Chapter 1

Introduction: The Seven-Sided Coin

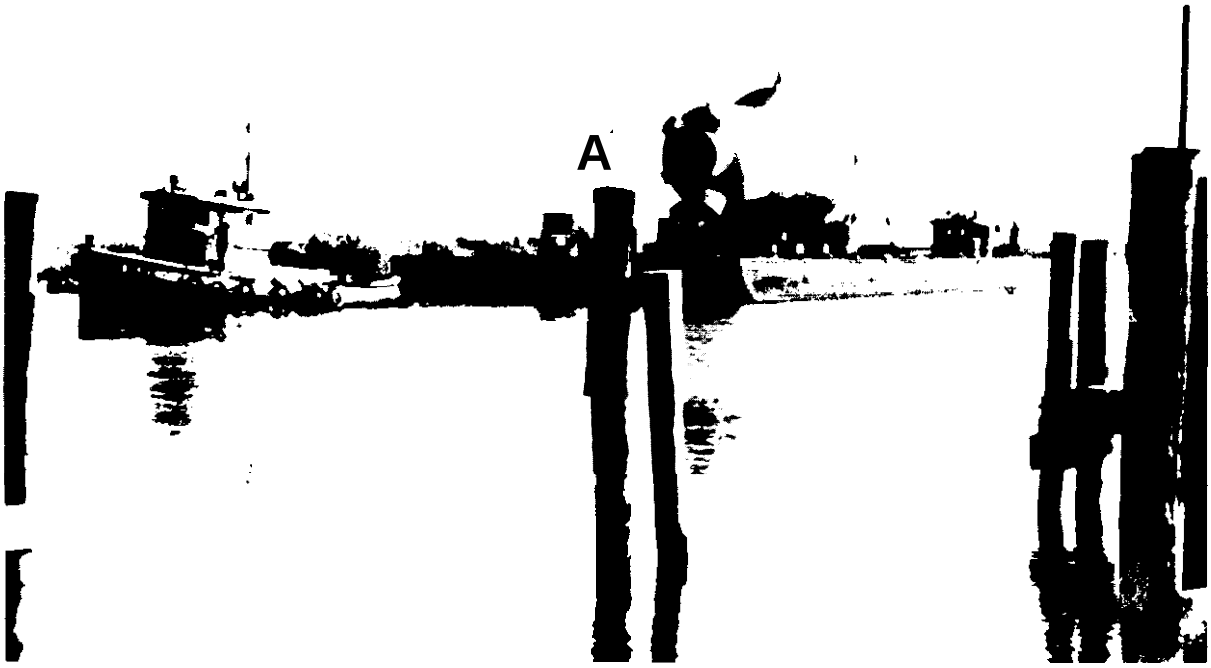

Photo credit: Atom/c Industrial Forum

Steam generator for a pressurized water reactor (PWR) arrives by barge

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THE POLICY PROBLEM

The nuclear power industry is facing a period of extreme uncertainty. No nuclear plant now operating or still under active construction has been ordered since 1974, and every year since then has seen a decrease in the total utility commitment to nuclear power. By the end of this decade, almost all the projects still under construction will have been completed or canceled. Prospects for new domestic orders during the next few years are dim.

Such a bleak set of conditions has led some observers to conclude that the industry has no future aside from operating the existing plants. Some conclude further that such an end is entirely appropriate because they believe that nuclear reactors will not be needed due to the low growth in demand for electricity, and that the present problems are largely a result of the industry's own mistakes.

If nuclear power were irrelevant to future energy needs, it would not be of great interest to policy makers. However, several other factors must be taken into account. While electric growth has been very low over the last decade (in fact, it was negative in 1982), there is no assurance that this trend will continue. Even growth that is quite modest by historical standards would mandate new plants—that have not been ordered yet–coming online in the 1990's. Replacement of aging plants will call for still more new generating capacity. The industrial capability already exits to meet new demand with nuclear reactors even if high electric growth resumes. In addition, reactors use an abundant resource. Oil is not a realistic option for new electric-generating plants because of already high costs and vulnerability to import disruptions which are likely to increase by the end of the century. Natural gas may also be too costly or unavailable for generating large quantities of electricity.

The use of coal can and will be expanded considerably. All the plausible growth projections considered in this study could be met entirely by coal. Such a dependence, however, would leave the Nation's electric system vulnerable to price increases and disruptions of supply. Furthermore, coal carries significant liabilities. The continued combustion of fossil fuels, especially coal, has the potential to release enough carbon dioxide to cause serious climatic changes. We do not know enough about this problem yet to say when it could happen or how severe it might be, but the possibility exists that even in the early 21st century it may become essential to reduce sharply the use of fossil fuels especially coal. Another potentially serious problem with coal is pollution in the form of acid rain, which already is causing considerable concern. Even with the strictest current control technology, a coal plant emits large quantities of the oxides of sulfur and nitrogen that are believed to be the primary source of the problem. There are great uncertainties in our understanding of this problem also, but the potential exists for large-scale coal combustion to become unacceptable or much more expensive due to tighter restrictions on emissions.

There are other possible alternatives to coal, of course. Improving the performance of existing powerplants would make more electricity available without building new capacity. Cogeneration and improved efficiency in the use of electricity also are equivalent to adding new supply. These approaches are likely to be the biggest contributors to meeting new electric service requirements over the next few decades. Various forms of solar and geothermal energy also appear promising. Uncertainties of economics and applicability of these technologies, however, are too great to demonstrate that they will obviate the need for nuclear power over the next several decades.

Therefore, there may be good national-policy reasons for wanting to see the nuclear option preserved. However, the purpose of the preceding discussion is not to show that nuclear power necessarily is vital to this Nation's well-being, It is, rather, to suggest that there are conditions

under which nuclear power would be the preferred choice, and that these conditions might not be recognized before the industry has lost its ability to supply reactors efficiently and expeditiously. If the nuclear option is foreclosed, it should at least happen with foresight, not by accident or neglect. This report analyzes the technical and institutional prospects for the future of nuclear power and addresses the question of what Congress could do to revitalize the nuclear option if that should prove necessary as a national policy objective.

NUCLEAR DISINCENTIVES

No efforts-whether by Government or the industry itself–to restore the vitality of the industry will succeed without addressing the very real problems now facing the technology. To illustrate this, consider a utility whose projections show a need for new generating capacity by the mid-**1990's. in comparing coal and nuclear plants, current estimates** of the cost of power over the plant's lifetime give a small advantage–perhaps 10 percent–to nuclear. Fifteen years ago, that advantage would have been decisive. Now, however, the utility managers can see difficulties at some current nuclear projects which, if repeated at a new plant, would eliminate any projected cost advantage and seriously strain the utility:

- The cost projections may be inaccurate. Some plants are being finished at many times their originally estimated cost. Major portions of a plant may have to be rebuilt because of design inadequacy, sloppy workmanship, or regulatory changes. Construction lead-times can approach 15 years, leaving the utility dangerously exposed financially. The severe cash flow shortages of the Washington Public Power Supply System (WPPSS) are an extreme example of this problem.
- Demand growth may continue to fall below projections. A utility may commit large sums of capital to a plant only to find part way through construction that it is not needed. If the plant has to be canceled, the utility and its shareholders must absorb all the losses even though it looked like a reasonable investment at the beginning. The long construction schedules and great capital demands of nuclear plants make them especially risky in the light of such uncertainty.
- The Nuclear Regulatory Commission (NRC) continues to tighten restrictions and mandate major changes in plant designs. Although the reasons for these changes often are valid, they lead to increases in costs and schedules that are unpredictable when the plant is ordered. In addition, the paperwork and time demands on utility management are much greater burdens than for other generating options.
- Once a plant is completed, the high capital costs often lead to rate increases to utility customers, at least until the plant has been partially amortized. This can cause considerable difficulty with both the customers and the public utility commission (PUC), If rate increases are delayed to ease the shock, net payback to the utility is postponed further.
- Most of the money to pay for a plant has to be raised from the financial market, where nuclear reactors increasingly are viewed as risky investments. The huge demands for capital to pay construction costs (and the high interest costs on this capital) make unprecedented financial demands on utilities at a time when capital is costly.
- There are many opportunities for opponents of a plant to voice their concerns. Some plants have been the focus of suits over specific environmental or safety issues. in the licensing process, critics may raise a wide variety of issues to which the utility has to be prepared to respond. These responses call for a significant legal and technical effort as well as long delays, regardless of the ultimate disposition of the issue.
- Plant operation may not meet expectations, Some reactors have suffered chronic reliability problems, operating less than 50 percent of the time. Others have had to replace major components, such as steam generators,

at a cost of tens of millions of dollars because of unexpectedly rapid deterioration. While there is no specific reason to think a new plant would not operate its full life expectancy without major repairs, no reactor is yet old enough to have demonstrated it. There also is the possibility of long-term shutdowns because of accidents such as Three Mile Island. Furthermore, a nuclear utility is vulnerable to shutdowns and major modifications not only from accidents at its own facility, but also from accidents at any other reactor.

- Public support for nuclear power has been slipping, largely due to concerns about safety and costs. Public concerns can manifest themselves in political opposition. Several states have held referenda banning nuclear power or restricting future construction. None has passed that would mandate shutting down operating reactors, but some have come close. Furthermore, State and local governments have considerable control over the plant through rate regulation, permitting, transportation of waste, and approval of emergency plans. If the public does not want the plant, all these levers are likely to be used against it.

Given all these uncertainties and risks, few utilities would now consider nuclear reactors to be a reasonable choice. Moreover, the pressures arising from virtually continuous interactions with contractors, NRC, the PUCs, financial institutions, and perhaps lawsuits by opponents, make nuclear power far more burdensome to a utility than any other choice. The future of nuclear power would appear to be bleak.

Yet there is more to nuclear power than the well-publicized problems affecting some reactors. In fact, many have been constructed expeditiously, and are operating with acceptable reliability. Some have enjoyed spectacular success. For instance, the McGuire unit 2 of Duke Power in North Carolina was completed in 1982 at a cost of $900/kW, less than a third of the cost of the Shoreham plant in New York. The Vermont Yankee plant operated in 1982 at 93 percent availability, one of the best records in the world for any kind of generating plant. Calvert Cliffs supplies electricity to Baltimore Gas & Electric customers at 1.7¢/kWh. Finally, safety analyses are improving steadily, and none has indicated that nuclear plants pose a level of risk to the public as high as that accepted readily from other technologies. These well-managed plants have operated safely while providing substantial economic benefits for their customers.

Such examples, however, are insufficient to counterbalance the problems others have encountered. Nuclear power has become entangled in a complex web of such conflicting interests and emotions that matters are at an impasse. The utility viewpoint discussed above shows that there is little advantage and a great many disadvantages to the selection of a nuclear plant when new capacity is needed. Therefore, there will be few– if any—more orders for reactors in this century without significant changes i n the way the industry and the Government handle nuclear power.

THE IMPASSE

Consider now the perspective of those Federal energy policy makers who believe the nuclear option should be maintained in the national interest. **It** is unlikely that the U.S. Government will heavily subsidize the purchase of reactors by utilities or that it will build and operate reactors itself. Therefore, new orders will be stimulated only by alleviating those concerns and problems that now preclude such orders. Any policy initiative that is proposed, however, is likely to be controversial, because there are at least seven parties with distinct–and often conflicting–interests:

- utilities,
- nuclear safety regulators,
- critics of nuclear power,
- the public,
- the nuclear supply industry,
- investors and the financial community, and
- State public utility commissions.

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To illustrate how these interests pull in different directions for different reasons, consider just one issue. Changes in plant licensing and safety regulation often are cited as necessary elements of any strategy to revitalize the option, but there is little agreement on either the type or extent of reform that should be instituted.

- Before **utilities** will make a commitment to invest several billion dollars in a nuclear plant, they want assurances that extensive modifications will not be necessary and that the regulations will remain relatively stable. Utilities contend that such regulatory changes delay construction and add greatly to costs without a clear demonstration of a significant risk to public health and safety. To the utilities, such assurances do not appear to be impossible to grant. They point out that NRC has licensed 80 plants and should know what is necessary to ensure operating safety. Therefore, they would support revisions to the regulatory process that would make it more predictable and stable,
- However, there is another side to this coin. No plant design has been analyzed exhaustively for every possible serious accident sequence, and operating experience is still too limited for all the potential problems to have been identified. Accidents at Three Mile Island and at the Browns Ferry reactor involved sequences of events that were not understood clearly enough until they occurred. if they had been, both could have been prevented easily. As the **NRC** and the industry recognize different accident sequences, backfits are needed to prevent future occurrences. Proposals to reduce NRC's ability to impose changes in accordance with its engineering judgment will be seen by safety regulators as hampering their mission of ensuring safety.
- But there is a third side to this coin. Not only do the industry and NRC see regulatory reform very differently, but **critics** of nuclear power find much to fault with both the utilities and the NRC. In particular, they feel that the NRC does not even enforce its present rules fully when such enforcement would be too costly to the industry. Furthermore, they believe that the technology has so many uncertainties that much greater margins of safety are warranted. Thus, nuclear critics strenuously oppose any changes in the NRC regulations that might limit their access to the regulatory process or constrain the implementation of potential improvements in reactor safety.
- The **public** is yet a fourth side. Public opinion polls show a long-term trend against nuclear power. The public demands that nuclear reactors pose no significant risks, is frustrated by the confusing controversy surrounding them, and is growing increasingly skeptical about any benefits from nuclear power. These conditions do not give rise to a clear mandate for regulatory reform in order to facilitate more reactor orders. Such a mandate will depend largely on improved public confidence in the management ability of utilities and their contractors, in the safety of the technology, in the effectiveness of the regulatory process, and on a perception that nuclear energy offers real benefits.
- The **nuclear supply industry's** interests are not synonymous with the utilities' and thus represent a fifth side of the coin. The utilities need to meet demand with whatever option appears least expensive. If that option is not nuclear power, something else will suffice. The supply industry, however, has a large vested interest in promoting nuclear reactors, and the careers of thousands of industry employees may hinge on policy changes to revitalize the nuclear option, including regulatory reform.
- **Investors** may be ambivalent about licensing reform. Lengthy and uncertain licensing makes nuclear power a riskier investment during construction, but any accident during operation can have the same, if not greater, effect. Insofar as more stringent licensing makes accidents less likely, it reduces the financial risk. However, investors probably will be more concerned with the near-term risks involved in getting a plant online and would be more supportive of streamlined licensing if it reduced those risks.
- As representatives of consumers' economic interest, **public utility commissions'** share

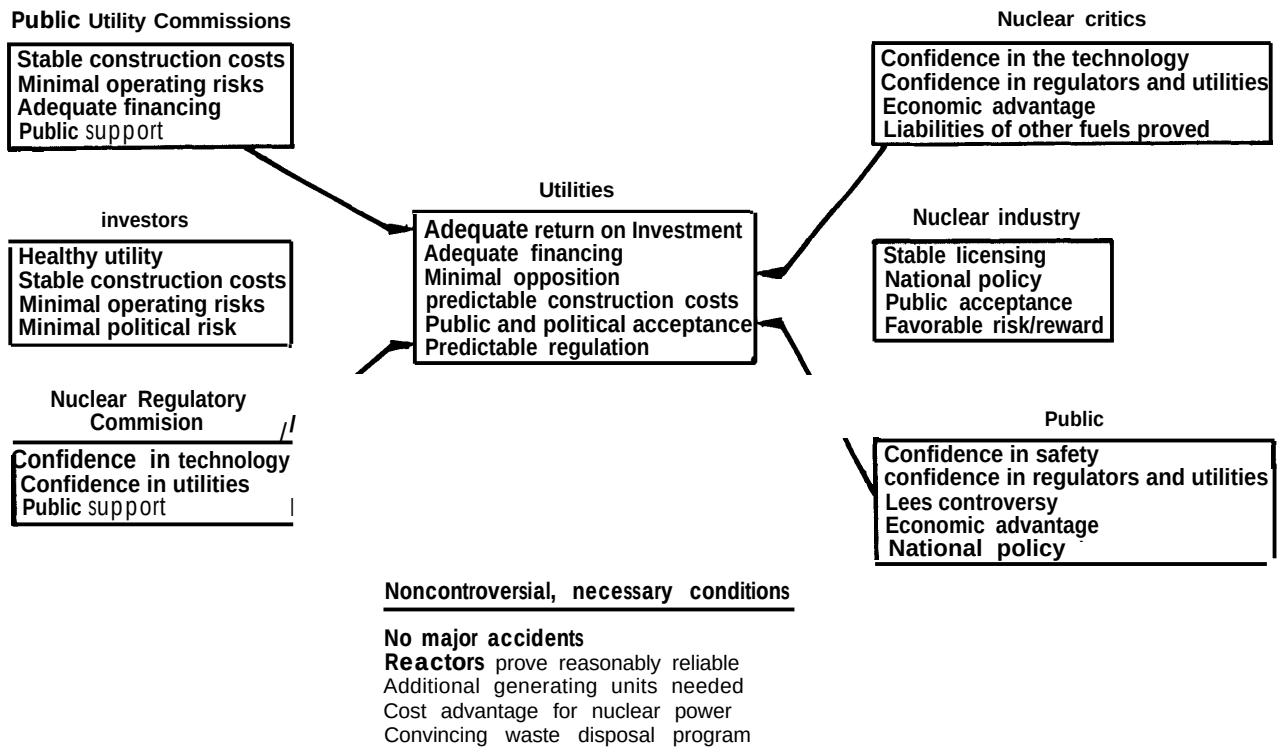
the investors' ambivalence, but they might give more weight to operating safety because an accident that shuts down a reactor for a prolonged period usually will mean the substitution of more expensive sources of electricity.

Thus, there are at least seven different parties in each policy debate on nuclear power: seven sides to the coin of each issue. No doubt others could be added, but those described above represent the major positions. Each party is a collection of somewhat differing interests, and each will look for different things in any policy initiative. Given such a multiplicity of interests, it is not surprising that the present impasse has developed.

Figure 1 illustrates these concepts. Utilities are at the center because they make the ultimate decision about whether to order a nuclear plant or something else. The other parties have considerable, sometimes decisive, influence over whether a nuclear plant will be built, how much it will cost, and how well it will work. Each of these parties has its own agenda of conditions that must be met before it would support a decision by a utility to order a reactor. These conditions are listed with each party. Those conditions that are common to all are listed at the bottom of the figure. For instance, nuclear power must be very safe, with a very low risk of core meltdowns or major releases of radioactivity. Disputes over this point relate to the degree of safety required, the adequacy of the methodology in determining safety, the assumptions of the analyses, and the actual degree of compliance with regulations. in any case, however, existing reactors must be demonstrably safe, and future reactors probably will be held to even higher standards.

A closely related issue is reliability. A smoothly operating reactor is more productive for its owners, and it also is likely to be safer than one that frequently suffers mishaps, even if those mishaps

Figure A.—The Seven Sides to the Nuclear Debate



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have no immediate safety consequences. Thus, it also will be considerably more reassuring to the public.

Other common criteria are that there must be a clear need for new generating capacity and a significant cost advantage for nuclear power. In addition, a credible waste disposal program is a prerequisite for any more orders.

Other conditions are especially important to some groups but less important to others. Some of these conditions already are met to some degree. The arrows in figure A drawn to the conditions under utilities indicate the major areas that are related to the other parties.

Many of the conditions in figure 1 are **necessary** before enough of the participants in the debate will be satisfied that nuclear power is a viable energy source for the future. It is much more difficult to know how many must be met to be **sufficient.** All the groups discussed above have considerable influence over the future of nuclear power. Efforts to revive the option—whether initiated legislatively, administratively, or by industry—are unlikely to be successful if some of the interests find them unacceptable. The task of breaking the impasse therefore is formidable.

THE PURPOSE OF THIS STUDY

This report responds to requests from the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources asking OTA to "assess how nuclear technology could evolve if the option is to be made more attractive to all the parties of concern" and to identify possible technical and institutional approaches for the Congress "that could contribute to the maintenance of this important industry." The report describes the major impediments to nuclear power relative to other types of generating capacity, identifies options that might be considered to remove those impediments in light of the problems and conflicts discussed above, and explores the consequences of not maintaining the nuclear option.

Changes could be made in the technology and in the institutions that manage it. If a reactor were to be developed that physically could not suffer a major accident or pose health and safety risks for the public, it might allay some of the concerns of the regulators, the interveners, and the public. Such a reactor might not require the ever more stringent standards of quality required for current light water reactors (LWRs), thus reducing the economic risks. Improvements also could be considered in management of the construction, operation, and regulation of reactors. If all reactors were to match the experiences of the best managed plants, there would be much less concern over the future prospects for the nuclear option.

It is the intent of this study to explore these possibilities in the light of the different interests and different concerns discussed above. The report details the various difficulties facing the future of nuclear power and the measures that would be useful and practical in overcoming these difficulties if the Nation wishes nuclear power to once again be a well accepted, viable energy option. The technological options are restricted to converter reactors similar to those now available on the international market. These are the reactors that could be deployed in the United States by the end of the century. Breeder reactors are not included because their development program will not make them commercially available until sometime in the next century. The other elements of the fuel cycle—uranium resources and enrichment, reprocessing and waste disposal–are not included either. Waste has been considered in great detail in a recent OTA report. The other elements need not pose constraints to reactor orders, which is the key issue addressed in this report.

This assessment was carried out with the assistance of a large number of experts from all sides of the nuclear debate—utilities, nuclear critics,

reactor vendors, consumer groups, NRC, academics, State PUCs, nuclear insurers, executive branch agencies, the financial community, architect-engineering (AE) **firms, and interested members** of the public, As in all OTA studies, an advisory panel representing most of these interests met periodically during the course of the assessment to review and critique interim products and this report. Contractors supplied analyses and background papers in support of the assessment (these are compiled in vol. **II).** In addition, OTA held three workshops to review and expand on the contractors' reports and to ensure that all the relevant interests on each issue would be considered. The first workshop examined the energy and economic context for nuclear power, including projections of electricity demand, capital costs for powerplant construction, and the financing and rate regulation of electricity generation. The second workshop focused on the technological, managerial, and regulatory context for nuclear power, identifying the problems with current LWRs and the licensing process for them, and assessing alternative reactor technologies and proposals for licensing revision. The third workshop examined institutional changes, public acceptance, and policy options for revitalizing nuclear power. Based on these and other discussions, the OTA staff developed a set of policy options. Advisory panel members, contractors, and workshop participants are listed at the front of the report.

The nuclear debate long has been characterized by inflexible, polarized positions. We see some evidence that this polarization is softening For the most part, the OTA workshop participants and advisory panel members showed a willingness to compromise, including admissions by industry representatives that many mistakes had been made, and by nuclear critics that nuclear power could be a viable source of electricity if managed properly.

Volume I of this report is organized as follows:

- Chapter 2 presents a summary of the report.
- *Chapter 3* sets the context for decisions on the future role of nuclear power–factors affecting electricity demand, financial considerations including rate regulation and the costs of nuclear plants, and other elements in utility planning.
- *Chapter* 4 considers the technological alternatives to today's light water reactor: improved LWRs; the high-temperature gas reactor as evolving from the demonstration plant at Fort St. Vrain, Colo.; the heavy water reactor as developed in Canada; the PIUS concept—an LWR redesigned to make catastrophic accidents essentially impossible; the effects of standardization and sealing down reactor size.
- *Chapter 5* examines the human element in building and operating reactors and ways to improve the quality of these efforts; it analyzes the wide range of experiences in construction costs and schedules and in reactor operation, new measures that may improve quality control (e.g., the Institute for Nuclear Power Operations), and further steps that could be implemented if existing efforts prove inadequate.
- *Chapter* 6 describes the present regulatory process and the various concerns with it, and evaluates the major proposals for revision.
- *Chapter 7* reviews the long term viability of the nuclear industry if no new orders are forthcoming to see if the option would be foreclosed without stimulation, and how the operation of existing reactors would be affected; and examines the management of nuclear power in other countries to see what lessons can be learned from alternative approaches.
- *Chapter* 8 focuses on trends and influential factors in public acceptance as one of the key elements in a revival of nuclear power, and evaluates measures designed to improve public acceptance.
- *Chapter* 9 analyzes a series of policy options that Congress might consider. Depending on one's views of the desirability of and necessity for nuclear power, a policy maker might see little need to do anything, want to improve the operation of existing reactors, or make the option more attractive so that it can play an expanded role in the Nation's energy future. The options are analyzed for effec-

tiveness and for acceptability by the various parties to the debate. Packages of options are considered to see if compromises might be possible.

Volume II of the report, which includes contractor reports and background papers prepared in support of the assessment, will be available through the National Technical Information Service, 5285 Port Royal Rd., Springfield, Va. 22161.