Westinghouse and General Electric have entered into joint ventures with the Japanese for design of new plants. The Westinghouse project, which is being developed in consultation with the NRC, anticipates both foreign and domestic demand while the General Electric concept is intended for the Japanese market only. Both companies have foreign marketing plans, but U.S. nonproliferation policies and favorable, state-subsidized financing available to the foreign competition represent major impediments to overseas sales. Most countries have policies that discourage nuclear imports and competition from other international vendors, especially the Japanese, Germans, and French, has become intense. The recent agreement by the U.S. to make nuclear technology and products available to China may presage substantial business for the NSSS vendors.

The reactor vendors are being further burdened by the decline in qualified nuclear component suppliers (see Section 3.4). Of the approximately 200 qualified suppliers from whom each reactor vendor has traditionally procured components, fewer than 100 are expected to remain in the business by 1990. This decline will result in higher costs and possible unavailability of certain components and may require reactor manufacturers to expand their internal production capabilities.[25]

To date, facility cancellations may have already reduced the U.S. capacity to supply nuclear power plants by as much as two-thirds. The common speculation is that, at a minimum, two of the four major vendors will not long survive (the projected casualties most often cited are Combustion Engineering and Babcock and Wilcox). Similar predictions have come and gone for years, however, without materializing.

3.2.1 NSSS Future Prospects

3.2.1.1 Nominal Projection

In the most likely scenario, within two years, NSSS fabrication for all domestic plants will be complete and the associated personnel and facilities either shifted to other activities or terminated. Many key personnel will likely gravitate to service organizations or to the utilities. Some manufacturing and engineering capabilities will be retained to serve a limited foreign trade and to build replacement fuel for existing reactors. The NSSS manufacturers are expected to continue forging partnerships with overseas concerns in efforts to further penetrate the foreign market and with AEs and other domestic firms to establish stronger positions in the services business. Reactor vendors will continue to promote advanced concepts, including standard designs and turnkey projects, and will be involved in the planning and promotion for new institutional configurations and regulatory reform.

By 1990 or earlier, manufacturing and engineering will have been reduced to the minimum needed to support fuel reload requirements and foreign commitments. Reactor vendors will be party to more connections with both foreign and domestic firms and may be experiencing some expansion in service-related business and in foreign orders. A shortage of parts and component suppliers may force the NSSS vendors to do more specialized manufacturing in-house or to order from abroad. Either eventuality would pose new problems for the NRC in terms of supplier qualification and inspection. Standard and advanced plants will be actively promoted and marketed, and the NSSS vendors are likely to be key participants in emerging new institutional configurations. Possibly one or two of the four major vendors will have abandoned the NSSS business.

Through 1995, the reload business will continue at a stable, profitable level and service and foreign business should grow moderately. An advanced plant demonstration or commercial unit may be under construction. The NSSS vendors will be increasingly involved with decommissioning, waste storage, and life extension. They are also likely to be lead actors in new institutional arrangements. Increased internal fabrication and/or foreign procurement of components and equipment will continue.

3.2.1.2 High Projection

A revival in nuclear construction would have general, very positive effects for the NSSS vendors. Over the next two years, less or perhaps no decline in engineering and manufacturing capability would occur as NSSS work in support of restarted projects begins. Promotion and development of standard and advanced design would intensify as would efforts to form new institutional arrangements and to capture more of the service business.

By 1990, the reactor vendors should be active in developing and marketing standard and/or advanced plants--either as independent suppliers or as key figures in new institutional configurations. Basic engineering and manufacturing capabilities would be intact. Reduced decline in component suppliers would require less in the way of foreign procurement or internal manufacture of components and equipment.

By 1995, NSSS business should be in a growth mode--perhaps for all four current major vendors. New sales of standard, advanced, and/or turnkey projects should have been made and manufacture of these is likely to be in progress.

3.2.1.3 Low Projection

The low projection scenario would provide some short term business stimulus in the form of design modifications and backfit-related work; however optimism for future NSSS business would disappear and the departure of personnel and some of the current vendors from the field would probably be accelerated. The only long term sustaining activities would be the reload business, a reduced service business, and some foreign involvement. Within two years, manufacturing and engineering capabilities would be reduced to the minimum commensurate with existing business. Plans for advanced designs and new institutional arrangements will have been abandoned.

By 1990 the traditional, domestic NSSS business will have ceased to exist. The reload business and some overseas involvement with foreign firms will continue as will NSSS vendor participation in the service business. The latter area may have been stimulated by the accident assumed in the low projection.

The situation in 1995 should be similar to that in 1990 with some additional general decline in all markets.

3.3 ARCHITECT ENGINEERING AND CONSTRUCTION FIRMS

Architect Engineering and Construction Companies (AE/Cs) have a broader market base than do other segments of the nuclear industry infrastructure. Consequently they have been and will be less severely affected by the decline in nuclear construction. (These firms have suffered setbacks but these are mainly attributable to the slowdown in total heavy construction in the U.S. during the past few years of high interest rates and general recession.) The

AE/Cs have major business volumes in many non-nuclear areas including petrochemical plants, industrial process heat applications, cogeneration, coal technology, fossil-fueled power plants, and a wide variety of other large construction projects. Given anticipated increased electricity capacity needs, the AE/Cs will reap the benefits of new plant design and construction whether a generating facility uses coal, uranium, or other energy sources.[25]

As with the NSSS suppliers, the AE/Cs have a sizeable backlog of nuclear work related to completing plants under construction, backfits, and plant upgrading and modification. If a significant number of cancelled projects were revived, most of the associated costs would take the form of increased business volume for the AE/Cs. The pessimistic scenario posed earlier would not diminish the cumulative AE/C business but would stretch current projects over a few more years. In the process, regulatory reaction to the postulated accident and normal escalation would probably increase AE/C workload and revenues.

Plant decommissioning will provide major business opportunities for the AE/Cs as may plant life extension depending upon technical and regulatory requirements. These activities will not generate major business volume until near the end of the century; however some decommissioning work will begin sooner, e.g., at Shippingport, West Valley, Humboldt Bay, and Hanford.

The AE/Cs have component supply problems qualitatively similar to those of the NSSS vendors; but because much of what they produce is of a more generic nature (concrete and steel structures, for example) these problems are less pervasive and severe.

Nuclear projects are relatively labor intensive; however, for the most part, the project management and construction skills required are common to other large projects. AE/C staffs are thus more easily diverted, assuming other needs exist, than are the staffs of other industry segments. Probably because of a general business decline, the AE/Cs, like other industry segments, are extending their marketing horizon further into the nuclear services area and perhaps into overall project and plant management.

3.3.1 Architect Engineer Future Prospects

3.3.1.1 Nominal Projection

A continuing general decline in AE and construction business is expected. The growth in other projects will fail to compensate the massive personnel needs characteristic of nuclear construction, and general force reductions will occur. Fluctuations of this sort are common in the construction business and are thus likely to be relatively easy for the AE/C firms to accommodate. Many key personnel will join the ranks of the utilities or service organizations.

Over the next two years, most of the basic construction of plants in progress will be completed. Backfit-related work and plant modifications will continue but at a combined, reduced level. The AE/Cs will be participating with the NSSS vendors and others in exploring new institutional configurations in which they are likely to be major participants. Major involvement in the services business and foreign nuclear projects should continue for the AE/Cs.

By 1990, AE/C nuclear staffs should be stabilized at minimum levels. Plant construction and most backfitting will be complete. Continued, stable business in the services sector and in plant modification is expected. Planning for new projects involving new institutional configurations should be well along. These are likely to include partnerships with NSSS vendors in advanced, standard, or turnkey plant proposals.

In ten years, new capacity needs, fossil, nuclear, or other, will have created new business for the AE/C firms with a resulting growth in staff and capabilities. There will be a growing involvement in decommissioning, life extension, and waste isolation. By 1995, the AE/Cs are likely to have a major role in new institutional arrangements involved in advanced, standard, and/or turnkey projects.

3.3.1.2 High Projection

A resurgence in nuclear construction would have a strong positive impact on business for the AE/Cs. Over the next two years, lay-offs now in progress should cease and perhaps be reversed as planning for project restarts gets underway. The increased long-term potential in the service business would probably encourage AE/Cs to expand their already substantial presence in that sector.

By 1990, major construction at restarted projects would be in progress but beginning to wind down. Compensating this somewhat should be substantial involvement of the AE/Cs in advanced, standard, and/or turnkey projects, which should be in design stages. The AE/Cs may have an owner as well as a prime contractor interest in these plants. The service business will continue to be strong.

Business in the mid 1990s should be strong and growing for the AE/Cs as commitments for new capacity of all types are implemented. Design and construction of new nuclear plants should be a major and growing business area. The service business, decommissioning, life extension, and waste isolation will continue to be important business areas.

3.3.1.3 Low Projection

The assumed low projection could result in a near term boost in AE/C business because of backfit and design change requirements precipitated by the hypothetical accident. This would be balanced by possible project terminations or slow downs. Over the next two years, some new backfitting work may develop and construction on current projects is likely to continue. Termination of projects would have an immediate, adverse effect on AE/C business; however delays may ultimately result in more revenue. New nuclear construction will cease to be a factor in long range business planning.

By 1990, nearly all construction will be complete as will most staff reductions. A moderate level of service, backfitting, and plant modification work will continue.

By the mid 1990s work will continue on an as-needed basis on plant modifications, decommissioning, and waste-related activities. The traditional nuclear design and construction experience base of the AE/Cs effectively will have ceased to exist except for isolated, knowledgeable individuals who have moved into non-nuclear business areas.

3.4 NUCLEAR COMPONENT AND EQUIPMENT SUPPLIERS

Nuclear component vendors have been more severely affected by the hiatus in nuclear-construction than any other segment of the industry. Companies that serve the backfit and plant modification market and/or have non-nuclear markets are in comparatively good condition, and most of these that are otherwise basically sound should survive the loss of the nuclear market. Many component suppliers, however, have focused on specialized nuclear items used primarily in new plant construction. These have been and will continue to be the most likely casualties.[25,26]

The decision to resume construction on a number of cancelled plants would be directly reflected in increased business for component suppliers. This may not represent a major boost in business because most cancelled projects had already acquired much of the component and equipment inventory needed to complete construction. For similar reasons, the low case scenario, in which a postulated, non-specific accident introduces delay into current construction schedules, should have little impact on the demand for components and equipment. Regulatory-decreed backfits, which might be precipitated by such an accident, would create some new opportunities for component suppliers (see Section 3.4.1).

One indication of the decline in the population of component suppliers is the proportion of sole source orders placed by utilities. This proportion has approximately doubled over the past 10 years from 15-20% to 30-50%. This trend has been accompanied by a general increase in prices--both because of less competition and because, with declining sales, the cost of nuclear quality assurance must be allocated to fewer units. Delivery lead times have also increased because of the practice of grouping orders and the reduced incentives for suppliers to be responsive.[24,25]

A second indicator of the general well-being of the component supply industry is the number of firms applying for or renewing "N-stamp" certificates. The N-stamp certificate is issued by the American Society of Mechanical Engineers (ASME) to manufacturers who meet the requirements for Class I components as defined in Section III of the ASME Boiler and Pressure Vessel Code. The N-stamp is accepted by NRC as qualification for components which comprise the pressure boundary in a nuclear plant (see 10 CFR 50.55a and 50.2 (v)).[27,28]

Initial certification and mandatory triennial renewals of N-stamp holders is done by the ASME, which charges a nominal fee ($5,000 to $15,000). The process may extend over 6 to 12 months, and the costs to the supplier for maintaining a dedicated portion of his plant and additional employees to execute required paperwork ranges from $25,000 to $150,000 per year. For small firms, this represents a significant investment. A major fraction of the costs and of the typically 2 to 3 times higher cost of certified versus non-certified, identical components derives from analytical and QA requirements. No other manufacturing operation, including work for NASA, DOD, and the Nuclear Navy Program, requires the detailed paper trail specified for commercial nuclear plant components.[25,26]

Several categories of N-stamp certifications are issued including N (nuclear components); NA (nuclear assembly); NV (nuclear safety and relief valves); MM (material manufacturer); MS (material supplier); OWN (owner); and INL (internal authorization). Trends in the issuance of the first of these (N-nuclear components) are most indicative of the economic state of component manufacturers. Since the TMI-2 accident in 1979, the number of organizations holding N-stamps has declined from over 300 to approximately 100.[28] About one-third of the latter number are foreign concerns, which seek certification for their export market. The number of foreign N stamp holders has remained essentially constant since 1979.[25] By any standards, the factor of three decline in certified manufacturers is a precipitous drop. There are mitigating circumstances that temper the significance of the trend to some extent, however, e.g., the fact that most companies that have opted to allow their certification to lapse had not been successful in their bid for nuclear contracts. Presumably, when these companies observed the end of the expanding market and the beginning of decline, they recognized the futility of their position and elected to invest no further in N-stamp certification. In addition, some of the decline in N-stamp holders is attributable to expiration of site-specific certificates that were not renewed after project completion.

The decline in business for component suppliers has been further leveraged by the availability of surplus components from cancelled plants. Optimum use of these would portend no market, except for replacement needs, for additional components from the present into the foreseeable future. In practice, the utility of parts and components from cancelled plants is limited because of lacking QA documentation, warranties, and accessories.

Changes in the component supply sector have created problems for the utilities in obtaining replacement parts. As plants grow older, parts and components, identical to the originals, in some cases become difficult or impossible to obtain. This seems to be a particular problem with instrumentation and control systems. This happens for various reasons: companies go out of business or discontinue nuclear lines, designs change with advances in the state-of-the-art, manufacturing processes or tooling are changed, etc. In the absence of identical replacement parts, design and modification of plant systems may be necessary. This is a costly process for the utility that may also introduce changes that require NRC review and approval and that may serve as a basis for requiring more general plant upgrading.

In general, the outlook for domestic nuclear component suppliers is discouraging. Companies most heavily involved in the business have seen their revenues decline most and soonest. The attitude of component suppliers is one of skepticism about re-entering the nuclear business even if new plant orders are placed. Expectations are that other business areas will offer better opportunities than will the nuclear industry.

In the event of a resurgence in nuclear power, the relatively short time required for obtaining N-stamp certification (less than 1 year) should allow recreation of lost capability in time to provide qualified parts as they are needed.[27]

3.4.1 Component Supplier Future

3.4.1.1 Nominal Projection

Business for the component suppliers will continue its rapid decline. Over the next two years, as many as 50% of the firms currently listed as qualified suppliers may have left the business. Some suppliers may attempt to penetrate foreign markets but it is likely that the reverse process--foreign entry into the domestic market--will predominate.

By 1990, the nuclear grade component and equipment supply sector, as traditionally constituted, will be greatly reduced. Surviving firms will provide replacement parts and equipment. Components which must be replaced periodically to maintain their environmentally qualified status will constitute a major portion of the market. Prices and delivery lead times will have increased appreciably. Utility requirements to "engineer around" parts and components or to buy from foreign firms will provide new challenges to the NRC in evaluating design changes and foreign qualifications.

The market in ten years will continue to be minimal. Many new and replacement parts may be purchased from abroad. Some new business potential may develop in connection with life extension and waste isolation programs, but foreign suppliers may have the advantage here also.

3.4.1.2 High Projection

Restart of a number of projects would increase business to some extent for component suppliers. Since most equipment and components for these plants have already been purchased, the effect is likely to be small. (Some electrical equipment and instrumentation which is installed in late phases of plant construction may be an exception to this.) New construction starts would have a much larger impact and would probably lead to issuance of new N stamps. Over the next two years, business decline should be less; however, the more attractive U.S. market may result in keener foreign competition.

By 1990, a basic industry core serving a reduced but viable market should have been achieved. The foreign presence in the U.S. market, either directly or through acquisitions, will be a major one.

By 1995, the component supply business should be healthy and growing assuming that a new generation of nuclear plants has been started. There will continue to be strong competition from foreign firms and, perhaps, from in-house efforts by the NSSS vendors.

3.4.1.3 Low Projection

The low case projection could yield increased business for component suppliers because of new backfitting requirements and a possible extension in the regulatory envelope. Some of these effects would occur over the next two years. A major accident in the U.S. would probably have adverse impacts on foreign as well as domestic nuclear programs. This may dampen foreign interests in the American market because of overall discouraging long term business prospects or could intensify foreign competition because of a contraction in the domestic markets in other countries.

By 1990, stimulus to the business that resulted as a by-product of the hypothetical accident would continue to have a positive but declining effect.

By 1995, the component supply segment will probably be significantly reduced and concentrated. Replacements will be more difficult to get and more expensive. The contraction in the market may result in quality problems if the net effect is to relegate nuclear components to a much reduced status in the business plans of suppliers. Conversely, concentration of the supply segment within a few companies will simplify quality assurance monitoring and may have the further beneficial effect of eliminating marginal firms which pose the greatest quality concerns.

3.5 NUCLEAR SERVICES

The nuclear service segment is a relative newcomer to the industry. It is also, currently, the only expansive segment. Over the past 20 years, as plants have become much more complex, the spectrum of special maintenance, operation-related, and technical support activities have expanded greatly. Rapidly increasing plant costs in this same time frame have provided major incentives to the utilities to minimize down time and maximize capacity factors. Few, if any, utilities permanently retain sufficient staff to efficiently cope with outages, backfits, plant modifications, and other major, intermittent activities that require specialized personnel and equipment and large amounts of readily available manpower. The nuclear service business has evolved to provide support to the utilities in these activities; and the utilities have become accustomed to calling upon specialized, outside firms for assistance.

Another factor which has stimulated the growth of service firms is the relatively low salary structure characteristic of at least some utilities. The most capable people can earn more working under contract to a utility. This leads the best talent to migrate to service firms which in turn renders their services more in demand by the utilities.

The range of services to which utilities subscribe is very broad. Service firms provide support in fuel management, training, security, environmental services, licensing, personnel administration, engineering analysis, records management, QA, quality control (QC), radiation protection, startup service testing, inspection, operations, maintenance, backfit engineering, waste management, laboratory services, management audits, system cleaning and decontamination, specialty tools and equipment, equipment repair and replacement, emergency preparedness, and procedure preparation to name a few. Approximately 1,000 firms are involved. These tend to be small, specialized concerns, often employing twenty or fewer people, which serve a limited market segment-both geographically and in terms of specialty. The major firms in the services business employ as many as 1,500 to 2,000, offer broad ranges of services both domestically and internationally, and maintain full-scale operations extending to research and development.[29] The largest of the nuclear service firms and their approximate annual business volume are NUS Corporation ($80-90 million); IMPEL ($80 million); QUADREX ($50 million); NUTECH ($30-40 million); Nuclear Engineering Services ($30 million); Management Analysis Corporation ($27 million); TERA ($25 million); TELEDYNE ($15 million); and Engineering, Planning, and Management ($10 million).[20]

The American Nuclear Society Buyers Guide provides an indication of the present extent of the nuclear services business.[30] The current guide contains over forty categories of services listing the names of nearly 700 firms. These include NSSS vendors, engineering firms, engineering constructors, laboratories, academic institutions, fabricators, component manufacturers, divisions of industrial conglomerates, nonprofit research institutions, many foreign firms, individuals, partnerships, small firms, small to medium size firms, single discipline or multiple discipline engineering or scientific companies, labor brokers, personnel agencies, single discipline contractors, etc. Although the legal community is not included in these listings, they represent a very large part of the system.

Annual revenues for the service business are estimated at $2 to $2.5 billion distributed as follows: specialized service firms--25%; NSSS suppliers--30%; architect-engineers--45%. Business volume is expected to increase as more plants come on line making this the only expanding market on the nuclear power horizon. This, coupled with the decline in markets in other industry segments, has led to more competition for service work from reactor vendor and architect engineer firms.[20]

The NSSS suppliers, with skills that address all facets of the service business, have experienced major declines in their traditional markets. In an effort to offset these reverses and preserve their basic technical capabilities, the reactor vendors have begun to aggressively pursue service-related business. In so doing, they have certain intrinsic advantages, e.g., extensive, first-hand knowledge of specific plants and equipment; established, recognized presence in the nuclear business; and an interest on the part of the utilities in the long term survival of the NSSS vendors. Both of the major NSSS vendors have recently made strong moves into the services market. General Electric has announced plans to capture the high technology portion of the

$2.5 billion international BWR services market including low level waste disposal, remote control pipe inspection, maintenance and training, plant-life-extension-related work, decommissioning, and waste disposal.[31] General Electric has also entered into a joint venture with Stone and Webster to manage Gulf States Utilities $30 million parts inventory for the River Bend reactor. The combine, named Nuclear Parts Associates, expects to negotiate similar arrangements with several other utilities.[32] Westinghouse is investing $7 million over the next 5 years in developing facilities, hardware, and software for implementing computer-based expert systems. The intent is to provide utilities with fast turnaround expert guidance in whatever technical or operational NSSS problems arise. Westinghouse has also contracted with Virginia Power Company (VPCO) to provide services required to maximize operating efficiency of the Surry reactor[33] and is pursuing similar agreements with six other utilities including Tennessee Valley Authority (TVA).[34] Many additional, short references to NSSS supplier inroads into the services business can be found in trade publications.

Some of the major utilities have also entered the services market place as vendors. These companies have developed large, capable staffs to build and service their own plants. As these units are completed, delayed, or cancelled, some utilities are left with a surplus of talent that they can retain for their future needs through providing services to other utilities. It is not uncommon for a utility to spend in the vicinity of 30% of its operating and maintenance budget on outside work--an economic base for supporting a sizeable staff.[20] Utilities also consider in-house work to be more economical, easier to control, and likely to reflect a higher level of staff commitment. In spite of these positive aspects of doing the work in-house, for most utilities, maintaining the varied, large staff and specialized equipment required to meet all or most of their service needs is not feasible.[20]

The architect-engineer firms perform the largest dollar volume of service work because of their involvement with expensive projects such as major plant modifications and backfits. Work of this nature will continue into the foreseeable future and may eventually be augmented by decommissioning and plant life extension. Compared with NSSS vendors, however, the AEs are under less pressure to diversify since their staffs can be diverted to construction of fossil fuel plants and other large construction projects. Some of the AEs have moved into the parts and equipment warehousing business in partnership with utilities or NSSS vendors,[32] and some have established service divisions which they are actively promoting.[29] In general, however, engineering and construction firms have been less aggressive in expanding their service business than have the other segments of the nuclear industry.[29]

The future of the nuclear services industry is clouded by the influence of regulation in determining what services will be needed. New regulations imposed following the TMI-2 accident were responsible for the creation of much of the service business as we know it today. New work of a "one-time-fix" nature, e.g. backfits, is winding down while work of a continuing nature, e.g. training, QA, security, will provide a market for service vendors into the foreseeable future. As new plants come online, the need for services will increase in direct proportion to the number of operating units.

With the transition from a composite industry, with plants both under construction and in operation, to an all-operating-plant environment, some elements of the services business will prosper and some will not. Demand for waste management and outside security services will increase over the next decade--the latter by a projected $70 million per year to $170 million by 1995. Training service costs, currently $100 million per year, are expected to increase also. Engineering analysis, QA, and QC services costs are expected to remain stable while the need for such services as fuel management, environmental services, and start-up services will decline--the later from $200 million annually to approximately $50 million by 1990.[29]

Assuming no reduction in demands imposed by NRC, INPO, NUMARC, Insurance Companies, SURAs, and other agencies, firms that specialize in assisting utilities in meeting regulatory requirements and achieving good performance in plant operations are likely to prosper. Fuel supply and spent fuel management activities should also continue at a high level whether new plants are built or not. This portion of the fuel cycle remains a lucrative sector of the nuclear industry for a number of suppliers and contractors, most particularly the NSSS vendors. Because of market constrictions in other areas, however, the fuel supply segment is becoming increasingly competitive. Recruiting and training of personnel will continue to be needed because of regulatory requirements that lead the industry to become increasingly more labor intensive. (One-third to one-half as many more employees are required to operate a plant recently licensed as one that began operations in the mid-1970s.) Use of temporary workers for work in radiation areas will probably require more sophisticated recruiting and monitoring services as the industry matures. A continued need for health physicists and specialists in employee health benefits and claims is anticipated. The need for legal services, which is already a major part of nuclear plant operating services, will probably expand to accommodate changes in the law that deal with health effects for workers. Public relations and political activities are likely to increase. Environmental specialists will no longer be necessary if no new plant sites are needed. However, their skills may be useful in making decisions concerning plant decommissioning and coping with any future operating accidents. Firms that were formed to meet specialized needs, e.g., licensing hearings, financing arrangements, and export procedures, will decline and perhaps cease to exist.[20] A resurgence in nuclear construction, as represented by restart of cancelled plants or new starts would portend a further boost in nuclear services business volume. Curiously, the pessimistic projection, which presumes a delay in current construction because of a presumed accident, may also be a boon to the services business. If the presumed accident stimulated the generation of regulations, as did TMI-2, the utilities may be forced into new activities that would require external support. These and other projections are discussed in more detail in Section 3.5.1. In general, the nuclear services business appears to have the brightest future of any of the main segments of the nuclear industry.

3.5.1 Service Industry Future Prospects

3.5.1.1 Nominal Projection

The well being of the service industry in some respects is inversely related to that of the nuclear industry as a whole. This reflects the fact that regulatory, financial, and technical factors that created burdens for the utilities also established the need for many of the services which they now procure.

Over the next two years, the service industry in general will expand significantly as more plants come on line. The balance of service needs will change but the net business volume will increase. Because services represent the only expansive industry segment, competition from all segments with relevant capabilities will become more intense. The NSSS suppliers, AEs, and some utilities will seek to enlarge their market share, often as composite entities. In self defense, some of the smaller, traditional service firms can be expected to consolidate to offer broader capabilities. This trend should be balanced somewhat by the competitive advantage inherent in the higher efficiency characteristic of small firms. The sale of services by one utility to another creates a situation of concern to the NRC in that the same organization within the utility may be servicing both its plants and those of other licensees. In the former capacity, these activities come under the purview of the NRC region while in the later, oversight is provided by NRC HQ. Care is in order to assure consistency between these two monitoring functions. Continuing, successful efforts by foreign firms to acquire a share in the U.S. services market are expected. These will be partly through acquisitions of and agreements with domestic firms but will also involve direct marketing by foreign companies.

By 1990, the services market should have peaked and stabilized. Much of the business will have been acquired by NSSS suppliers, AEs, utilities and combinations thereof. The successful traditional services firms will, in many cases, have found it necessary to align themselves with former competitors to meet the challenge of larger newcomers. There is likely to be a sizeable, minority foreign presence in the business that will inhibit new domestic startups, and the work force and business base should be stable in a highly competitive environment.

Business should continue strong and fairly stable through 1995 with approximately the same mix of participants as in 1990. Some decline in business volume could result as reactor operations become more routine and noncontinuous activities associated with construction and startup are completed. This should be compensated by new work in life extension, decommissioning, waste isolation, and advanced plant planning and design.

3.5.1.2 High Projection

A revival in nuclear power presumes an easing in the financial constraints and perhaps the regulatory requirements that gave rise to much of the services market. Overall improvement in industry prospects might thus be accompanied by a reduction in service needs or could result in increased demand for services because of the overall increase in business activity. Over the next two years, growth in the services sector would still occur--perhaps as rapidly or more so than in the nominal case since more plants will be under construction. Traditional service firms will confront growing competition from NSSS suppliers, AEs, utilities, and foreign vendors and in some cases will join forces to compete more effectively. The trend to agglomerate is likely to be stimulated by a growing tendency on the part of utilities to reduce the number of service firms under contract and to require competitive bidding.

By 1990, a larger, growing business base would exist and strong competition will continue. Planning and possible orders for advanced plants may ope new service markets. New businesses formed to tap these may require increased NRC resources to ensure that adequate QA programs are being followed.

In 1995, the service business should remain strong and would have developed to serve new plant construction, decommissioning, life extension, and waste isolation needs.

3.5.1.3 Low Projection

Just as a general improvement in the nuclear industry could reduce the level of service business. The hypothesized accident of the low case projections may spark a new surge in service needs. This would occur in response to new regulatory requirements and possible extensions of the regulatory boundary. Over the next two years, new business derived from the hypothesized accident together with on-going services as forecast for the nominal case may make for increased service business in the short term. Because of reduced long term prospects, NSSS vendors and AEs, may be less inclined to enter the market. There are likely to be few, if any, new firms started and more consolidation of existing companies.

By 1990, the business base should have stabilized with a somewhat reduced number of firms involved.

The service business should remain fairly stable through the mid 1990s with decreases in conventional services associated with plant startup and operations complemented by some increases from decommissioning, life extension, and waste isolation. The business base would be mature and viewed as declining in the future.

3.6 OTHER FACTORS

3.6.1 Foreign Entry into U.S. Markets

Although the U.S. continues to have substantially greater nuclear generating capacity than any other nation, other countries are continuing their construction of nuclear plants and are gaining rapidly. Since 1978, although no new orders for nuclear plants have been placed in the U.S., twenty-six new orders have been placed in France, West Germany, Great Britain, and Japan and

fifteen in the rest of the world. In France alone, 15 new reactors were ordered between 1979 and 1983; and nuclear power, which presently provides more than half of France's electricity, is expected to provide 83% by the year 2000. In Japan, eleven nuclear units have been ordered since 1978 and presently approximately 20% of the electricity generated in Japan is provided by nuclear. As is the case in France, construction periods in Japan are short relative to those in the U.S., i.e., 4-1/2 to 6 years versus 6 to 15 years. Construction costs abroad are substantially below those in the U.S. The West German experience has been less encouraging but nuclear power is still considered substantially cheaper in Germany than power generated by coal. With the exception of Great Britain, virtually all nuclear plants built or being built in the western world use variations of light water technology originally developed in the U.S.
Almost without exception, the number of engineering and construction man hours utilized per kW of capacity built in foreign countries is substantially less than in the U.S.[1,6]

Foreign firms have clearly indicated their willingness to compete for U.S. component and services orders. In so doing, they emphasize "proof" of good products, as evidenced in the superior performance and lower costs of foreign nuclear plants, and highly competitive prices--largely because of the inflated value of the U.S. dollar. Foreign interest in U.S. business is prompted not only by the fact that a sizeable market exists here. Demand for nuclear power overseas has declined for the same reasons responsible for the reduction in domestic demand. The principal foreign competitors for U.S. business, i.e., Germany, France, and Japan, are also experiencing a maturation in their internal nuclear power programs. As the nuclear capacity fraction has increased (with comensurate decreases in consumption of imported oil) demand for new construction has expanded less rapidly with the result that NSSS, AE, and component supply capabilities are underutilized and must seek new markets.

Ready availability of foreign made components is apparent from reference to the ANS Buyers Guide.[30] A high and non-declining proportion of the firms listed are foreign. Trends in N-stamp holders also attest to the foreign market presence. While the number of domestic N-stamps has decreased by a factor of three over the past 6 years, the number of foreign firms holding N-stamps (approximately one-third of the total) have remained essentially constant.

Foreign firms have the domestic market base, which U.S. firms now lack, needed to underwrite costs of developing export markets. American firms have not capitulated, however, and combined efforts to develop foreign markets are continuing. As an example of the latter, an interagency task force consisting of representatives of the Department of Commerce, DOE, State Department, and U.S. Export-Import Bank was recently formed to promote overseas sales by U.S. nuclear suppliers.[36] Prospects for the success of these and similar efforts are uncertain at best and, realistically, probably not very encouraging. Not only do the European and Japanese competition have stronger economic bases--countries that have traditionally been importers of nuclear components, e.g. Argentina, Taiwan, Spain, are increasingly developing their own internal sources thereby further shrinking the potential export market.

American nuclear services business is being actively pursued by most of the major foreign vendors. This is being done directly, by acquisition of smaller U.S. firms, and through joint ventures with domestic nuclear suppliers.

Kraftwerk Union (KWU) has agreements and partnerships with several domestic firms through which they have done considerable service work in the U.S. e.g., ultrasonic inspection of recirculation piping in the Dresden, Quad Cities, Fitzpatrick, and Hatch Plants. KWU is a 93% owner in the U.S. Firm Utility Power Corporation through which they recently acquired 100% control of Universal Testing Laboratories with whom KWU has had a long-term, cooperative agreement on testing, QA functions, and non-destructive examinations. This new consortium intends to expand UTL's activities "to encompass all kinds of automated inspections on piping, reactor pressure vessels, and steam generators" and to bid for "all types of repair services for steam generator tubes" in the U.S.[37,38] Virginia Power Company (VPCO) has contracted with a German firm, Gesellschaft fuer Nuklear-Service mbH (GNS), for casks made in the Federal Republic of Germany (FRG) to be used at an independent spent fuel storage installation (ISFSI) for which VPCO is seeking license. As part of the license approved process for the VPCO ISFSI, the NRC staff evaluated GNA QA and compliance assurance practices in the context of QA requirements posed in 10 CFR 50 pt. 71.72. The intent of the evaluation was to establish equivalencies between U.S. and FRG practices leading to an NRC policy on acceptance of FRG QA and QC procedures--in this case, primarily those implemented through the TUVs[a] in the FRG.[39]

The French have not been as successful in the U.S. market, or elsewhere, as have the Germans. Framatome's stated position is that heretofore they have been appraising the American market and have only recently made the decision to mount an aggressive sales campaign based upon their highly successful domestic nuclear program. Among the services being offered by Framatome are replacement parts, maintenance services, and specialized equipment and expertise for steam generator repair.[37,38,40] French marketing activities in the U.S. will be simplified by NRC blanket approval of Framatome's QA program which is being solicited by means of a topical report, addressed to the NRC, describing the program in detail.[41]

As discussed previously, the Japanese are the principal partners with the major U.S. vendors (General Electric and Westinghouse) in developing new plant designs for both U.S. and foreign markets and have indicated a general, if discreet, interest in selling services and equipment to American utilities.[37,38] The Japanese are also collaborating with U.S. utilities. One agreement, under INPO auspices, involves Commonwealth Edison and Tokyo Electric Power and is aimed at technology exchange in the areas of preventive maintenance and minimizing outage lengths.[42] Virginia Power Company has a formal agreement for general exchange of information with Japan Atomic Power Company.[43]

(a) TUV: Technische Uberwachungs-Vereine; independent, non-profit organization of technical experts which provide verification of QA, QC, and technical adequacy for German industry and government agencies. Seven of the 11 TUVs have some involvement with nuclear power.

Brown-Boveri, a U.S. subsidiary of the Swiss turbine-generator manufacturer, has had a U.S. market presence for years through their nuclear customer service program and is attempting to expand this base with programs to improve capacity factors, reduce radiation exposures, extend steam generator life, and detect fuel rod failures.[37,38]

A Swedish-U.S. combine (ASEA-ATOM/Westinghouse) has been successful in marketing reload fuel in America and is presently marketing services in the areas of radiation exposure reduction, shortening of refueling outages, power uprating, and water chemistry to domestic utilities.[37,38]

With the expansive nature of the nuclear services business, the worldwide decline of other market sectors, the strong technical and economic base of the foreign nuclear industry relative to its U.S. counterpart, and present currency ratios, it is reasonable to expect substantial foreign entry into the U.S. market for services and components over the next 10 years and beyond.

3.6.2 Pending Legislation

As of mid-1985, there are six pieces of pending or foreseeable legislation that would have significant impact upon the regulation of nuclear power in the U.S. Four of these bills mandate changes in the way in which the NRC regulates the industry and one would change the management and organization of the NRC by transforming it to an agency headed by a single administrator. All five of these bills are currently before committees of the House or Senate and none have been subjected to hearings. A sixth, near term legislative action of concern will be whether or not to extend the Price-Anderson act which expires in 1987.

A synopsis of the major points included in each pending bill is summarized as follows:

1. Bill to Reorganize the Functions of the NRC, by establishing the Nuclear Regulatory Agency Senate Bill 1235-June 4, 1985--Introduced by Senator Alan Simpson.

   This bill would reorganize nuclear industry regulation under an agency headed by a single administrator. The Nuclear Regulatory Agency (NRA) would supersede NRC. The Director, Deputy Directors and four Assistant Directors would be appointed by the President and confirmed by the senate. The four Assistant Directors would be assigned to nuclear reactor regulation, inspection and enforcement, nuclear material safety, and research.

2. Nuclear Powerplant Licensing and Standardization Act--House Res. 1447--Introduced March 6, 1985--Representative M. Udall. Also introduced as Senate 836 by Senator A. Simpson--April 2, 1985.

   This bill would amend the Atomic Energy Act of 1954 to require the NRC to issue combined construction permits and operating license for a thermal neutron power plant after public hearings and finding that the facility will operate according to the application and NRC regulations. The NRC is expressly prohibited from modifying final determinations on an issue made in a permit or license proceeding unless significant new information concerning public safety is brought to light.

The NRC is authorized to issue 10-year (renewable) site permits for power plants before the utility has filed application for either a construction permit or a combined construction permit--operating license.

The NRC is directed to establish procedures permitting the approval of standardized thermal neutron power plants. These procedures should be in place before an application for either a CP or CP&OL for a standardized plant is considered by the Agency.

3. Nuclear Power Plant Standardization Act of 1985--House Resolution 1029 introduced Feb. 4, 1985 by Representative J. Broyhill and 37 Co-Sponsors.

   This act would require the NRC to "establish procedures, standards, and criteria permitting the approval of standardized 10-year facility designs. Declares that a design approval shall be considered to be a license for the purpose of such act ..."

   Like H. R. 1447, this act calls for 10-year site approvals with renewals on request. Public hearings are also mandated. The NRC must also find the utility competent to construct and operate a nuclear power plant in conformity with the application.

4. Nuclear Facility Standardization Act of 1985--House Resolution 2488 Introduced May 14, 1985 by Representative J. Broyhill.

   This act seeks to encourage standardized designs by authorizing the NRC to standardize designs for plant subsystems. As such the bill is complementary to HR 1029 introduced in February. Other parts of the bill are refinements to the HR 1029.

5. National Nuclear Powerplant Personnel Training Act of 1985 introduced January 3, 1985 by Senator Moynihan.

   The purpose of this act is to ensure the adequate availability of trained power/plant personnel by establishing the National Academy for Nuclear Power Plant Safety. The NRC would establish this academy and establish training programs for all staff positions in power plants requiring a license.

The Price-Anderson provisions of the Atomic Energy Act of 1954 as amended have the objectives of:

1. Removing the deterrent to private sector investment in nuclear power by the threat of potentially large liabilities in the event of a severe accident.

2. Streamlining procedures for the public to receive compensation and assure that adequate funds are available to satisfy liability claims.

The Act, as originally constituted, limited liability for a nuclear accident to $60 million in private insurance required to be carried by each plant owner, plus $500 million in federal funds. Under current law, plants must carry $160 million in private insurance, and each licensed plant would have to contribute up to $5 million to an insurance pool if claims associated with an accident exceeded the $160 million. The Act has been extended for two 10 year periods. If Congress takes no action, current provisions would expire on August 1, 1987, after which the current situation would continue for plants already licensed but new plants would not be covered. The NRC recommended in 1983 that Congress extend the Price-Anderson Act but that an annual limitation on liability be substituted for the present absolute limitation. NRC also recommended that Congress change the premiums charged each reactor in the event of a catastrophic nuclear occurrence and that the Statute of Limitations for filing of claims be extended to 20 or 30 years.[44] In a more recent decision, the Commission reversed their position on liability limits and indicated support for a continuation of the present approach which limits liability to a set amount per nuclear accident.[45]

3.6.3 Personnel

Projections of critical skills needs for the nuclear industry have been the subject of recent, exhaustive studies.[46] Only a brief summary of conclusions is presented here.

Barring an unexpected resurgence of interest in nuclear power, the supply of engineers, scientists, and technicians is expected to be adequate at least through the turn of the century. A few categories, e.g., health physicists, electronic technicians, and reactor operators are and will continue to be in short supply.

Total employment in the civilian nuclear industry is expected to remain fairly stable at approximately 220,000 through the 1980s. During the 1990s, personnel numbers should remain stable or increase slightly. Between 1990 and 2000, attrition is likely to lead to about 10,000 job openings for electrical engineers, electronic engineers, mechanical engineers, nuclear engineers, electronic technicians, health physics technicians, and reactor operators. Projections for new graduates in this time frame indicate that these positions will be fillable. Some concern has been expressed in the decrease in enrollment of nuclear engineers and health physicists, and DOE is considering providing more support for students seeking careers in these areas.[47]

3.6.4 Nuclear Power Plant Life Extension

Nuclear power plants in the U.S. have been licensed for terms of either 30 or 40 years. In some cases, this commenced with the issuance of the construction permit and, in others, when the plant began commercial operation. The stipulated operating life of 40 years is based upon accounting considerations, i.e., plants were expected to be fully depreciated over 40 years. No technical basis for this limitation has been demonstrated. Many similar facilities, e.g., coal-fired plants have operated for periods much greater than 40 years. Because of the huge investment represented by a nuclear plant and the inexpensive power that it will produce following amortization of capital costs, there will be great interest on the part of the utilities to continue plant operation beyond the 40 years specified in licenses. Federal regulations anticipate this by providing that nuclear plants approaching the end of licensed life may apply for an operating license renewal (10 CFR 50.51). Technical implications and licensing process modifications associated with life extension are largely unexplored areas. It is expected that considerable research and development, both physical and regulatory, will be required before applications for life extensions can be made and approved.

On first consideration, it would appear that life extension should not become a matter of concern until near the end of the century. Table 7a lists the license expiration dates and generating capacities for plants currently in operation, and Table 7b shows similar data that presumes an adjustment of license term to begin with the issuance of the operating license.[11] These data are plotted in Figure 7 which shows the availability of nuclear generating capacity through the end of the current license term for all plants in operation in 1985. Clearly, no significant capacity decrease because of license expiration will occur until after the turn of the century. First generation, large plants (San Onofre, 436 MW; Haddam Neck, 575 MW; and Oyster Creek, 620 MW) all received construction permits in 1964 and operating licensees in 1968-69 and can thus operate until 2004 with no license modification or until 2008 if the licensee effective date were changed to coincide with the operating license. While this seems well in the future, a simple breakdown of time requirements for activities that must transpire during this period shows that near-term consideration of life extension is in order.

Assuming a 10-year lead time for new nuclear plant construction, the license extension decision for the above three plants must be made by 1994.[a] This leaves 9 years, 1985 through 1994, during which life extension programs and confirmatory research and development must be initiated and performed. During this same period, the NRC will have to develop and codify the regulatory base for evaluating and approving license extension applications. The situation becomes more demanding if the oldest plants now on line, e.g., Yankee Rowe, CP:1957, seek license extensions as they are likely to do. In the most-pressing-case scenario, there would be a need for reliable regulatory guidance

(a) Assuming coal to be an option to nuclear, this date can be extended approximately five years.

TABLE 7. License Expiration Timetable for Current Operating Plants

A. License Expiration for Current[a] Operating LWRs

Year	Units	MW
1997	1	165
2000	1	71
2004	3	1,632
2005	1	610
2006	5	3,591
2007	14	10,754
2008	22	18,330
2009	6	5,571
2010	9	7,732
2011	4	3,803
2012	4	3,311
2013	6	6,688
2014	1	1,250
2017	1	810
TOTAL	78	64,328

(a) As of December 31, 1983.

B. License Expiration for Current[a] Operable LWRs Assuming License Term Commencement with Operating Permit

Year	Units	MW
2000	1	175
2002	1	71
2007	2	1,012
2009	4	2,494
2010	4	2,358
2011	2	1,583
2012	6	4,257
2013	14	11,190
2014	14	11,649
2015	3	2,965
2016	6	5,157
2017	5	4,802
2018	2	1,653
2020	3	2,667
2021	4	4,527
2022	4	4,478
2023	3	3,090
TOTAL	78	64,328

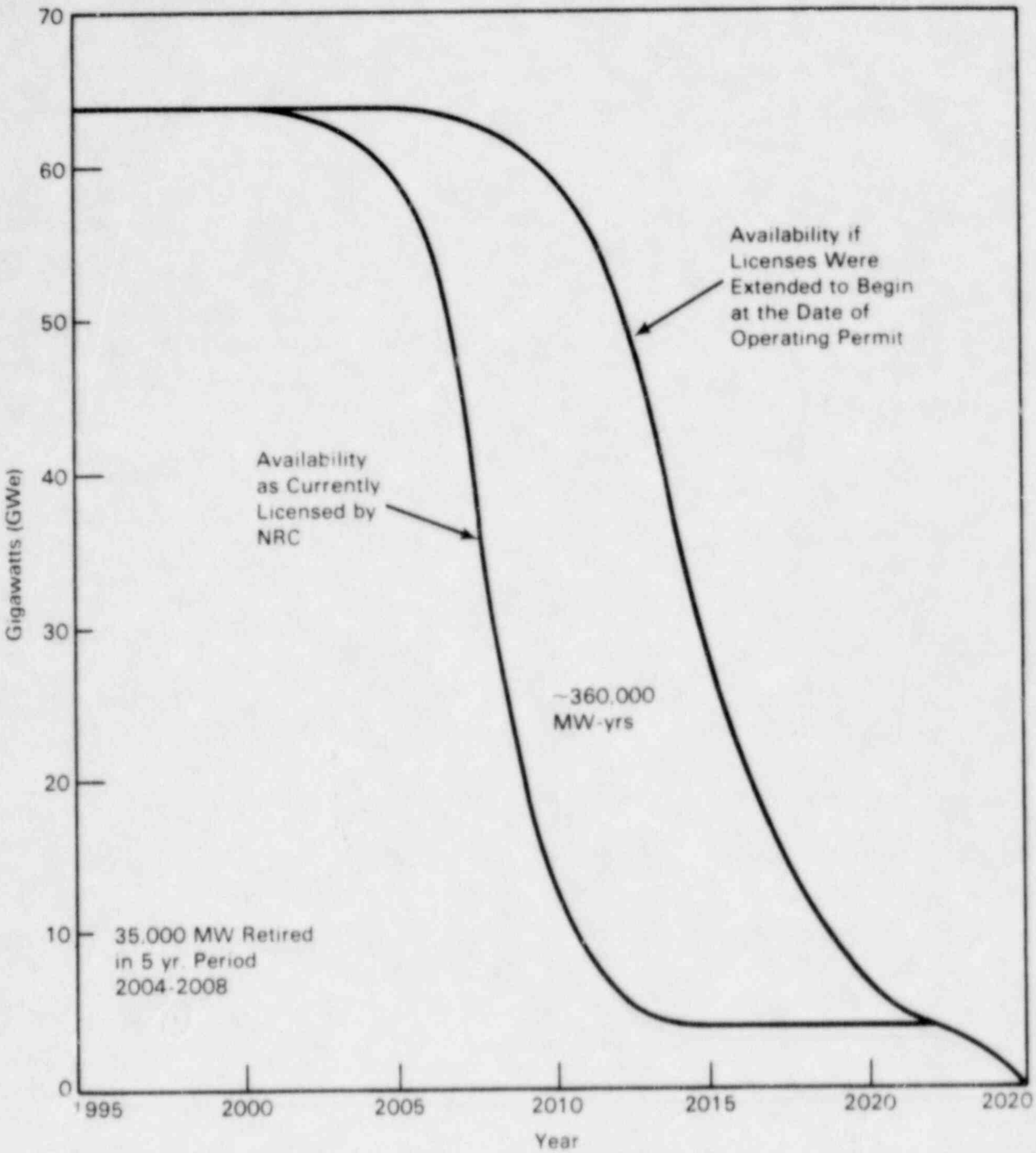

FIGURE 7. Decline in U.S. Nuclear Generating Capacity Because of License Expiration

as early as 1986. Orderly development of such guidance will probably require a structured, time consuming process. Considerations might include:

1. Identification of safety, environmental, socioeconomic, and legal issues.

2. Review of life extension experiences and requirements in other industries, e.g., commercial aviation, the chemical industry, fossil-fired power plants, hydroelectric plants, and military and production reactors.

3. Examination of federal regulations, legislative and other requirements to determine which may effect nuclear plant life extensions. This might include NRC generic issues, unresolved safety issues, FEMA requirements, EPA requirements, OSHA requirements, and other federal requirements and orders that may be pertinent.

4. Analysis of policy issues that may be involved, e.g., backfit rules, siting policy, decommissioning, operation and management requirements, maintenance issues, etc.

5. Definition of information requirements for a license extension application.

6. Preparation of a regulatory plan and schedule for submitting a license extension application.

To accomplish these, including necessary review and approval cycles, will require considerable, high-priority attention in the part of the NRC over the next few years.[48,49,50]

3.6.5 Decommissioning

When a plant reaches the end of its useful life, as defined by the license, economics, or other considerations, it becomes the owner's responsibility to deal with the site in such a way as to assure public health and safety and protect the environment. This has been a recognized requirement from the beginning of nuclear power development. Over the past 25 years, six licensed power reactors, four demonstration reactors, six licensed test reactors, and about fifty research reactors have been decommissioned.

As part of the plant licensing process, the owner commits to financial responsibility for eventual decommissioning, which may be done by one of a variety of methods. These are defined in Regulatory Guide 1.86, which is the most long-standing reference on decommissioning alternatives as:

1. Mothballing: putting the facility in a state of protective storage. In general, the facility may be left intact except that all fuel assemblies and the radioactive fluids and waste should be removed from the site. Adequate radiation monitoring, environmental

surveillance, and appropriate security procedures should be established under a possession-only license to ensure that the health and safety of the public is not endangered.

2. In-Place Entombment: sealing all the remaining highly radioactive or contaminated components (e.g., the pressure vessel and reactor internals) within a structure integral with the biological shield after having all fuel assemblies, radioactive fluids and wastes, and certain selected components shipped offsite. The structure should provide integrity over the period of time in which significant quantities of radioactivity remain with the material in the entombment. An appropriate and continuing surveillance program should be established under a possession-only license.

3. Removal of Radioactive Components and Dismantling: All fuel assemblies, radioactive fluids and waste, and other materials having activities above accepted unrestricted activity levels should be removed from the site. The facility owner may then have unrestricted use of the site with no requirements for a license. If the facility owner so desires, the remainder of the reactor facility may be dismantled and all vestiges removed and disposed of.

4. Conversion to a New Nuclear System or a Fossil Fuel System: This alternative utilizes the existing turbine system with a new steam supply system. The original nuclear steam supply system should be separated from the electric generating system and disposed of in accordance with one of the previous three retirement alternatives.

A great deal of analysis, both regulatory and technical, has been expended on decommissioning. Table 8 lists some of the authoritative references and correlates much of the varied terminology that has been generated.[51]

Much more consideration has been given to decommissioning than to life extension. Consequently, the regulatory alternatives associated with decommissioning are relatively well defined and documented. If plant life extension becomes a widespread option, emphasis on decommissioning will diminish or, conversely, will intensify if life extension is not allowed.

A major decommissioning project is in progress at the Shippingport reactor. Under the supervision of the Richland Operations Office of the Department of Energy, the General Electric Company, with Burns and Roe as AE, is in the process of dismantling the plant and restoring the site to its original status. The project is expected to be completed over the next few years. The Humboldt Bay Reactor is also in the decommissioning process.

The first of the currently operable commercial plants to face decommissioning will be Yankee Rowe in 1997 and 1998. Other plants will follow with a

TABLE 8. Comparison of Decommissioning Approaches

COMPARABLE TITLE	REFERENCE DOCUMENT
Regulatory Guide 1.86 Title: Mothballing	
Mothballing	AIF/NESP-009[2]
Stage 1	IAEA-179[3]
Option 1	IAEA Draft Report[4]
Safe Storage, Passive	NUREG/CR-0129[5], NUREG/CR-0130[6], and NUREG/CR-0672[7]
SAFETY OR	NRC Program Status Paper, May 1980[8]
Regulatory Guide 1.86 Title: Entombment	
Entombment	NUREG/CR-0129 and NUREG/CR-0278[9]
Stage 2	IAEA-179
Option 2	IAEA Draft Report
ENTOMB	NRC Program Status Paper, May 1980
Regulatory Guide 1.86 Title: Removal of Radioactive Components and Dismantling	
Prompt Removal/Dismantling	AIF/NESP-009
Dismantlement	NUREG/CR-0130, NUREG/CR-0278, and NUREG/CR-0672
Immediate Dismantlement	NUREG/CR-0219
Stage 3	IAEA-179
Option 3	IAEA Draft Report
DECON	NRC Program Status Paper, May 1980
Regulatory Guide 1.86 Title: No Equivalent Title	
Safe Storage, Custodial	NUREG/CR-0129, NUREG/CR-0130, and NUREG/CR-0672
Safe Storage, Layaway	NUREG/CR-0278
Safe Storage, Hardened (temporary)	NUREG/CR-0129, NUREG/CR-0130, and NUREG/CR-0672
Entombment (temporary)	AIF/NESP-009
Mothballing - Delayed Removal/ Dismantling Combination	AIF/NESP-009
Entombing - Delayed Removal Dismantling Combination	AIF/NESP-009
Safe Storage with Deferred Dismantlement	NUREG/CR-0129

pattern that is a mirror image of that shown in Figure 7 which plots plant license expiration dates. Operating licenses for the 82 presently operable commercial plants will all expire between 1997 and 2025. Current utility plans call for 61 of these to be immediately dismantled, seven to be mothballed, and five to be entombed with delayed dismantlement (three with a delay of 30 years, one with a delay of 100 years, and one with an unspecified delay). The decommissioning mode for seven of the current plants has yet to be determined.[52]

Plant decommissioning may eventually generate considerable business for service firms, AEs, and the NSSS vendors who have intimate familiarity with specific plants. These business activities will not commence in earnest until after the turn of the century and thus will not have an effect on the industry in the 1985 through 1995 time frame.

3.6.6 Advanced Concepts

Several new concepts which may, in time, stimulate and/or significantly change the nuclear power industry are under development or have been proposed. These may be categorized as relating to 1) institutional relationships, 2) regulatory reform, 3) advanced plant design, and 4) technological innovation. Concepts for departures from traditional institutional arrangements, which involve individual utilities or conglomerates of utilities as licensee/owners contracting with vendors, designers, and constructors, have potential for fundamentally changing nuclear power. Analysis of this complex issue, which was briefly discussed earlier, is beyond the scope of this study. Similarly, regulatory reform, except for the options for change posed in later sections of this report, cannot adequately be dealt with here. Physical innovations, as represented by advanced design and technological improvements to existing systems have more tractable potential for influencing the nuclear industry infrastructure in the near term.

3.6.7 Advanced Plant Design--Subsequently Safe Configurations

A number of plant design innovations intended to ease plant licensing through increased use of safety features have been proposed. In general, these have been structured to be more integrated and to avoid remaining concerns over LWR safety, i.e., those expressed in unresolved safety issues. "Inherently safe" reactor concepts being considered include:[53]

1. High-Temperature Gas Cooled Reactors (HTGR). The HTGR is inherently less subject to catastrophic failure than are LWRs for several reasons:

   a. The helium coolant is non-corrosive and is not activated by neutron irradiation.

   b. The high heat capacity of the graphite moderator reduces temperature rise following a loss of coolant thereby avoiding the need for a containment heat removal system.

c. Core power density is only one-tenth that of a LWR thus reducing temperature rise following a loss of coolant. This provides operators more time to diagnose and correct an off-normal situation. (Ft. St. Vrain has experienced seventeen loss-of-coolant accidents with no damage to any components.)

d. The HTGR uses a prestressed concrete reactor vessel (PCRV), which is stronger than the steel vessels used in LWRs. The PCRV encloses the entire primary coolant loop thus preventing rapid loss of coolant in the event of a pipe break.

e. The "modular" HTGR is a small version of full-scale, traditional plants. It is sized to allow dissipation of decay heat by radiative and convective transfer thereby avoiding the need for an active decay heat removal system.

2. Process Inherent Ultimately Safe Reactors (PIUS). This design is basically a LWR with two important safety-related features:

a. The core is situated at the bottom of a very large, water filled, concrete pressure vessel. This provides passive assurance of adequate emergency core cooling water.

b. Emergency cooling water, which is heavily borated, is prevented from entering the core only by balanced hydraulic forces. An upset in the presence-temperature-volume relationship in the normal cooling water causes spontaneous flooding of the core by bornated water with no need for electrical, mechanical, or human intervention.

3. Small LWRs. A variety of economically-based arguments have been advanced for returning to smaller reactors, i.e., perhaps 300 MWe versus 1000 to 1200 MWe for contemporary LWRs. Smaller plants may be inherently safer as well in terms of ease of management of off-normal events and the amount of radioactive material that would be dispersed in a worst-case accident.

The inherently safe concepts discussed above may have long term potential, but given probable requirements for research, development, and demonstration plants (perhaps 20 years in total) they hold little promise for impacting the industry significantly in the next decade. A minor exception would be R&D support received by NSSS vendors in connection with concept development and testing.

3.7 ADVANCED LWRs[54,55]

There exist strong sentiments within the industry (in particular among the NSSS vendors) to the effect that radical departures from present LWR designs would be a mistake. This position rests on the main argument that, because of the long lead time needed to bring a new concept to commercial practicality, the only hope for the nuclear industry to compete for new generating capacity to be added this century is with evolutionary development of current technology that is sound and proven. Resulting plants would be optimized versions of present plants with fewer unnecessary complexities, reduced design margins and conservatisms, and improved constructibility, maintainability, and operability. Guidance in plant design would be sought from utilities and regulatory bodies.

Examples of possible areas of simplification include reducing the number of and standardizing valves, eliminating pipe whip restraints, simplifying feedwater and condensate systems, eliminating containment spray, simplifying waste systems, reducing the number of technical specifications and associated tests and operating condition limitations, and designing for steam generator and other component installation and removal.

Overall design conservatism should be evaluated with special attention to high pressure residual heat removal systems, core power density, natural circulation contributions, small coolant leak margins, large pressurization, operating limitations based on nil-ductility assumptions, and the presently stipulated plant life of 40 years. Constructibility might be improved through increased factory assembly, shipyard-type assembly of nuclear islands, modularization, improved transportability, and development of innovative construction practices. An aggressive optimization effort should lead to simplified plant designs based on proven technology that minimize problems that occur in current plants, reduce construction times and cost, and improve availability, operability, and maintainability.

Basic to the concept of advanced LWRs is plant standardization. In principle, only two standard plant designs exist--the BWR and the PWR, which has become the standard for the world. In practice, in the U.S. the wide variety of design feature variations that have resulted from the many combinations of licensees, vendors and AEs all overlain by a rapidly changing regulatory climate resulted in no two plants being alike. Each new construction project has been, in some important respects, a new experience. These seem to be an industry concensus that standardization of plant design must occur if construction costs and lead times are to become competitive. Standardization is also viewed as tied to one-step licensing and other, more permissive regulatory changes. A standard design could have the further effect of reducing the man hours expended in plant design and limiting the number of NSSS vendors and AEs who participate in future orders. This may not be in the financial interest of some large companies.

The hope on the part of the industry is that design improvements and standardization will be recognized by the NRC as important contributions to plant safety and that the Agency will respond with simplified licensing and stabilization or perhaps reduction in regulation. If this comes to pass and improved, more economical LWRs evolve in the near term along with regulatory reform, nuclear power should be a serious contender for new capacity additions in the 1990s.

3.8 TECHNOLOGICAL INNOVATION

A great variety of technical improvements to current practices can be envisioned. One application area, expert systems and artificial intelligence (AI) in particular should be noted.

Over the next decade a variety of computer based decision aids and controls will be coming into use at U.S. nuclear power plants. The implementation of these devices will be gradual rather than sudden, but the net impact on the industry and the NRC will be profound.

Many areas in which artificial intelligence and expert systems applications may be developed exist, and the potential impacts on the overall management and regulation of the industry are substantial. The potential of both AI and expert systems has thus far greatly exceeded their practical application, and the introduction of these technologies into the nuclear business will not be accomplished without considerable difficulty. Establishing operational systems will probably be as troublesome as it has been in other industries.

The two areas where AI and expert systems have the most obvious impact on operational reactors are as control room decision aids and in some applications where controls on equipment are automated. Currently, many utilities are installing Safety Parameter Display Systems (SPDS) to provide operators with an integrated display of key plant functions. Other support areas where these systems are likely to be used include maintenance, scheduling, management, and planning.

In 1985 there are no functional expert systems in place on the nuclear side of a power plant. Applications of computer based systems that provide guidance to plant operating personnel are evolving very rapidly, however. The trend of the evolution is toward "smarter" computerized analytic devices. At the present time, all of the NSSS vendors in the U.S. and abroad have research, development and test demonstration programs underway. The speed with which these applications spread will depend on how successful they are in meeting the needs and gaining the confidence of plant operators. The current applications and results of test projects suggest a promising future.

3.8.1 Near Term Developments

3.8.1.1 Operations Applications. Computerized operator support systems are being developed very rapidly in a variety of applications. Some representative systems under development include Safety Parameter Display Systems (SPDS), reactor vessel integrity analyzer, on-line auxiliary feedwater system monitoring, and (XIPP) an Expert System for Control of axial xenon oscillations. These support systems are being developed in operational power plants. Many are being tested and modified in actual working situations. At this time, they are used only as decision aids to an operator and have no automatic control functions.

The future development of intelligent diagnostic and control technology appears promising. Extending the technologies of artificial intelligence and advanced computing to nuclear power plants may enhance future operations considerably. In the ten year time frame, it seems likely that most advanced computer applications will not be widely employed for nuclear plant control. However, major advances can be anticipated in operator decision aids, system monitors, and devices for training operators.

3.8.1.2 Support Operations. Advanced computing and robotic developments will likely impact many critical plant support functions. Maintenance, scheduling, and planning are areas where advanced computing will be widely introduced over the next five years.

Several service companies are marketing computer systems that perform such functions as monitoring plant compliance with technical specifications, maintenance of engineering drawings in a current status, integrated systems to provide a complete engineering data base and equipment history of the plant, and maintenance scheduling and management systems.

Expert systems also have the potential to aid NRC inspectors in various ways, e.g., as specific inspection aids covering any or all inspection modules. Finally, it may be possible to develop knowledge banks using input from experienced inspectors that could be utilized by any member of the inspection staff on a regular basis. Licensees will be able to maintain better data on critical aspects of their operation by employing expert systems which use key information for on-line diagnostics.

In summary, the prospects presented by the introduction of expert systems into the operation, maintenance, and inspection of nuclear power plants are promising. The NRC should anticipate that expert systems and other forms of automated controls, robotics, and decision aids will gradually be introduced into nuclear plants over the coming decade. The prospect also exists that NRC may make use of expert systems and other diagnostic aids in power plant regulation.

3.8.2 Inspection Technology

Significant advances in non-destructive testing will occur over the coming decade. This has implications for NRC in that some of the new NDE capabilities will be able to provide better information on equipment wear, piping and vessel condition, and expected service life of components. Introduction of new techniques will create new training needs for NRC inspectors and will require licensed QA/QC personnel to be properly qualified in their use.

3.9 SUMMARY OF INDUSTRY PROJECTIONS

Over the next five years, new construction activities at nuclear power plants in the U.S. will be completed, and the nuclear industry will enter an era of all operating plants. It is likely that this status will persist until at least 1995 and perhaps well beyond. This transition is expected to fundamentally affect the American nuclear industry of the future. A delay in initiation of new plant construction much beyond 1990 is projected to have the following effects:[19,24,35]

- The design teams (vendors, AEs, and suppliers) will be considerably diminished if they exist at all.
- Field construction teams would lack first hand experience in the specialized processes and project management required by nuclear plant construction.
- Technical specifications may be obsolete for some components or in need of extensive revision.
- Component supply firms would have to spend approximately 1 year qualifying for N-Stamp certification.
- Inspection as well as construction teams may have to be assembled and trained prior to new plant starts.
- Contractors would have lost their nuclear-specific competence and would require on-the-job training.

In general, the industry would face many, if not most, of the problems that the new industry had to contend with in the 1950s and 1960s. The only apparent exception would be the fuel services business, which would have survived and prospered based upon long-term fuel supply contracts.

Given a sufficient hiatus in new construction in the U.S., domestic capabilities for designing and manufacturing competitive reactors may atrophy to the extent that, given a renewed demand for nuclear power, our utilities will have to consider purchasing foreign-made plants. Although this may not occur within the next decade if it should, new problems in connection with licensing of designs and components and administrative and regulatory confusion associated with blending foreign and domestic technology would surely arise.

A more likely near-term effect is an increase in the presence of foreign firms in the U.S. components and services market. Manufacture of major components for plants under construction in the U.S. is complete. With the disappearance of the domestic market and the softness and elusiveness of the foreign market, U.S. suppliers are in difficult straits. This is demonstrated by their decline in numbers and business volume. Unless new domestic orders begin to materialize in the next 5 to 10 years, U.S. firms, if they survive at all, may be forced to align themselves with Japanese, German, or French firms--in some cases as minority partners. If this occurs, American utilities that elect to build plants beyond the 1990-1995 time frame and U.S. regulatory bodies will have to deal with foreign technology and quality practices. In addition, "buy American" pressures would limit the flexibility of the utilities in selecting suppliers.

Specific projections for each of the five major nuclear industry segments were developed in Sections 3.1 through 3.5. These are summarized in Table 9, which follows.

A. Nominal Projections

Projection	Utilities	NSSS Suppliers	Architect-Engineers	Components Suppliers	Service Industry
2 Year Nominal (General Capacity - 110GWe, 10 Plants Under Construction)	• Continuing major construction involvement • Pressed by PUCs for higher capacity factors • Large disallowance cases in progress or resolved against utilities • Pressed by shareholders and rate payers for greater economy • Generally healthy, but some on verge of bankruptcy • Main construction problems behind them • Involved in lengthy operating license proceedings • Serious interest in new institutional arrangements (if reg. reform looks promising) • Some expansion in services--self and for other licensees • Diversifying into non-power areas • Planning and implementing grid expansion	• NSSS fabrication for domestic plants complete • Perhaps some limited foreign work • Further shifting of design and fabrication personnel to service work. • Further ROFs/general decline • Strong and growing reload business • Promoting new institutional setups/regulatory reform • More collaboration with foreign firms • Forming more domestic consortia for competitive advantages • Possibly promoting new standard plant turnkey projects/advanced plants • Further plant shutdowns/conversions • Key personnel moving to utilities and elsewhere	• Continued decline in engineering employment • Continued major involvement in construction and transition to operating status • Continued substantial backfit work • Exploring new institutional set-ups--probably a major participant • Limited expansion in services--perhaps as NSSS partner • Key personnel moving to utilities or elsewhere • Continuing foreign nuclear construction	• Further decline in number of suppliers perhaps by 50% • General malaise in domestic industry • Expanding foreign presence--some through acquisition or agreements with U.S. firms	• Continued expansion as plants come on-line • NSSS suppliers, some AEs, and some utilities expanding in market • Consolidation of smaller companies • Small companies threatened by intrusion of NSSS et al. • Foreign efforts to penetrate market--directly or through acquisition or agreements with U.S. firms
5 Year Nominal (General Capacity - 120 GWe, Construction Just Terminating)	• Rate base litigation still in progress causing financial problems for some • All construction nearly complete • Still some under threat of bankruptcy • Disbanding construction-related staff • Some operating license hearings still in progress • Power shortages looming in South/Middle South, North, East, and California • Reduced to hard core	• Reload business good, many more consortia--domestic and international • Possibly two out of business • Continued R&D and promotion of standard and advanced plants • Perhaps expanding foreign market with foreign vendors • Finding alternative component suppliers (foreign or in-house)	• Reduced, stable engineering staff • Major shift or reduction in nuclear design/construction capability complete • Backfit work complete • Probable participant in new institutional set-up experiments/planning • May be subcontractors to NSSS in turnkey or standard plant proposals	• Industry as traditionally constituted, essentially defunct • Perhaps a few suppliers servicing replacement market • Continued foreign presence	• Service volume peaks • Strong presence of big firms, NSSS, AEs, and utilities • Significant but not majority foreign presence • Stable work forces and business base • Highly competitive business

TABLE 9. Summary of Projections for Nuclear Industry Segments

TABLE 9. (contd)

Projection	Utilities	NSSS Suppliers	Architect-Engineers	Components Suppliers	Service Industry
5 Year Nominal (Generating Capacity = 120 Gwe, Construction Just Terminating) (contd)	• Economic pressure for high capacity factors and low maintenance and operating costs • Planning or experimenting with new institutional set ups • Stable, limited services business • Grid expansion/optimization in progress • Further non-power diversification	• Probably main participant in new institutional set ups	• Continued steady involvement in services/w NSSS perhaps • Plant modifications as needed • Continuing foreign nuclear construction		
10 Year Nominal (Generating Capacity = 120 Gwe)	• Ratebase and licensing hearings finished • Stabilization in general--any failures behind them • New capacity (not nuclear) being constructed • Financially very healthy • Planni ; for life extension • Optimizing maintenance and operating costs on existing plants • Possibly new institutional setups facilitating nuclear const. (if reg. process eased and stabilized) • Stable services business • Increase in life extension and decommissioning planning and activities • Distribution system optimized	• Much reduced, stable operations • Reload business stable and healthy • Stable, limited foreign NSSS business as partner with foreign firms • Possible demo of advanced design plant • Developing involvement with life extension--planning and development • Increasing decommissioning planning and involvement • Strong involvement in services • Possible participant in new institutional setups--maybe turnkey plant supplier/licensee • More involved in full spectrum of equipment manufacturer or in overseas procurement • Increasing decommissioning work. • Planning and early involvement in long-term waste storage	• Some staff growth in response to new capacity development • Participant in new institutional setups--possibly as licensee • Probable main subcontractors on turnkey or advanced/standard plants • Stable services business alone and with NSSS • Increasing involvement in decommissioning • Life extension--planning and development • Waste storage planning and early involvement • Continuing foreign nuclear construction	• Same as 5 year projection	• Continued strong business with same mix of participants as 1990 • Some decline in business volume as operations become more routine • Possible new markets in life extension, decommissioning and advanced plants

B. Perturbations Caused by High Projections

Projection	Utilities	NSSS Suppliers	Architect-Engineers	Components Suppliers	Service Industry
2 Year High (Generating Capacity = 120 GWe, 15 Plants Under Construction)	• Improved economic prospects for some utilities • Possibly intensified disputes with PUCs because of high costs of restarted or new plants • More interest/commitment in new institutional set-ups and advanced plant designs	• Completing NSSS systems for restarts • Rejuvenation of R&D on new designs and advanced technology • Pressing for government/industrial programs on standard/advanced plant development • Less decline in engineering/manufacturing capabilities • Strong competition for service business	• Increase in businesses of restarted projects • Greater interest in service business	• Some new business--not extensive • Regeneration of interest with perhaps some new N stamps • More aggressive foreign intrusion	• Probably some growth, but possible decline if industry revival reflects relaxed regulations • Greater competition from NSSS, AEs • More foreign competition • More consolidation
5 Year High Generating Capacity = 135 GWe, 3 Plants Nearing End of Construction)	• Expanded construction staff and activities • Planning for (possible orders for) standard/advanced plants to meet future capacity needs • New institutional set-ups may be reality	• Basic engineering/fabrication capability retained--supported by development work on advanced designs • Active in development, promoting and possibly sales of standard or advanced plants. • Participant in new institutional set up	• Continuing but declining construction • Reduction in engineering and construction forces • Strong involvement in new institutional setups as principal or partner • Collaboration with NSSS in turnkey or advanced plants • Greater involvement in service business	• Basic industry core retained • Business reduced but optimistic • Active foreign--domestic competition	• Strong, growing base • Intense big firm and foreign competition • Service mix changing to accommodate new concepts
10 Year High (Generating Capacity = 138 GWe)	• Expanded presence in services	• Growing efforts on advanced plant design--fabrication in progress • Possible new sales • Possible turnkey revival--alone or as part of new institutional set up	• Upsurge in nuclear business if new plant sales • Collaboration with utilities and NSSS in new institional setups, and advanced designs and concepts	• Growing, healthy business if new orders • Continued foreign competition and possibly also from in-house efforts by NSSS vendors	• Continued high business volume • Growth in certain segments if new orders

TABLE 9. (contd)

C. Perturbations Caused by Low Projections

Projection	Utilities	NSSS Suppliers	Architect-Engineers	Components Suppliers	Service Industry
2 Year Low (Generating Capacity = 90 GWe, 13 Plants Under Construction Construction/Licensing Hiatus in Progress)	• Greater involvement in hearings and litigation • Strong intervener pressure • Costly delays in construction projects • Backfits and other changes (design, operating, etc.) being debated and imposed • Plant costs escalating • Possible bankruptcy for some weaker utilities • Elimination of any future for nuclear power • Increased hostility from PUCs	• Gross reduction in interest and optimism • Probably some vendors quitting entirely • Reload business continues • Possibly some continuing consortia with foreign firms--foreign market only • Continued but reduced interest in service business • Termination of most R&D/advanced technology development • Termination of work on standard and advanced designs	• Some boost in business because of backfits and design changes • No future planning	• Possibly some increase in business because of backfits/extended regulatory envelope • Reduced foreign interest in U.S. market and firms	• Growth in business because of new requirements placed on utilities • Probably less intrusion by NSSS, AEs, foreign firms because of lessened future prospects
5 Year Low (Generating Capacity = 108 GWe, 2 Plants Nearing End of Construction)	• Survivors have responded to required changes • Construction nearing completion • Probably significant backfitting/modification of a number of plants • Adversarial relationship with PUCs • No advanced planning for nuclear	• Reload business continues at reduced level • Traditional NSSS supply industry ceases to exist • Some overseas involvement with foreign firms • Stable service business	• Some but reduced backfitting/plant modifications in progress	• Some continuing but declining business • Reduced foreign interest and presence	• Continuing stable business • Relatively little foreign presence
10 Year Low (Generating Capacity = 110 GWe)	• Stable industry--no expansion • Allowing current plants to wear out--replace with fossil or other non-nuclear capacity	• As in 1990 with some additional general decline in all markets	• Work on as-needed basis--plant modifications, decommissioning, life extension--minor part of AE business • Nuclear experience base essentially gone	• Essentially defunct--replacements expensive and hard to get	• As in 1990 but with no long term future prospects • Mature/declining business base

TABLE 9. (contd)

4.0 CHALLENGES FOR THE NRC--1985 TO 1995

As the character of the nuclear industry changes, the nature of and potential for quality assurance problems will change as well. The preceding discussion of anticipated trends for individual industry segments (Section 3.0) projects quite different futures for the five major components of the current nuclear industry. Most are expected to contract--some severely; but for others, e.g., the services business, considerable expansion is in store. Some activities that currently require NRC concern over QA will decline or cease, e.g., basic plant design and construction, while other areas such as foreign imports, life extension, computerization, handling, and waste isolation will gain more prominence. A number of issues that are expected to require future attention from the NRC were surfaced in Section 3.0. These are aggregated and further analyzed in the following.

4.1 OVERALL CHALLENGES FOR NUCLEAR REGULATION

If and when projected trends in the nuclear industry materialize, new developments will require adjustments in regulatory practices. These can be facilitated by anticipating changes and devising, a priori, modifications to the regulatory framework which will mesh with the evolving industry milieu in timely and efficient ways. Possible future problems revealed by the analyses in Section 3.0 relate to the totality of nuclear regulation. Although the basic concern of this study is quality-assurance-related trends and future problems, it is useful to first collect and classify the broader challenges of which QA problems will be subsets.

Impending challenges to the NRC generally fall into three categories:

1. Internal NRC Issues. Concerns that can be resolved within the Agency without significant recourse to or interaction with other organizations.

2. Industry Issues with Safety/QA Implications. Problems or developments within the nuclear industry that will require regulatory oversight.

3. External Influences with Safety/QA Implications. Anticipated or possible developments in areas external to NRC or the traditional industry infrastructure that may become of legitimate regulatory concern.

Some of the emerging issues relate to more than one of the above categories; but for the most part, they can be grouped as indicated (Table 10).

4.2 QUALITY-RELATED ISSUES

The challenges for NRC listed in Table 10 will accrue naturally from the overall industry trends forecast in Section 3.0. These are broad issues which have implications for most elements of the U.S. nuclear regulatory program. Some aspects of many of these issues also relate specifically to NRC quality assurance policies and programs. These QA issues are of primary concern in this analysis, and it is on these that the balance of this report will focus.

Of primary interest are quality concerns which are expected to arise as a natural and predictable consequence of the decline and termination of plant construction and the accompanying increase in the number of operating plants. Findings that relate to this trend and its upper and lower bounds represent the basic results of this study. There are also general trends not directly associated with the transition to an all operating plant environment which have significant future quality implications for the NRC. These include technological developments; possible changes in overall regulatory policies; and several, unclassified, extraneous trends the most important of which is the increasing presence of foreign suppliers in the domestic market. Sorting prospective, quality-related challenges to NRC to conform to these four types of issues leads to the following functional classifications of issues:

1. Issues arising from the routine transition from a mixed construction/operations environment to one in which all plants are operational.

2. Issues stemming from the introduction of new technology into operating LWR plants.

3. Issues which may develop because of regulatory policy changes.

4. External issues, e.g., those beyond the influence of the NRC or other bodies which impact the NRC.

Of these four categories, the first, which was the principal subject of this study, is the most extensive and relates most specifically to identifiable elements of the QA program. Categories 2 through 4 are included because of their important, if somewhat less direct, potential impact on NRC quality policies.

The general effects of the industry transition on NRC quality assurance responsibilities will be to shift technical emphasis to plant operations and to develop new regulatory bases to deal with changes in a timely way. Barring some dramatic and inherently unpredictable event (such as TMI-2), the need for revisions in NRC QA policies and practices should evolve in an orderly way. Over the next 10 years, the nature of NRC regulation can be expected to change gradually in a manner consistent with industry trends. The net effect of these changes will probably be substantial. A proactive posture on the part of NRC to anticipate these changes will lend to the effectiveness of the Agency in fulfilling its mission.

TABLE 10. New Safety/QA Challenges for the NRC--1985 to 1995

A. Internal NRC Issues

- There will be less need for construction-oriented inspectors within the NRC and a greater need for inspection staff in operating plants. This will impact both training and hiring practices.
- There will be a continuing, if declining, major NRC resource commitment to resolving allegations and hearings. Intervenor emphasis will shift towards transportation problems, operations and maintenance concerns, and waste management issues.
- It will be necessary for NRC to retain a core of competence in the areas of plant design and construction to deal with plant modifications, life extension, new design problems, and in anticipation of a revival of design and construction activities in the future.
- A possible decline in number and competence of available NRC QA/QC and other inspectors and changes in inspection scope and emphasis may require changes in training and inspection procedures.
- In an all-operating reactor environment, maintenance and plant modification become more important considerations. Additional requirements governing examination and certification of key licensee staff in these areas may require consideration.
- Regulatory requirements for nuclear power plant life extension should be developed as soon as possible.
- Regulatory implications of construction project restarts, standardized plants, and advanced designs must be anticipated. The extent to which resources should be expended in preparing a regulatory framework for possible future generation plants is a high-priority, near-term issue.
- Unresolved safety issues will require resolution to facilitate standard plant licensing.
- The NRC should make a deliberate effort to retain functional awareness of the historic quality problems in design and construction.
- NRC QA policies and practices should be regularly assessed and revised, perhaps on a scheduled basis, to maintain currency with industry conditions.
- Quality assurance guidance for participants in waste management programs is a high priority need.

TABLE 10. (contd)

B. Industry Concerns with Safety/QA Implications for NRC

- Utilities under pressure to achieve high capacity factors or to compensate for construction disallowances by SURAs may be inclined to economize in maintenance and other quality-related areas.
- Utilities with severe financial problems may be tempted towards similar economies that could result in quality lapses. Economic pressures may lead some utilities to do their own outage design work without relating i to the original detailed AE design which may only be available from the AE at substantial cost.
- Quality requirements must be adequately communicated to and followed by service vendors.
- New institutional arrangements, i.e., new types of licensees, may have implications for safety and quality assurance.
- Problems with replacement of components, materials, or subsystems, because of lack of availability of identical parts or advances in the state-of-the-art, will have to be considered in terms of overall impact on plant design and reliability and whether or not the original plant design bases are being compromised.
- The increasing use of computer technology (software in particular) in plant operations, especially in direct operation control modes, will require more concern on the part of NRC for QA in both hardware and software development.
- Technical and regulatory guidance needs for plant life extension should be defined and addressed.
- If mothballed projects are restarted, there may be special quality concerns over deterioration of materials and components, records, and conformance to current regulations.
- Utilities should consider a framework for assuring appropriate, timely NRC involvement with restarts and new generation plants, e.g., one-step licensing and readiness reviews.
- Introduction of advanced equipment and measuring techniques may increase the technical complexity of inspections (or could simplify procedures) requiring upgraded training for inspectors.
- The increasing need for qualified operators may create more concern over training and certification.

TABLE 10. (contd)

C. External Influences with Safety/QA Implications for NRC

- There will be shifting public, political, and intervenor emphases from design and construction to plant operations, transportation, and waste-related problems. The level of allegations will depend upon the effectiveness of utility management attention to employee concerns.
- Foreign participation in the domestic market, either directly or through acquisition of U.S. firms, may lead to changes in quality practices.
- The extent to which foreign or other agency or industry quality practices can be accepted in lieu of current NRC practices should be evaluated; perhaps international working agreements on standards, practices, and reciprocity require development.
- Special arrangements may be necessary for inspection and monitoring of foreign suppliers.
- Quality requirements must be adequately communicated to and followed by foreign vendors.
- Heightened concern over terrorist activities, primarily abroad but perhaps in the U.S. as well, may require more concern for quality assurance for protective systems.
- Overall trends in the economy and the cost of financing will directly influence power demand and probably prospects for growth in nuclear generating capacity.
- Changes in cost or availability of alternate fuels (coal, natural gas, and oil) will be directly reflected in changes in demand for nuclear power.
- Potential impacts of pending legislation on NRC QA policies should be evaluated and anticipated.

The likely impacts of projected industry trends on the NRC QA program are summarized in Table 11. Each potential issue may affect the QA program differently under each of the alternative industry scenarios discussed in Section 2.0. The columns at the right of the table show a rough estimate of the impact which each problem will likely have given the high, nominal and low projections developed in Section 2.0.

Sections 4.2.1 through 4.2.4 expand upon each of the issues listed in Table 11. The discussion of each issue covers: 1) a brief summary of the source and significance of the issue for nominal, high, and low industry projection, and 2) suggestions for changes in or additions to the current NRC QA program which should effectively deal with the issue.

4.2.1 Issues Arising from a Transition to an All-Operating Nuclear Plant Environment

In all three nuclear power development scenarios examined in this report, the overall trend in the coming decade is to a situation where roughly 120 ± 15 nuclear plants are operational, and few, if any, are under active construction. The QA challenges for NRC over the coming decade will be primarily determined by problems arising from this transition that relate to the issues listed in Table 11. These issues and related QA implications are discussed in the following.

4.2.1.1 Expanded Inspection Needs

Operating plants characteristically require more surveillance by resident inspectors than has been provided in the past for plants under construction. Thus, as more plants come on line, there will be increasing demands on the regional NRC offices for more inspection personnel. Displaced construction inspectors may not substitute on a one-for-one basis because inspections at operating facilities require somewhat different qualifications and training. As a consequence, replacement as well as addition of personnel may be required.

Any of the three industry projections imply needs for more qualified inspectors with the nominal scenario probably requiring the fewest additional people. The high projection would clearly require a larger inspection staff because more plants would be both under construction and in operation. Under the low projection, fewer plants would require inspection coverage but the hypothetical accident would probably identify more inspection needs in both construction and operation.

The market for qualified inspectors is and should continue to be strong--a factor which may place the NRC at a disadvantage in hiring and retaining inspection personnel with the desired qualifications. New incentives, monetary or positional, may be required to maintain a high caliber inspection corps.

TABLE 11. Issues Which May Influence Development of NRC Quality Assurance Policy and Practices Between 1985 and 1995

	Industry Projection (Section 2.0)[a]		
1) Transition to all operating reactor environment			
Issues	Hi	M	Lo
• Expanded Inspection Needs	+	+	+
• Knowledge Base Retention	0	+	+
• Personnel Qualifications	+	+	+
• Plant Aging/Life Extension	+	+	+
• Maintenance/Outage Management	+	+	0
• Component Replacement/Plant Alterations	+	+	+
• Restart of Mothballed Plants	+	0	NA
• Severe Accident Response	NA	NA	+
• QA in Nuclear Waste Programs	+	+	+
2) Introduction of New Technology			
Issues	Hi	M	Lo
• Advanced LWR Concepts	+	+	0
• Computer Systems	+	+	+
• Equipment Materials and Measurement Techniques	+	+	+
3) Regulatory Policy Issues			
Issues	Hi	M	Lo
• Shifts in Intervenor Emphasis	-	0	+
• SURA Pressures for Cost Savings	-	+	+
• Legislative Actions	+	0	+
• New Institutional Arrangements	+	0	+
• Deregulation of the Utility Industry	+	+	+
4) External Influences			
Issues	Hi	M	Lo
• Foreign Entry into US Markets	+	+	0
• Impacts from Other Fuel Systems	0	0	0
• Economic Cycles	+	+	+
• Terrorist Threats	+	+	+

(a) Key
+ = Increased need for NRC concern and resources
0 = Neutral (same as now)
- = Decreased need for NRC concern and resources
NA = Not applicable

Efforts to increase inspection productivity by prioritizing procedures and developing more effective inspection approaches would also be helpful. An alternative approach might be to utilize non-Agency personnel, e.g., contractor or licensee employees, to supplement the efforts of NRC inspectors. Examples of the latter are the Engineering Assurance and Readiness Review programs now used in the plant construction phase. Similar initiatives could provide leverage for NRC resources in the operations phase.

Staffing in general may pose problems in the future. With fewer new graduates in nuclear specialties, and the migration of technical personnel to other industries, the pool of potential new employees will decline. The NRC may need to place greater emphasis on training and retention of present staff.

4.2.1.2 Knowledge Base Retention

If plant construction declines to zero and does not revive for several years, there is a risk of losing much of the construction-related experience base and knowledge accumulated over the past twenty years. This will be offset, at least partially, by needs for similar skills in monitoring plant modifications, retrofits, and other construction activities which will be ongoing at operating plants.

The rate of knowledge atrophication is likely to be lower for the high projection than for the nominal and low projections. In the high case, construction would continue to a later date. In the low case, although additional backfits probably would be required, these are much smaller in scale than new construction projects. In any of the these cases, however, failure to begin new plant construction to 2000 or beyond will result in the loss of availability of NRC staff with critical insights should new plant orders ever be placed.

Retention of construction lessons learned can be facilitated by the creation of a records system which documents these lessons in retrievable and usable forms. To accomplish this may require some innovative approaches--it seems doubtful that a file cabinet filled with NUREGs and inspection reports will suffice to properly orient an inexperienced inspection staff. A more "user friendly" approach which might employ video programs featuring experienced, key individuals who have been instrumental in achieving the present level of agency sophistication should be considered. These may be useful training aids as well as filling the function of archiving important and irreplaceable knowledge. This approach could be integrated into a simplified expert system to most efficiently and effectively train new inspectors.

4.2.1.3 Inspection Personnel Qualifications

Availability of inspection staff with requisite qualifications will pose an increasing problem over the next ten years independent of industry projection. Three factors will contribute to this: the need for more inspectors, more competition for capable personnel (both previously noted in Section 4.1.1) and the growing complexity of inspection techniques.

It will be necessary for inspection training programs to remain abreast of contemporary technology and for inspectors' training to be upgraded in regular and timely fashion. Conceivably, technological upgrading of the inspection staff could produce more effective inspectors, a desirable esprit de corps, and conspicuously more impressive qualifications which might justify the increase in recompense which may be necessary to keep turnover rates to a manageable level.

The potential of advanced computerized techniques, e.g., expert systems, in developing more effective training methods should be kept in mind. These methods coupled with modern video and data communications might lead to more effective, decentralized training which may accomplish desired results faster and at lower ultimate cost than do present approaches.

An additional possibility for maintaining inspection qualifications is to create an elite team with the mission of regularly visiting region inspection staffs to train and indoctrinate them in new as well as traditional techniques. This approach may be effective in both assuring the proper qualification of regional personnel and in introducing greater inter-regional consistency in inspection practices.

4.2.1.4 Plant Aging and Life Extension

As plants grow older, the related issues of aging and life extension will gain prominence. Aging should be of little concern for environmentally qualified components, certain electrical parts, and disposable components, such as filters and seals, that are replaced on a regular basis. Other plant components and systems are subject to regular inspection and maintenance; however there are few, if any, validated theories for predicting design life of such basic components as pipes and valves. These items are manufactured to applicable standards and inspected in-service at regular intervals. This approach, modified by experience, has been successful and is likely to continue to be the principal procedure for verifying the safety of such components in aging plants. The common wisdom holds that system redundancies provide adequate insurance against the consequence of age-related failures. Further study of aging seems justified and is, in fact, in progress. Independent of future developments in the industry, NRC inspectors should maintain an awareness of the state-of-understanding of aging processes and the methods used to monitor and document these in each plant. Possible needs for more intensive inspection using advanced techniques and a commensurate increase in QA coverage should also be anticipated. To make effective use of NRC resources, a system for communicating experience gained at older plants to the inspection staff at large should be developed.

Plant life extension was discussed at length in Section 3.6.4. The low industry projection presumes little or no interest in life extension; however, for the nominal and high projections, near-term pressure for NRC action seems inevitable. A list of the activities envisioned as necessary before license terms can be extended is given in Section 3.6.4. In summary, these involve identification of the issues involved, review of similar experience in other industries, evaluation of pertinent regulation and policies, determination of information requirements, and preparation of regulatory guidance for life extension applications. The latter activity should include development of specifications for licensee quality assurance programs. Presumably these would be based upon 10CFR50 Appendix B; however, detailed programs will differ in significant ways from those which have been applied to plant construction and operation, e.g., in requirements for data qualification. If these differences are not currently being examined, a study to do so should begin as soon as possible.

4.2.1.5 Maintenance and Outage Management

Routine maintenance and the similar activities which occur during outages will be subjects of increasing concern to the NRC over the next few years both because more plants will be operational and because of perceived, possible inadequacies in present practices. Qualitatively, the problems posed will be independent of industry projection but will be of greater magnitude for more optimistic scenarios.

Maintenance of mechanical components within the pressure boundary must conform to the requirements of Section XI of the ASME Boiler and Pressure Vessel Code. A sizeable NRC program directed toward developing indicators of maintenance adequacy at operating plants was recently launched. While projections of likely modifications in maintenance programs which will derive from this and related efforts is premature, possible new insights might lead to additional procedural standards; specific procedures for specific components; additional personnel qualifications, training, and licensing; and specific requirements for organization of maintenance departments. An additional procedural change which might be considered is NRC review and signoff on major maintenance projects. Generic changes in maintenance program requirements will require commensurate changes in quality assurance thus the Quality Assurance Branch should remain abreast of new developments and their QA implications.

Outages are periods of very intense activity involving changes in core configuration and maintenance, replacement, and repair which cannot be performed when the plant is at power. Prior to each planned shutdown, a utility prepares a detailed outage plan the intent of which is to assure that all necessary work is completed in minimum time. Contingency plans are also prepared in advance to take advantage of unscheduled outages.

As incentives increase for higher net capacity factors, pressures to reduce outage duration will intensify. More activities with safety implications will be done in parallel using concentrated staff with the result that the already very demanding NRC inspection burden during outages will become even more taxing. An increase in the NRC inspection staff may be needed to meet these demands. Alternatively, it may be possible to ease this burden and better assure that all requisite inspections are performed by developing standardized inspection procedures to be followed during outages. These together with indepth pre-outage planning and review of the licensee outage management plan should contribute to the efficiency of the NRC inspection effort. Post-outage review of the maintenance, repairs, and modifications performed including review of failures which stemmed from work done during the outage, evaluation of documentation of outage activities and inspections, and assessment of any degradation in plant safety which may have occurred during the outage would provide better assurance that proper inspections were performed.

4.2.1.6 Plant Alterations and Component Replacement

Replacement parts and components identical to the originals can become difficult to obtain as plants grow older. This happens for a number of reasons, e.g., suppliers go out of business or discontinue providing nuclear qualified items, the designs of components change with advances in the state-of-the-art, or manufacturing processes and tooling are changed. Replacement part availability problems will probably become more severe independent of industry trend. Unavailability of identical replacements creates requirements for re-engineering and re-design of affected plant systems. NRC inspection efforts should recognize this and provide oversight for the QA programs applied to engineering design work to assure that original plant design bases and other licensing conditions are not compromised. On-going attention will also need to be applied to assure that different parts and/or components are properly certified under required QA programs.

An alternative approach to easing the growing shortage of nuclear qualified replacement or original parts is to establish equivalency and acceptability of qualification practices in other industries. For example, the military procures equipment, components, and materials which are similar or identical to those used in nuclear power plants. These are not now acceptable for nuclear applications because they do not bear ASME N stamp certification. They are subject, however, to rigorous qualifying standards, e.g., MIL-Q standards, which may fulfill the intent of nuclear qualification. The NRC may find it useful to evaluate the quality programs and their implementation required under other-than-nuclear certification standards and, where possible, establish equivalencies which would allow use of non-nuclear grade items in nuclear plants.

A third option is to review certification requirements and their bases with an eye to relaxing them where appropriate.

4.2.1.7 Restarting Mothballed Plants

The restart of significant numbers of mothballed plants and/or construction projects that may be cancelled in the future is considered viable only under the optimistic industry projection. Some licensees are maintaining mothballed units in a fashion which would facilitate their restart. The Washington Public Power Supply System, for example, has developed a comprehensive preservation plan covering mechanical and electrical equipment and structures. The program derives from standards developed by ANSI, ASME, IEEE, and the American Nuclear Insurers.

It seems desirable for the NRC to establish guidelines for conformance of construction and components to updated regulatory requirements and for demonstrating that no significant deterioration has occurred while the project was inactive. Quality assurance requirements will be a major portion of whatever guidance is forthcoming and will require considerable thought and development. Relevant experience is available from plants which have been delayed for lengthy periods before becoming operational, e.g., Diablo Canyon and TMI-1. A task force and/or workshop to evaluate these experiences as sources of generic guidance could be useful.

4.2.1.8 Severe Accident Response

A severe accident analogous to TMI-2 would almost certainly pose new quality assurance problems for the NRC. The specifics of these cannot be anticipated; however some general characteristics of the optimum regulatory response may be worth considering. With TMI-2 as a model, it may be possible to speculate on how changes in quality policy might be made more effective and timely in terms of general dichotomies. For example, would quality program changes in response to the TMI-2 accident have been more effective or less effective had they been 1) more generic versus more prescriptive; more performance oriented versus more compliance oriented; more persuasive versus rule making (carrot versus stick); more cooperative and supportive versus more adversarial; etc? These general considerations deliberately posed against the real example of regulations in practice afforded by the aftermath of TMI-2 could provide useful policy guidelines for responding to any future accident. To be realistic, such speculations would have to be modulated by parameterized estimates of the political and economic implications of and responses to a hypothetical severe accident. This process would entail large uncertainties and may not be capable of generating sufficiently precise insight to be of value.

4.2.1.9 Quality Assurance in Nuclear Waste Isolation

Nuclear waste isolation, although somewhat peripheral to the future prospects for nuclear power, entails quality assurance issues which will be of continuing concern to the NRC. Long term waste disposal will be required regardless of future developments in nuclear power generation. The schedule for the deep repository calls for final site selection in mid-1991 and an operational facility by 1998. Current DOE-sponsored programs are aimed at characterizing candidate sites in terms of their utility for long term retention of high level radioactive wastes.

The repository is subject to NRC license and site selection will be a licensing issue, thus the bases for site characterization will have had to be generated under programs subject to acceptable quality assurance. The basic elements of waste-related QA programs will derive from 10CFR50 Appendix B as modified by 10CFR60 Subpart G. In the past, this had been applied to power reactors which pose significantly different technical and safety problems than will waste isolation facilities. The specific requirements for QA programs and their implementation in selecting, designing, building, and operating waste repositories must be developed by NRC over the next few years. The most immediate needs concern research and development, currently in progress, which will provide the rationale for site selection in 1991. NRC QA guidance for these activities should be articulated in the near future.

4.2.2 Introduction of New Technology

The principal anticipated technological innovations which will impact NRC QA policies were discussed in Section 3.6. These relate generally to advances in reactor design, increased use of computers in plant operations, and new developments in inspection technology.

4.2.2.1 Advanced Reactor Design

For the best estimate and particularly for the optimistic industry projection, serious proposals for construction of new plants employing advanced NSSS designs will probably have to be dealt with. Advanced in this case is construed to mean modifications of present LWR technology to yield simpler, safer, and/or standard designs that are easier to license or can be granted generic licenses. Quality assurance requirements in building and operating such plants should be similar to those currently applied.

If, as envisioned, the new plants are simpler to construct, maintain, and operate, implementation and verification of acceptable QA practices should be easier than it is now. More attention to QA in the design phase may be required-both because design receives comparatively less QA scrutiny now than do construction and operations and because of the intent to reduce design conservatism in advanced reactors.

A major question which NRC must resolve is the extent to which resources should be invested in developing a regulatory framework for advanced plants. A substantial portion of this framework will deal with QA issues.

4.2.2.2 Advanced Computer Applications

Independent of industry projection, new computing and analysis technology will be coming into wider use in nuclear plants over the next ten years. Computerized reactor control, robotics, and expert system application are likely growth areas.

The major challenges posed to NRC will fall in two categories: 1) establishing surety programs for computer software used for safety-related applications and 2) training QA and inspection staff in the new technology.

Quality assurance in the design, development, documentation, implementation, and maintenance of software substantially lags that in other technical disciplines. This problem is exacerbated by the lack of NRC guidance or endorsed standards for software QA. This is a recognized deficiency, and the NRC has ongoing programs to assess the magnitude of the problem and develop appropriate guidance. Given the rapid growth in computerization and the dynamic nature of the software business it seems desirable that these programs come to fruition in the near future.

There exists a widespread tendency to computerize for computerization's sake. For some tasks, the use of computers may not be beneficial and, in fact, may be counterproductive in terms of not simplifying or expediting the work and possibly increasing risks. NRC staff should be competent to independently judge when computerization is advantageous and when it is not.

The introduction and use of advanced computing technology in nuclear plant operations will require different types of inspection than do mechanical systems. Resident inspectors will have to become sufficiently conversant with plant computer hardware and software systems to evaluate the effects of computer system problems on plant safety. NRC will need to devote significant resources to training both resident and regional inspectors in carrying out their monitoring functions.

There are opportunities as well as challenges for NRC implicit in the computer revolution. Greater use by the staff of personal computers and advanced technology such as expert systems for training and data storage and analysis should result in better qualified, more efficient inspectors.

4.2.2.3 New Inspection Technology

New inspection methods, primarily for non-destructive examinations will continue to be introduced and should provide inspectors with better data on which to base their judgments. Concommitant with these advantages will be the requirement that both licensee and NRC inspectors be adequately trained in the use of new techniques.

4.2.3 Regulatory Policy Issues

There are several areas in which the changing industry infrastructure will lead to needs to assess and probably modify in a broad sense NRC policies and practices. The issues involved are generally beyond the control of the Agency, and their quality assurance implications for the most part are not immediately apparent. As some of these issues develop, however, it seems likely that they will require changes in the basic fabric of nuclear regulation including, probably, some reassessment of the NRC posture towards quality. Little can be said concerning specific impacts on the QA program, but the potential significance of these issues warrants including them in the context of this study.

4.2.3.1 Shifting Intervention Emphasis

As construction winds down, intervention aimed at preventing plants from becoming operational will decline--at least for the best-estimate projection. If a severe accident should occur (low projection), efforts to stop projects and close operating plants would probably intensify appreciably. The high projection presumes some generally increased acceptance of nuclear power thus, for this scenario, intervenor pressures should abate. It is likely, though, that committed groups would continue their efforts on a local basis.

The fact that intervention aimed at frustrating the granting of operating licenses will diminish should not be construed to mean, however, that the overall level of intervention will diminish. Sentiments for foreclosing the nuclear option may increase as plants become operational and construction costs translate into increased power costs. Antinuclear activists and other concerned groups will probably refocus their efforts on plant operations, transportation of radioactive wastes and fissile materials, and long term nuclear waste storage. The latter area, waste storage, is under increasing attack in connection with repository siting. Almost certainly, the NRC role in licensing waste repositories will be carefully scrutinized and any aspect of the QA program or its implementation which can be construed as lacking in assurance of quality or safety will be so portrayed. The NRC should, from a safety standpoint alone, attempt to anticipate and neutralize, by effective regulations, the QA-based objections which will arise to waste storage, transportation, and power plant operations. In some cases, this will require regulation which assures technically sound QA programs implemented in a correct, defensible way--in others oversight capability which allows for anticipating and correcting lax management practices on the part of licensees, contractors, and suppliers may be needed.

4.2.3.2 Pressure on Licensees for Cost Savings

The growing trend for State Utility Regulatory Agencies (SURAs) to pressure utilities to greater economies is discussed in Section 3.1. Penalties for low capacity factors and refusal to allow certain construction costs to be included in the rate base are approaches currently being used by SURAs to reduce "rate shock" to consumers.

These pressures will persist independent of industry projection. They are likely to be more intense for the low projection because the hypothesized accident would probably increase costs associated with construction delays and new backfit requirements. The high projection implies less financial pressure from SURAs in order for utilities to favor nuclear power to meet new capacity needs.

Capacity factor thresholds may be beneficial in encouraging a licensee to improve his maintenance program thus resulting in a safer plant. The regulatory concern is that, rather than improving maintenance and outage management, a utility may seek to reduce outage time in the short term by not doing all desirable maintenance, testing, and inspections. New NRC programs (Section 4.1.5) to develop methodology for assessing maintenance program effectiveness will, if successful, yield the oversight necessary to assure proper plant maintenance. Optimized inspection coverage of outage activities would further reduce the risk of licensee neglect of important tasks.

SURA disallowance of significant construction costs in the rate base can pose a threat to the very existence of a utility (Section 3.1). A licensee with serious financial problems has a heightened incentive to save money in any way possible. The potential that this poses for neglect of expensive maintenance, work which may be best performed by service firms, and other costly tasks with safety significance raises the same regulatory concerns as do pressures for high capacity factors.

4.2.3.3 Legislative Action

Pending legislation which would directly affect the NRC is summarized in Section 3.6.2. Current bills deal mainly with streamlining the licensing process. A bill to reorganize the NRC and one to establish a national training academy for reactor operators are also under consideration. The intent of all of these is to allow for more effective regulation while easing the regulatory burden on licensees. The principal QA concerns for NRC derive from proposals for one step licensing and licensing of standard plant designs. The extent to which resources should be committed to evaluating the implications of these proposals for the QA program and for restructuring the regulatory framework to accommodate proposed new approaches should be addressed in the near future. Future legislative trends are difficult to project with the possible exception that, if another serious accident were to occur, significant new legislation with implications for the NRC would probably be enacted.

4.2.3.4 New Institutional Arrangements

Various alternatives to the traditional plant owner/licensee role of the utilities have been suggested. Possibly, in the future, NSSS vendors, AE/Cs, or some combination thereof may play a larger part in the ownership and/or operation of plants. Joint ventures and private or government-owned regional nuclear power consortia could also supplant individual utilities as generating entities. In several of the possible new arrangements, the utility would retain responsibility only for distribution and sales of power purchased from a second organization which would have responsibility for building and operating plants.

The concept of new licensee arrangements is relevant mainly to the high industry projection, for which new arrangements may be a driving force, and, to a lesser extent, to the nominal projection. The low projection anticipates no new plant construction in the future, thus, no need for institutional revisions except as possible reactions to the postulated accident.

The basic requirements for safety and assurance of quality are the same under any institutional arrangement. The main incentives for new arrangements are to increase the financial and technical strengths of licenses--both trends which should lend to quality. Alternative institutional arrangements are thus seen as likely to reduce the QA problems with which the NRC must contend. Serious, specific proposals for new licensee arrangements would require individual analysis to verify that they represent no compromise of NRC quality requirements.

4.2.3.5 Deregulation of the Utility Industry

The possibility of rescinding federal regulations which define and control marketing and distribution areas for all United States utilities is under consideration by the Federal Energy Regulatory Commission (FERC). If this should happen, the power generation and sales business would enter a free market economy in which competition may supplant the cooperation which now characterizes the utility industry. In the process, organizations jointly maintained by member utilities for their mutual benefit, e.g., EPRI, INPO, NUMARK, EEI, may be weakened or destroyed. Some of the functions of these organizations are supportive of NRC goals and some directly supplement NRC functions, e.g., the accreditation and training programs conducted by INPO. If this support is diminished or lost, the NRC may find it necessary to commit resources, some of them quality-assurance-related, to fill the void.

4.2.4 External Influences

Some of the new challenges which will confront the NRC over the next ten years will derive from developments external to the Agency or the traditional nuclear industry infrastructure. Sources of these developments may include the growing presence of foreign firms in the U.S. nuclear market, factors that may encourage or discourage the use of fossil fuels or other non-nuclear energy sources, national and international economic cycles, and expanding terrorist activities. Neither the NRC, its constituent bodies, nor the domestic nuclear industry will exercise great control over most of these factors. They are, nevertheless, potential sources of important change which will create requirements for alterations in NRC QA policies and programs.

4.2.4.1 Entry of Foreign Suppliers Into the U.S. Market

Despite the general downturn in the U.S. nuclear business, foreign firms regard the U.S. market as worth pursuing. Section 3.6.1 discusses the status of and prognosis for foreign involvement in the U.S. market. In summary, sales by foreign firms of components, nuclear services, and technical support to U.S. plants are currently significant and are given high priority by French, Japanese, Swedish, German, and Swiss companies. This situation presents the NRC with four quality-related concerns: 1) evaluation of foreign QA programs; 2) determination of their QA equivalencies; 3) special inspection requirements; and 4) routine communication of new QA requirements to foreign vendors. The NRC is aware of the need to resolve these concerns and is actively involved with at least two overseas procurement situations which require decisions on the acceptability of foreign nuclear QA programs (see Section 3.6.1). Additional evaluation of QA program and practice equivalencies will have to be done in the near future as will some resolution of whether or not new procedures for overseas inspection and control of subtier vendors are needed. Possibly, the NRC will find it necessary to establish a physical presence in foreign plants for certain types of procurements. If so, resources will need to be identified and appropriate QA and inspection organizations may have to be formed.

4.2.4.2 Impacts from Other Fuel Systems

Capacity needs will grow largely independent of energy source; and economic, environmental, and political factors will combine to dictate the preferential source. Developments which discourage the use of fossil fuels (pollution, cost, world political developments) may encourage greater reliance on nuclear power. Emerging trends should be periodically reviewed in advance planning for NRC resource needs.

4.2.4.3 Economic Cycles

The character of the national economy, as reflected in capacity need projections, should also be viewed as a bellwether of changing situations which may evoke more or less concern over nuclear QA. As an example, the proliferation of nuclear plant orders in the early 1970s over taxed the design and construction capabilities of U.S. AEs forcing some utilities to engage firms and/or project teams with limited experience in construction of nuclear plants. This situation was partially responsible for some of the quality breakdowns in plant design and construction which occurred in the late 1970s and early 1980s. In retrospect, it should have been possible for the utilities and the NRC to recognize the situation as a possible source of problems and to have implemented preventative measures. The NRC needs to remain alert to the development of similar, growth-cycle-related situations.

4.2.4.4 Terrorist Activities

The continental U.S. has been fortunate in experiencing relatively little of the indiscriminate terrorism plaguing much of the world. If the situation changes, nuclear plants could be prime targets. The NRC should consider whether more rigorous quality assurance should be applied to plant protective systems.

4.3 SUMMARY AND CONCLUSIONS--FUTURE NRC QA CHALLENGES AND OPTIONS

Sections 4.1 and 4.2 discuss quality-related problems likely to confront the NRC as consequences of anticipated trends in the nuclear industry between 1985 and 1995. Options available to the NRC for anticipating and responding to these developments were also identified. The majority of the alternatives that might be exercised by the NRC take the form of modifications to the Agency's structure or practices. In responding to certain challenges, new regulatory guidance may be the best approach, and some formal revisions in, or additions to the regulatory base may be required to affect certain of the suggested internal changes.

An overview of predicted impending issues with QA implications and a list of corresponding possible options for dealing with them is presented in Table 12. This summarizes in a more accessible way the findings developed in the preceding parts of Chapter 4.0.

TABLE 12. Summary of Projected Quality Issues and Resolutions

ISSUES	RESOLUTION OPTIONS
I. Transition to All Operating Reactor Environment	
A. Expanded Inspection Needs	
o Greater inspection presence required at operating plants. o Different qualifications for operations vs construction. o More competition for qualified personnel. o Fewer new graduates.	o Expand inspection staff. o Better training for inspectors and other QA staff. o Monetary or other incentives. o Use of licensee or contractor staff to supplement inspection staff.
B. Knowledge Base Retention	
o Diminished need for constuction-related inspections thus loss of expertise. o Possible future need for lessons learned in construction.	o User-friendly archiving of present expertise for future use. o Expert system to aid future use of lessons learned.
C. Inspection Personnel Qualifications	
o Increases in technical complexities of plants and inspection techniques.	o Advanced training, use of computerization and video training aids and communications. o Expert training team serving all regions.
D. Plant Aging and Life Extension	
o Need for more and/or different inspections at older plants. o Uncertainty regarding prospects for license extension.	o Continued aging studies. o Staff training on aging phenomena. o Staff training in new inspection methods. o Develop criteria and guidance for license extension application.
E. Maintenance and Outage Management	
o Maintenance program effectiveness. o Effective QA during outages.	o More prescriptive guidance on maintenance. o QA Program structured to accomodate new maintenance requirements. o Standarized outage inspection procedures.
F. Plant Alteration and Component Replacement	
o Lack of original parts. o Shortage of certified parts. o Alteration effects on design bases.	o Evaluate equivalencies of non-nuclear certification. o Review/relax certification requirements. o More QA oversight for alterations.
G. Restarting Mothballed Plants	
o Conformance to current regulatory requirements. o In-storage deterioration. o Documentation adequacy.	o Guidance on application of regulatory requirements. o Evaluation of deterioration mechanisms and effects. o Survey deterioration experience. o Guidance on preservation and documentation requirements.
H. Severe Accident Response	
o Effectiveness of general, short response changes in QA.	o Evaluation of TMI-2 experiences in terms of effectiveness of type of approach.
I. QA in Waste Isolation	
o Site selection/licensing of repository.	o Develop guidance for QA on site characterization R&D.

TABLE 12. (contd)

II. Introduction of New Technology	
A. Advanced Reactors	
o Market uncertainty. o Viability of concepts. o Differences from present LWR's in QA needs.	o Define QA program and resource needs for regulatory revisions. o Scope new regulatory frameworks.
B. Advanced Computer Applications	
o Computer use in reactor control. o Development and implementation of expert systems and other artificial intelligence to supplement maintenance, inspections, and trouble shooting. o Rapid growth in use of computerization generally.	o Develop regulatory guidance for software QA. o Training of staff (HQ and inspectors) in QA for software and computerized systems. o More use of computerization by HQ and regions - training, data handling, expert systems. o Hire staff with computer backgrounds. o Develop criteria for appropriateness of computerizations.
C. New Inspection Technology	
o Adequacy of license qualifications.	o Inspector training in new methods. o Regular review of license qualifications.
III. Regulatory Policy Issues	
A. Shifting Intervenor Emphasis	
o Fewer allegations of construction QA problems. o Refocus on operations, transportation, and waste storage.	o Shift resources as appropriate. o Evaluate new staff capability needs. o Verify effectiveness of QA guidance for operations, transportation, and waste storage and upgrade as appropriate.
B. Economic Pressures on Licensees	
o SURA pressures for increased capacity factors and for disallowing costs in rate base encourage utilities to save where possible.	o Develop methods for assessing maintenance and inspection effectiveness. o Develop more efficient, prioritized inspection procedures. o Increase inspection staff at affected sites. o More prescriptive guidance on maintenance.
C. Pending Legislative Action	
o Issues as identified in current bills.	o Maintain awareness and identify response options.
D. New Institutional Arrangements	
o Different licensee arrangements for future plants.	o Analyze serious proposals for QA implications.
E. Deregulation of the Utility Industry	
o Loss of support for key industry groups.	o Maintain an awareness and identify response options.
IV. External Influences	
A. Foreign Suppliers in U.S. Markets	
o Safety related items qualified to other than N-stamp requirements. o Manufacture of safety related items abroad. o Modifications to U.S. manufacturers' practices because of their alliances with foreign firms.	o Evaluation of foreign QA programs for conformance to NRC requirements. o Determination of equivalance between foreign QA practices and NRC requirements.

TABLE 12. (contd)

o Economic pressures on traditional U.S. supplies.	o Determine need for NRC inspection abroad and implement. o Regularly monitor U.S. suppliers for degradation in QA practices.
B. Impacts From Other Fuel Systems	
o Economic, environmental, and political influences which encourage or discourage non-nuclear fuel use.	o Remain aware of trends and plan for compensating nuclear trends-increase or decrease QA/inspection staff to anticipate trends.
C. Economic Cycles	
o Overall trends in the national and world economies causing changes in capacity needs.	o Maintain awareness of trends and their expected effect on licensees and NRC resource needs.
D. Terrorism	
o Possible increased threats to U.S. plants.	o Verify that adequate QA is applied to protective systems.

The general implication of the alternative projections developed in Chapters 2.0 and 3.0 and the resultant policy issues and options discussed in Chapter 4.0 is that the nature of NRC quality-related responsibilities and work load will change substantially over the next ten years. Neither significant, sudden increases nor declines in overall personnel or other resource requirements can be foreseen. Anticipated changes should be evolutionary in nature and can be effected in an orderly way without serious disruption in staff or resource allocation if the agency recognizes and prepares for change in a timely, efficient manner. Training and staff development are important elements in dealing with many of the expected trends. These activities are under the direct control of the NRC and can be quickly and economically supplemented to meet new needs. Some near term needs for new regulatory guidance exist, e.g., in the areas of nuclear waste isolation, plant life extension, computer software, maintenance, mothballing of partially complete plants, and determination of equivalencies between NRC and foreign and non-nuclear quality programs.

The question of issue prioritization has been avoided in this study for two reasons:

1. The trends from which issues derive are predictions which include significant uncertainty. Tangible indications that a trend is materializing are required to justify substantive action by the NRC.

2. The NRC must contend with organizational and political exigencies which must be considered in conjunction with technical issues in determining priorities. Resolution of these composite factors can be accomplished only internally, i.e., within the Agency by NRC staff.

Finally, the fact that an issue is cited in the foregoing should not be construed to suggest that the NRC has not been aware of or has been unresponsive to that particular problem. Many of the issues noted are of current (and some of long term) concern to the NRC, and in a number of cases, initiatives to resolve cited issues are in progress.

REFERENCES

1. "Report of the Edison Electric Institute on Nuclear Power," February 1985, pp. 1-5.

2. ibid, p. 6-8.

3. ibid, p. 11.

4. ibid, p. 30.

5. ibid, p. 31.

6. ibid, p. 33.

7. "Commercial Nuclear Power 1984 - Prospects for the United States and the World," DOE/EIA-0438(84), Nov., 1984.

8. "The Future of Electric Power in America, Economic Supply for Economic Growth," DOE Office of Policy Planning and Analysis, Washington, D.C., June 1983, Ch. 3.

9. "Nuclear Power: Technology Overview, Statistics and Projections; Updated 1/28/85" Robert L. Criviak, Congressional Research Services, Order Code IB/1070, February 1985.

10. "Annual Energy Outlook, 1983". DOE Energy Information Administration, Washington, D.C., May 1984.

11. J. R. Seigel and T. O. Sillin, "Rethinking Utility Strategy Under Conditions of High Growth, "Public Utilities Fortnightly, September 13, 1984.

12. "Historical Profile of U.S. Nuclear Power Development," Atomic Industrial Forum, January 1985 (June 1985 updated).

13. Nuclear News. August 1985, pp. 107-111.

14. "Nuclear Power Facts and Figures." Atomic Industrial Forum, March 1984 (updated June 1985).

15. "U.S. Nuclear Power Plants: Construction Progress," Nuclear Industry, March 1985, p. 22-23.

16. "DLJ Issues Updated Report on Nuclear Plant Construction Costs," Nucleonics Week, March 14, 1985, p 4.

17. "Rescue Nuclear, Bolster Industry, EEI Urges," Electric Light and Power, April 1985, p. 16.

18. "Nuclear Power Plant Construction: Paying the Bill," <u>FRBNY Quarterly Review</u>, Summer 1984.

19. "Nuclear Power in an Age of Uncertainty," Office of Technology Assessment, OTA-E-216, February 1984, p. 179.

20. "Nuclear Services: Surviving the Shakeout," proceedings of McGraw Hill Conference, April 1984.

21. Electric Utilities Week, April 15, 1985.

22. Newsday press release, July 1, 1985.

23. ibid (20).

24. "Nuclear Power in an Age of Uncertainty." OTA-E-216, Working Papers, Vol. II, November 1984.

25. ibid. 19. Ch. 7.

26. "Decline in Nuclear Industry Worries Vendor, AEs, Utilities", <u>Nuclear Industry</u>, July 1982, p. 8-10.

27. R. J. Smith et al., "Future Viability of Component Manufacturers for Nuclear Reactor Power Plants." PNL Letter Report to P. Lang, DOE, January 1982, Contract DE-AC06-76RLO 1830.

28. American Society of Mechanical Engineers, "Companies Holding Nuclear Certification of Authorization Annual."

29. C. J. Jones. "What Is the Nuclear Service Industry Today and How Is It Doing?" Nuclear Services Surviving the Shakeout, proceedings, McGaw-Hill Conference, April 1984.

30. "Buyer's Guide '85". <u>Nuclear News</u>. Vol. 28, No. 4, 1984.

31. "G. E. Wants. "High Tech' End of $2.5 Billion Services Market," <u>Nucleonics Week</u>. Feb. 2, 1984. p. 8.

32. "S&W-GE Team Signs Spare Parts Management Contract with Gulf States," <u>Nucleonics Week</u>, March 31, 1985, p. 10.

33. "Westinghouse Plans to Invest Heavily in High Tech Software," <u>Nucleonics Week</u>, Dec. 6, 1984. p. 10.

34. "Westinghouse Virgnia Power Given Incentive to Maintain Steam Generators." Nucleonics Week, February 21, 1985, p. 5.

35. "AIF Study - Nuclear's Future Clouded by Non-Vitality Today," <u>Nuclear Industry</u>, August 1984, p. 3-8.

36. "Interagency Task Force to Follow Nuclear Projects Around the World," Nucleonics Week, May 2, 1985. p. 11.

37. "European, Japanese Firms Ready to Rescue U.S. Reactor Performance," Nucleonics Week, May 2, 1985. p. 10.

38. "Nuclear Services Strategies." Proceedings of McGraw-Hill Conference, May, 1985.

39. "NRC Approves GNS Castor V Storage Cask," Nuclear Fuel, November 7, 1985. Vol. 10, No. 20.

40. "Framatome Tenders Equipment in U.S. Market Entry," Nucleonics Week. March 14, 1985, p.9

41. "Framatome Hopes to Get NRC Approval of Their QA Program." Nucleonics Week, July 25, 1985.

42. "INPO and Commonwealth Edison Set Up Maintenance Exchanges with Japan," Nucleonics Week, March 21, 1985, p. 8.

43. "Virginia Power's Ferguson says Nuclear Fate is Tied to Better Operation." Nucleonics Week, July 4, 1985, p. 10.

44. R. L. Civiak et al. "Nuclear Energy Policy Updated 3/1/85." CRS Issue Brief IB 82054.

45. "NRC Majority Flip-Flops to Endorse New Price-Anderson Liability Limit." Nucleonics Week, June 7, 1985, p. 3.

46. "Energy Related Manpower," DOE/ER-0134/1, DE84 007082, ORAU, November 1983.

47. "Enrollment Dips and Academia Frets about Its Ability to Train." Nuclear Industry, Feb. 1984, p. 3-9.

48. "To Retire or Revitalize," Nuclear Industry, Feb. 1985, p. 3-9.

49. "Power Plant Life Extension Economics, Plans Explored at American Power Conference." Electric Light and Power, June 1984, p. 27.

50. "CG&E Executive Sees Plant Life Extension Major Strategy in Coming Year." Electric Utility Week. April 8, 1985.

51. W. J. Manion and T. D. La Guardia, Decommissioning Handbook, DOE/EX/10128-1, November 1980.

52. "Public Interest Effort Surveys Decommissioning Tactics and Funding," Nucleonics Week, April 28, 1985, p. 10.

53. ibid, 19, p. 94.

53. ibid, 19, p. 94.

54. K. E. Stahlkopf, "A Perspective on Advanced LWRs." October 22, 1984.

55. "Nuclear Power: The Next Generation," EPRI Journal, March 1985, p. 6-13.

56. "NRC Takes Public Lead in Fostering New N-Reactors," Electric Light and Power, May 1985, p. 1-2.

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

1. REPORT NUMBER (Assigned by TIDC, add Vol. No., if any): NUREG/CR-3959 PNL-5769

2. TITLE AND SUBTITLE: Transition to an Operating Reactor Environment--Implications for NRC Quality Assurance Programs Based on Nuclear Power Industry and Regulatory Projections Through 1995

3. LEAVE BLANK

4. DATE REPORT COMPLETED: MONTH March YEAR 1986

5. AUTHOR(S): J.A. Christensen, H. Harty, C.R. Schuller, M.G. Patrick

6. DATE REPORT ISSUED: MONTH March YEAR 1986

7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Pacific Northwest Laboratory
PO Box 999
Richland, WA 99352

8. PROJECT/TASK/WORK UNIT NUMBER

9. FIN OR GRANT NUMBER: FIN P-2003

10. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Division of Quality Assurance, Vendor, and Technical Training Center Programs
Office of Inspection and Enforcement
US Nuclear Regulatory Commission
Washington, DC 20555

11a. TYPE OF REPORT: Technical-final

b. PERIOD COVERED (Inclusive dates)

12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)

This report develops projections for nuclear power plant regulatory needs in general, and those relating to quality assurance in particular, for the time period 1985 to 1995. This required an assessment of future prospects for the nuclear power industry and its primary segments. Electric power demand projections and their relationship to estimated schedules for nuclear plant construction and operations were evaluated, and estimates of anticipated business volume and long term economic viability were made for each of the major segments of the U.S. nuclear industry (utilities, NSSS vendors, AEs, constructors, component suppliers, and service vendors). These estimates were made for two, five, and ten year intervals through 1995. Other significant factors that are not specific to any one industry segment were also reviewed. These included: 1) the expanding foreign presence in U.S. markets; 2) pending legislation; 3) trends in personnel availability; 4) new institutional arrangments for nuclear power generation; 5) nuclear plant aging, life extension, and decommissioning; 6) reactivation of mothballed projects; 7) advanced and standardized plant designs; and 8) likely technological developments in computer applications and inspection methods. The trends revealed by these analyses imply a number of significant challenges for nuclear power regulation in the U.S. Many projected changes have implications for NRC QA policies and practices. These issues were broken into functional elements each of which was analyzed in terms of its significance and kinetics of emergence for each of the overall industry projections. Finally, NRC options for dealing with each QA-related issue were assessed.

14. DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS

Nuclear Steam Supply System Vendors
Architect-Engineers
Commercial Nuclear Power Plants
Nuclear Components
Nuclear Generation
Quality Assurance
Nuclear Industry
Construction
Nuclear Equipment
Nuclear Services
Capacity
Power Plant Life Extension
Foreign Suppliers
Decommissioning
Advanced Reactors

b. IDENTIFIERS/OPEN ENDED TERMS

15. AVAILABILITY STATEMENT: UNLIMITED

16. SECURITY CLASSIFICATION
(This page) UNCLASSIFIED
(This report) UNCLASSIFIED

17. NUMBER OF PAGES

18. PRICE

DO NOT PRINT THESE INSTRUCTIONS AS A PAGE IN THE NUREG REPORT

INSTRUCTIONS

NRC FORM 335, BIBLIOGRAPHIC DATA SHEET, IS BASED ON GUIDELINES FOR FORMAT AND PRODUCTION OF SCIENTIFIC AND TECHNICAL REPORTS, ANSI Z39.18-1974 AVAILABLE FROM AMERICAN NATIONAL STANDARDS INSTITUTE, 1430 BROADWAY, NEW YORK, NY 10018. EACH SEPARATELY BOUND REPORT—FOR EXAMPLE, EACH VOLUME IN A MULTIVOLUME SET—SHALL HAVE ITS UNIQUE BIBLIOGRAPHIC DATA SHEET.

1. **REPORT NUMBER.** Each individually bound report shall carry a unique alphanumeric designation (NUREG) assigned by the Division of Technical Information and Document Control, ADM, in accordance with American National Standard ANSI Z39.23-1974, Technical Report Number (STRN). Use uppercase letters, Arabic numerals, slashes, and hyphens only, as in the following examples: NUREG-0100, NUREG/CP-0010, NUREG/CR-0100, and NUREG/BR-0010. For reports in a series add Vol., Supp., Revision, and Addendum, when necessary. Add contractor cross-reference identification number (if any) below NUREG number, e.g., PNL-XXXX, SANDXX-XXXX, SAI-XXXX.

2. **TITLE AND SUBTITLE.** Title should indicate clearly and briefly the subject (coverage) of the report; including any subtitle to the main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific volume. Use upper and lower case letters, but capitalize computer code names. Do not use acronyms and initialisms in titles; may be added in parenthesis.

3. **LEAVE BLANK.**

4. **DATE REPORT COMPLETED.** Each report shall carry a date indicating month and year project/task completed.

5. **AUTHOR(S).** Give name(s) in conventional order (e.g., John R. Doe, J. Robert Doe). List author's affiliation if it is different from the performing organization.

6. **DATE REPORT ISSUED.** Each report shall carry a date indicating month and year published.

7. **PERFORMING ORGANIZATION NAME AND MAILING ADDRESS.** Give name, street, city, state, and ZIP code. List no more than two levels of an organizational hierarchy. Display the name of the organization exactly as follows: Division, Office, Organization or Government agency, and address.

8. **PROJECT/TASK/WORK UNIT NUMBER.** Use the project, task and work unit numbers under which the report was prepared (if any).

9. **FIN OR GRANT NUMBER.** Insert the FIN or grant number under which report was prepared.

10. **SPONSORING ORGANIZATION.** List NRC Division, Office, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

11. a. **TYPE OF REPORT.** State draft, final, preliminary, topical, technical, regulatory, quarterly, etc., and, if applicable, inclusive dates.

    b. **PERIOD COVERED.**

12. **SUPPLEMENTARY NOTES.** Enter information not included elsewhere but useful, such as: Prepared in cooperation with . . . Presented at conference of . . . To be published . . . Docket No. . . . When a report is revised, indicate whether the new report supersedes or supplements the older report.

13. **ABSTRACT.** Include a brief (200 words or less) factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey or multiple volumes, mention it here. Abstract is to be prepared by author or project manager.

14. **DOCUMENT ANALYSIS**

    a. **KEY WORDS/DESCRIPTORS.** Select from the Energy Data Base Subject Thesaurus, DOE/TIC-7000R R-5, the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.

    b. **IDENTIFIERS AND OPEN-ENDED TERMS.** Use identifiers for project names, code names, equipment designators, etc. Use open-ended (keywords) terms written in descriptor form (14a) for those subjects for which no descriptor exists in the thesaurus.

15. **AVAILABILITY STATEMENT.** Denote public releasability, for example "unlimited", or limitation for reasons other than security.

16. **SECURITY CLASSIFICATION.** Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., unclassified).

17. **NUMBER OF PAGES.** Leave blank. (Added by NTIS)

18. **PRICE.** Leave blank. (Added by NTIS)