Basic Energy Sciences Advisory Committee

Review Committee
Final Report

High Flux Isotope Reactor Upgrade
And User Program
Oak Ridge National Laboratory

Site Review Conducted
August 31—September 1, 1998

Date of Report
October 23, 1998

Submitted on Behalf of the Committee

Jack Crow

Jack Crow, Chair

Basic Energy Sciences Advisory Committee

High Flux Isotope Reactor Upgrade and User Program Review Committee Final Report

Tables of Contents **Page**

EXECUTIVE SUMMARY:

The Department of Energy is making a significant investment in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) to increase its capacity to better serve its diverse user community: neutron scattering, isotope production, and materials irradiation. The Basic Energy Sciences Advisory Committee commissioned a review to assess the quality of the scientific output driven by both the HFIR staff and users, the effectiveness of the user program and user support at the HFIR, the reliability of the facility, and vision, planning and status of the upgrade.

A Review Committee was established. Based on printed material provided the Review Committee and the site visit that occurred on August 30 and September 1, 1998, the Review Committee has the following observations.

- There is an urgent need for this facility and the upgrade. ORNL and its staff are to be commended for taking the initiative to make possible a new and important capability for the neutron science community associated with the upgrading of HFIR into a world class scattering facility.
- The HFIR has played and will continue to play an important role in the neutron scattering/isotope production/materials irradiation research communities.
- The quality of the neutron scattering science is excellent but does not have the breadth needed to truly capitalize on the investment reflected in the upgrade. The HFIR needs to strengthen its biological, life sciences, and other areas of materials research focus and to involve other parts of the ORNL research community to a greater degree than is now apparent.
- Reliability is an issue of fundamental importance. There is evidence that the decrease in reliable performance due to aging equipment has had a negative impact on all aspects of user involvement. It is essential that these issues be addressed at an early stage in this upgrade program.
- There needs to be a much greater focus on strategic planning, which encompasses the development of a users program with both HFIR and SNS unified, a clear vision and goals for the instrumentation upgrade, and implementation of the expanded user involvement.
- The funding of the Joint Institute for Neutron Scattering offers an excellent opportunity to stimulate and build a truly world class program. The Committee applauds the contributions made by the State of Tennessee.

ORNL should:

1. develop a practical plan that can be implemented on a short time scale to address the long-term reliability of HFIR. This plan should identify the amount and source of the new resources necessary to provide reliability.
2. develop a coherent and broad vision of the expected outcome of the ongoing upgrades, and develop and implement a management plan to reach that goal. While there are diverse

aspects of the program and different sources of funding, it is highly desirable to treat this as a single program, as close coordination between different parts will be necessary for success. An organization with a single manager is an important part of such a plan.

3. develop a viable plan to produce a high quality user program at the upgraded HFIR that is tightly coordinated with the user program at the SNS.
4. consult the relevant neutron scattering communities to develop a plan for staffing for increased utilization. This plan should take into account the need to broaden the existing basic and applied science program.
5. work closely with the irradiation and isotope communities while developing plans for increased utilization of the HFIR, to ensure that their evolving needs are met to the maximum possible extent.

INTRODUCTION:

The Basic Energy Sciences Advisory Committee (BESAC) was asked by Dr. Martha Krebs to review the operations, research activities, and user program at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). This review was called because the Basic Energy Sciences (BES) program is making significant investments to upgrade the capabilities for both cold and thermal neutron scattering and because of the very important role this reactor plays in supporting research and technology critical to BES programs and to the neutron science community. In response to this request, an External Review Committee chaired by Dr. Jack Crow was created. The charge to the review committee was outlined in a letter to the Committee Chair from John Stringer, then Chairman of the Basic Energy Sciences Advisory Committee. A copy of the charge letter is included in Appendix A. The Committee included experts in neutron scattering, isotope production, materials irradiation, and facility management. A list of the members of the External Review Committee is attached, see Appendix B.

As charged by BESAC, the External Review Committee reviewed the full range of activities at the HFIR regardless of whether they, were or were not supported by the BES program. The Committee examined the quality of the scientific output of the scientific staff; the effectiveness of the user program, user support and proposal review mechanisms; and the availability, dependability, and reliability of the facility for neutron scattering, isotope production, and materials irradiation. Specifically, the Committee addressed the following issues and questions:

1. What has been the scientific and technological impact of the High Flux Isotope Reactor during the past decade, and what is it expected to be during the next decade?

2. What is the level of user demand for the reactor, and how is it changing? How does the current shutdown of the High Flux Beam Reactor at Brookhaven National Laboratory affect the user demand at HFIR?

3. Are the full range of user issues currently being adequately addressed with respect to the current operating schedule?

4. From the user perspective, evaluate the availability, dependability, and reliability of the reactor.

5. What is the relationship of the HFIR to other activities at the ORNL, e.g., the planned Spallation Neutron Source and the Radiochemical Engineering Development Center?

The Committee held two conference calls prior to scheduling a site visit to the HFIR and visited the reactor on August 31 and September 1, 1998. A copy of the agenda for the BESAC review of the HFIR is contained in Appendix C.

The External Review Committee wishes to thank all of the staff members at the Oak Ridge National Laboratory for their help in conducting this review, for their presentations, and for their willingness to respond frankly to the questions and concerns of committee members. Without this forthcoming attitude, we could not have completed our task in the time allotted. The Committee also wishes to note that this has not been an exhaustive study of all of the issues involved in the HFIR upgrade project, nor of the reactor operation. Such a study would have required more time and preparation than was available for this review. Rather, we have chosen to concentrate on the specific issues raised in the charge letter (Appendix A) and listed above, and have structured this report around the answers to these issues and questions.

This report includes a brief background section that gives some of the history leading to the present situation and the need for an upgrade in the facilities at the HFIR. This section is followed by commentary from the Committee on the specific questions listed above. Finally, the Committee concludes the report with recommendations for further action by the Department of Energy (DOE) and/or ORNL.

BACKGROUND:

The HFIR began full-power operations in 1966 at 100 MW until a temporary shutdown in 1986. The HFIR has been one of the world's most powerful research reactors with a thermal neutron flux of 1.0 x 10^{15} neutrons/(cm^2 sec) at the end of the beam tubes and 2.5 x 10^{15} neutrons/(cm^2 sec) in the flux trap at 85 MW operating power. At the time of construction, the primary mission of the HFIR was the production of isotopes including californium-252 (Cf-252) and other transuranium isotopes for research, industrial, and medical applications. In addition to this role, the HFIR provides irradiation facilities and supports a variety of neutron-scattering instruments and neutron activation analysis capabilities. In 1986, the HFIR was shut down due to indications that the reactor vessel was being embrittled by neutron irradiation at a rate faster than predicted. After a thorough review, the HFIR was restarted in 1989, and in 1990, the reactor resumed normal operations at 85 MW. Recent studies indicate that the vessel lifetime for the HFIR can be extended to 50 effective full-power years of operation, or though about 2035.

In the autumn of 1992, a DOE panel, chaired by Professor Walter Kohn, carried out a thorough and wide-ranging study of current and future neutron science and neutron facilities in the United States. The Kohn Panel recommended that the United States move ahead with the construction of a new reactor, the Advanced Neutron Source, as its first priority and also called for the design and construction of a 1 MW pulsed neutron source, with the characteristics of the Spallation Neutron Source (SNS). Because of budgetary pressures, Congress unfortunately concluded that the Advanced Neutron Source was not economically feasible in the foreseeable future, but did recommend that the design and construction of a next-generation pulsed neutron source should be pursued.

Congress's decision not to proceed with the Advanced Neutron Source raised the question of how the nation's critical needs for steady state neutron sources could best be addressed. This critical need led to a BESAC study of both spallation and reactor sources for neutrons and the creation of a panel chaired by Dr. Robert J. Birgeneau. The panel evaluated the best course of action with regard to the future of the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory (BNL) and the HFIR at Oak Ridge National Laboratory. The report of this panel, along with the reports of two other panels that examined the scientific drivers and technical design options for a new spallation source and upgrades at LANSCE and IPNS, are contained in the Report of the Basic Energy Sciences Advisory Committee on Neutron Source Facility Upgrades and the Technical Specifications for the Spallation Neutron Source submitted to DOE in 1996. Based on this study and other input, BESAC recommended to DOE that the upgrades to the HFBR and the HFIR be pursued.

The HFIR upgrades were partially funded beginning in 1996. These upgrades provide for a number of projects at the HFIR to improve neutron scattering capabilities and ensure continued operation. These projects include:

- replacement of the beryllium reflector,
- installation of larger beam tubes and shutters,
- installation of a high-performance hydrogen cold source,
- installation of new beam lines with state-of-the-art neutron guide systems, and
- installation of new and upgraded neutron scattering instrumentation.

In addition to the enhancements in support of neutron scattering, improvements in its capacity to service the needs of the nation with isotope production, irradiation capabilities and neutron activation capacity will also be pursued. When completed, the HFIR will have 14 state-of-the-art neutron scattering instruments with internationally competitive steady-state neutron beam fluxes and will be better positioned to serve the nation’s needs in isotope production, materials irradiation, cold and thermal neutron scattering, and neutron activation analysis.

REVIEW REPORT:

As indicated in the INTRODUCTION, the Committee was asked to explore the full range of activities at the HFIR and was specifically requested to focus on five areas that have been listed above. This report provides separate responses to the five questions posed by DOE.

Question 1: What has been the scientific and technological impact of the High Flux Isotope Reactor during: the past decade. and what is it expected to be during the next decade?

The HFIR has been a unique national resource since its commissioning in the 1960s. Its design is optimized to produce the highest possible neutron fluxes in an internal flux trap in order to produce transuranic elements and to provide high flux irradiation facilities for other purposes. In addition, it provides four horizontal beam tubes that penetrate into the Be reflector for neutron beam research. The neutron fluxes at all of these facilities are comparable to the best available elsewhere in the world, providing ORNL with a great opportunity for world class research. There is clear evidence that high quality and important science and technology have come out of the

HFIR in all three main areas: isotope production, materials irradiation, and neutron scattering. Over the history of HFIR, this potential has been well exploited to produce transuranic elements for research and industry; to produce isotopes for medical research, diagnosis, and treatment as well as isotopes for industrial use; to irradiate materials for radiation damage studies; and to conduct high quality research using neutron scattering methods.

In neutron scattering, the major emphasis has been in the area of highly correlated electron systems, with important efforts in neutron diffraction and soft condensed matter. This research has been productive, with a large number of scientific papers (with excellent citation records) published in high quality journals. The research performed in the search for the origins of high temperature superconductors is significant, and has led to many insights into the continuing puzzle of this phenomenon. ORNL was an early leader in the application of polarized neutron beams to problems in magnetism and condensed matter physics, and in the past decade has continued that tradition. From a user facility perspective, however, the research efforts have been somewhat narrowly focused. This issue could be favorably impacted by the development of stronger associations with other components of ORNL. For example, research on highly correlated electron systems, in particular the recent discovery of orbital and charge ordering in these systems, could have benefited from closer ties to ORNL's electron microscopy program. In addition, the research program at the HFIR needs to more aggressively pursue the field of biology and other areas of materials science that are not currently well represented. Such activities have been extremely limited in the past and should become a very visible part of the research program in the future. An effort to attract more industrial users would also help to broaden the program.

Historically, materials radiation science and engineering was well served by a large number of irradiation facilities both in the United States and abroad. In the United States, facilities included a number of intermediate flux university research reactors. High flux/fluence irradiations were carried out at the fast spectrum Experimental Breeder Reactor II (EBR II) and the Fast Flux Test Facility (FFTF), as well as at the mixed spectrum reactors including HFIR, the Advanced Test Reactor (ATR), and the Oak Ridge Research Reactor (ORR). The EBR II and FFTF were essentially dedicated to materials and fuel irradiating. Today, only the ATR, mainly serving the naval reactor program, HFIR, the University of Missouri MURR, and a low-to-intermediate flux facility at the University of Michigan Ford Research Reactor either remain in active operation or retain useful irradiation facilities. The multipurpose HFIR has long been a workhorse for a number of energy technologies; and for the past two decades it has been particularly critical to the fusion materials program. There are key characteristics that make the HFIR unique for materials irradiations, e.g., a mixed thermal and fast flux that can produce high levels of displacements per atom; the capability of spectral tailoring; the well developed ancillary facilities, like hot cells; the outstanding engineering design group that supports complex experiments; and the availability of world-class research capabilities in materials characterization within ORNL's Metals and Ceramics Division. The HFIR has played a central role in many nuclear materials and fuel development programs supporting both fusion and fission efforts. The historical scientific and technical contributions of irradiations in the HFIR are too numerous to mention in detail. There is no compilation of papers, citations, and scientific awards that can be used to assess (quantitatively) the quality of the work in materials irradiation. However, based on general reputational assessments, the quality and productivity of the HFIR's irradiation programs appear to be generally of high quality.

The HFIR also has been a center of excellence for the production of feedstock for heavy and super heavy elements. The reactor was specifically designed to respond to isotope production and possesses one of the highest available neutron fluxes for isotope production. The reactor's production of Cf-252 is particularly important because it has become the nuclide of choice for the start-up of power reactors and for use as a portable intense neutron source for industrial, medical, forensic, and experimental research applications. The use of Cf-252 for non-destructive evaluation of fatigue and defects in military aircraft is noteworthy and may have a significant future.

For the future, the potential contributions of the HFIR to science and technology are impressive. The reactor vessel embrittlement issue now seems to be in hand, and a long lifetime can be foreseen for all of the programs (see also responses to Questions 3 and 4 below). The present assessment of the lifetime of the vessel will ensure that important national research and technology efforts that are absolutely dependent on HFIR operation can continue, including especially the transuranic element chemistry program, the materials irradiation program, and the production of isotopes for medicine and industry. In the neutron scattering area, the potential for enhanced performance is even greater, as a result of the upgrade of facilities now underway. The new liquid hydrogen cold neutron source, which calculations indicate will have a brightness comparable to the best in the world, will provide a much needed addition to the national capability. Although the geometry of the source restricts the number and size of beams that can be extracted, the three planned cold neutron guides will provide the basis for several new cold neutron instruments that are in great demand nationwide. The proposed 35 m Small Angle Neutron Scattering (SANS) instrument should be competitive with the D22 facility at the Institut Laue Langevin (ILL), the instrument generally acknowledged to have the highest intensity in the world. The cold neutron triple axis spectrometer and reflectometer also should provide highly competitive facilities, greatly enhancing national capabilities. It should be noted that instruments of this type at the NIST Center for Neutron Research are over-subscribed by factors of as much as 4. Even the addition of the HFIR capability will not come close to meeting national needs for cold neutron research, and the extensive capability that the High Flux Beam Reactor at Brookhaven National Laboratory can provide is urgently needed.

The HFIR's research program has well defined strengths in highly correlated electron systems and in soft condensed matter science areas. These areas will continue to be of considerable interest in the near future, and it is anticipated that the HFIR research programs will be significant contributors to the advancement in these areas.

In addition, neutron scattering has expanded its impact in recent years in a range of fields, including in biology. Here the reactor's past research record has been weak and needs enhancement to meet the increased demand that already exists within the biological sciences community. Recent years have seen a number of advances in sources and instrumentation for small-angle scattering that have yielded gains in the flux of neutrons on the samples thus facilitating more rapid experiments on smaller samples at lower concentrations. The cold source upgrade at HFIR will dramatically increase the potential for structural biology applications in the United States using neutrons. While the niche for neutron protein crystallography has been overtaken by alternate, more attractive techniques (see BERAC Structural Biology Subcommittee Report from the August 1998 meeting in Chicago), small-angle scattering studies of biomolecules are on the rise. In the past two years, publications of small-angle X-ray and neutron scattering studies of biomolecules have at least doubled as the technology becomes more accessible and more sophisticated. Small-angle scattering is an inherently low-resolution technique, but it can provide unique information that complements high resolution structural studies. In particular, small-angle neutron scattering, combined with specific deuterium labeling and contrast variation techniques, is the only method that can yield information on the conformations and dispositions of individual components within biomolecular complexes or assemblies in solution. When combined with high-resolution information, scattering data are extremely powerful for probing the dynamic interactions and conformational flexibility inherent in the regulated functioning of molecular networks that, for example, transmit and amplify signals, or are involved in energy transduction, transport, mechanical movement, etc.

Small-angle neutron scattering from biomolecules requires the highest intensity cold neutron sources and instrumentation that delivers neutrons with the lowest backgrounds achievable. The United States has had a critical shortage of cold neutrons. As a result the ILL has been, for the past two decades, the leader in small-angle scattering applications in biology, and the NIST facilities now provide the only internationally competitive facilities in the United States. The HFIR cold neutron source can provide the U.S. structural biology community with small-angle scattering capabilities that are competitive with those at the ILL. These capabilities will be all the more significant when combined with other advances. For example, biotechnology development has made sample production, including with deuterium labeling, easier and cheaper. Faster and cheaper computers have facilitated the development of more sophisticated modeling packages for scattering data interpretation. A growing interest in small-angle scattering is being stimulated at synchrotron sources for time-resolved studies of biological processes. Taken together these technological advances, when combined with the current move toward structural and functional genomics aimed at understanding how networks of biomolecules interact to achieve coordinated function, are poised to make very significant contributions to the fundamental science that underpins advances in medicine and biotechnology applications. It is clear that the HFIR has and will continue to be an important component in the United States' arsenal of neutron research capabilities addressing issues of national importance in the biological, chemical, and condensed matter sciences.

Another important opportunity relates to use of neutrons, almost always in conjunction with other characterization techniques, to study the nano-microstructures in technological materials over the range of length scales and in combinations that relate to functional properties. This would include structural metallic alloys, ceramics and composite systems, where mechanical properties are usually the main focus. However, this would also relate to other functional material systems where the substructures are important in mediating electrical, magnetic, and optical properties as well. Strengthening these areas would benefit the materials community, in general, and very strong programs in these areas at ORNL (but outside of Solid State) in particular.

The need for irradiation studies to support fusion programs has been and will continue to be the largest user of the HFIR irradiation facilities. These irradiations are generally carried out as part of international collaborations, and the HFIR has a central role in these studies. The performance goals of materials used for fusion structures are staggering. Programs at the HFIR are generally of high quality and will continue to significantly impact fusion materials development and even some areas outside the fusion sciences.

There will be a continuing demand for isotopes for nuclear medicine and other areas, and it is critical to provide continuity in the production capacity within the United States. The ability of the HFIR to address needs in this area effectively will depend heavily on the reliability of the reactor operations in the future. This issue is addressed more completely below.

Question 2. What is the level of user demand for the reactor, and how is it changing? How does the current shutdown of the High Flux Beam Reactor at Brookhaven National Laboratory affect the user demand at HFIR?

It is quite difficult to estimate the level of user demand for the reactor at the present time because of recent problems with reactor reliability and availability. It is quite clear, however, that unreliable operation has discouraged users in all areas from reliance on the HFIR for their research. Following the long shutdown that ended in 1990, user demand (as measured by the number of users) had been steadily increasing. In 1997 and 1998, however, this trend was reversed, presumably as a result of reactor reliability and availability problems.

The level of user demand for the neutron scattering program at HFIR has to date been modest. The user program as such has been driven primarily in a collaborative mode. While this mode of operation has been scientifically productive, especially given the level at which the project has been funded, it has led to a very focused and relatively narrow impact in the condensed matter science community. The anticipated increase in the number of users with the upgrade project will require a dramatic change in both user operations and culture.

Within the neutron scattering programs, the mix of users across disciplines has not changed greatly over the past decade, primarily since the available equipment has not changed greatly. It should be noted, however, that the origins of the users have been changing over the past few years with a decrease in the number of university users and an increase in the number of government laboratory users. This shift also seems to be traceable to the decrease in reliability of the reactor, which places a strain on outside university users. It can be anticipated that this will change after the upgrades are completed. The shutdown of the HFBR at Brookhaven National

Laboratory has certainly increased demand for the facilities at HFIR; unfortunately this has coincided with decreased running time at HFIR. The result has been that HFIR could not meet as many of the BNL needs as might have been anticipated and several of the HFBR researchers have been accommodated at NIST, ILL, and reactors in Japan. User demand for the SANS and other low angle instruments currently exceeds available beam time by about 50%. It also should be recognized that the present SANS capabilities at ORNL cannot compete with NIST or HFBR, so that HFIR cannot accommodate most of the HFBR SANS users. This has had a serious negative impact on the national and DOE programs in neutron scattering research.

The lack of availability of the HFBR has not had a measurable impact on those researchers interested in materials irradiation. This is because the HFBR had played a much less significant role in this area than the HFIR. Isotope production demand has waned as a result of the unfortunate unreliability of the HFIR in the recent past. This has resulted in the development of generally inferior irradiations being pursed at alternative reactor sites that give reliable schedules even if the flux dependent activation is sub-optimal.

Question 3. Is the full range of user issues currently being adequately addressed with respect to the current operating schedule and within the facilities available?

There was a general feeling by the Committee members that there needs to be a change in the attitude toward users as reflected by a sense that an "old boy" network exists. This situation has developed out of the predominantly collaborative approach to managing the user program. The HFIR and ORNL must change its cultural approach to management of the user programs. It was surprising that ORNL has not given more thought to the development of a formal user group since resuming operation in 1990. Such a group is absolutely needed as the upgrades and new research programs are considered. A user group should be consulted on instrument development issues and should have input on setting priorities as options impacting the reliability and upgrade of the research facilities are considered. This users group should have full representation from the communities that are or could be served by the HFIR and be sensitive to those communities where significant potential for growth exists, e.g., biological structure. The funding of the SNS has helped drive a renewed focus on user input to management and operations of both facilities. Efforts by ORNL to address the issue of user involvement are reflected by the upcoming Users Group meeting in November, 1998, and the proposed Joint Institute for Neutron Scattering mentioned below. However, ORNL must work harder toward fully integrating the user programs for the SNS and the upgrade and reliability issues at the HFIR. As the SNS comes online, there will be a shift of some portion of programs over to the SNS, with other programs preferring to remain at the HFIR. This transition and the impact of these two sources on the broad user community must be part of the ORNL planning process. We address this issue more fully in the next section, RECOMMENDATIONS.

The Joint Institute for Neutron Scattering partially funded by the State of Tennessee is a highly laudable development and could serve as a nucleating point for the development of a fully integrated neutron users group incorporating the HFIR and SNS facilities However, the intellectual role of this new institute in helping to drive programs and user activity at both the SNS and the HFIR is not clear at this time and requires more thought. It is hoped that they will continue taking steps to improve involvement of the user community. More can and should have been done to respond to the reliability issue (addressed further below) and involve the user community in the development of priorities and planning for the upgrade and implementation of measures to improve reliability.

As has been stated in several parts of this report, the current (1997 and 1998) HFIR operating schedule is not satisfactory and has severely restricted program activity. Management steps have been taken to address some of the issues. The Committee will return to this point as it responds to Question 4. In recognition of some of these concerns, ORNL management has identified several steps that are required to improve the situation.

The facilities within the reactor for irradiation have improved steadily, and new vertical facilities are now available for instrumented irradiations. The isotope handling facilities at the REDC have also been improved, and further improvements are foreseen, especially if the proposal for a hot cell within the reactor is supported. This addition to the capabilities should also have a beneficial impact on isotope production activities. In both the irradiation and isotope production areas, there are continuing problems with customer orientation and the meeting of customer expectations due to the lack of a reliable operating schedule. Also, the irradiation and isotope production programs depend on the reliability of the reactor to accumulate fluence, to interface with other program schedules, and to meet programmatic commitments. Short unplanned shutdowns probably have a more devastating impact on isotope production activities as compared to the utilization of the materials irradiation and neutron scattering capabilities. Where an HFIR operational occurrence can be solved by a discretionary, unscheduled shutdown, then consideration should first be given to the status of the known operating schedules of other U.S. reactors before such a shutdown be actioned. This would enable assessment of the wider, potential knock-on effects of the discretionary HFIR shutdown, particularly on the isotope manufacturing users.

Within the neutron scattering area, many users commented on the friendly and helpful nature of their ORNL colleagues and expressed great appreciation for the help given. However, many users requested that a greater effort be made to develop versatile, portable data reduction and analysis programs to make research easier at the facility and data handling easier at their home institutions. In general, the computational resources appear to be inadequate. It can be stated that the current user policies and procedures at the HFIR scattering facilities are informal but generally working reasonably well. This reflects the relatively low level at which the user program is operating, which allows allocations to be made on an ad hoc basis. However, the plan presented to support the increase in users (which the upgrades can and should bring) is not adequate. Proper user support will require more formal and detailed user procedures. A plan to achieve this, which includes detailed resource requirements, should be prepared to ensure full exploitation of the new capability. If the resources are not available, then the scope of the user program must be reduced to a level that can be adequately supported. If this is not done, the inevitable result will be user discontent and a less-than-optimum use of facilities.

Question 4. From the user perspective. evaluate the availability, dependability, and reliability of the reactor and user support infrastructures, including: critical instrumentation packages and support personnel.

The operating experience of the HFIR over the past two years (1997 and 1998) is not adequate to support a first-class operation. Reactor availability has slipped from 70% (which is the best possible) to 46% and 43% respectively, implying an efficiency of only 65%. The excessive unscheduled downtime has led to numerous interruptions and loss of beam time, thus seriously interfering with the scientific and service mission of the HFIR. Improving the reliability of the HFIR, neutron beam delivery, and instrumentation dependability are of paramount importance to the neutron scattering community and to customers using the facilities. The reactor reliability must be the highest priority of all since it affects all users. At this time, reactor reliability is a significant problem.

There are many reasons for this decline in performance including the impact of aging infrastructure and management issues. The Review Committee was impressed with the presentation by George Flanagan Acting Director of the Research Reactors Division, and the openness of the management of ORNL concerning this issue. It appears that they recognize how critical this issue is to the future of the user programs in all areas served by the HFIR. It is clear that some thought has been given to an analysis of the causes of the decline in operating efficiency and this concern has led to a management restructuring within the Research Reactor Division. The report that has been prepared will be invaluable to the incoming director, Lee Watkins. This Committee believes that the new director should immediately review this plan and prepare a detailed case for the additional investments in infrastructure that are essential to efficient operation. This study should clearly establish priorities and present optimal implementation scenarios for the benefit of the funding agency. In view of the importance of the HFIR to national goals, and of the planned improvements to HFIR, this is of the utmost importance. At this time, reactor reliability is a significant problem and solving this problem will require a proactive approach to replacement of aged infrastructure and the development of a responsive preventive maintenance program.

There are other areas of user infrastructure that require improvement; some of these were mentioned above (data analysis software, computers for data reduction). Others should be addressed in a plan for operation of the neutron scattering facilities in a full user mode, including technical support, sample environmental equipment, etc. In addition, there are a number of issues associated with the isotope production and irradiation facilities that require attention. For the isotope production community, reliability as a supplier is the primary concern. This community and the irradiation community also would be better served with improvements in reliability and supportive infrastructure, e.g., the installation of a hot cell at the reactor, which has been proposed. Also, it is important for the management of ORNL to recognize that it is essential to develop an outreach program to rebuild the isotope producer/user base and re-establish the isotope user community commitment to using the HFIR. The lack of confidence in the reliability of the HFIR has badly shaken the commitment of the irradiation and isotope production communities. In summary, the primary observation here is that the laboratory must improve its customer focus and provide those who rely on its services the necessary reliability and support for success. If they do so, the programs will grow even beyond what is now envisioned.

Question 5. What is the relation of the HFIR to other activities at ORNL, e.g., the planned Spallation Neutron Source and the Radiochemical Engineering Development Center?

After the upgrades are implemented, the flux of and the instrumentation at the HFIR will be competitive with similar facilities and instrumentation at the world's best neutron sources. Thus, the HFIR can play a major role in its own right along with being a significant contributor to the move toward the planned Spallation Neutron Source. The HFIR's role in re-establishing a formal external user group and helping to increase the neutron user base in the United States provides a bridge to the SNS user program of the future. It should be understood that the HFIR will continue to be an important component of the national neutron user infrastructure long after the completion and commissioning of the SNS. One must remember that the Kohn Report placed a new reactor source as the highest priority with a spallation source second. There will be communities who will continue to require the continuous neutron flux and unique aspects of a reactor-based facility. This is particularly true for SANS experiments where the HFIR will provide significant capabilities beyond what the SNS will provide. Certainly, the isotope and materials irradiation communities will remain at the HFIR and are not directly impacted by the SNS.

A successful user program at the HFIR (as distinguished from a Users Group, which is a different concept) would lead the way for the development of a similar program at the SNS. This is a vital need for the SNS and the HFIR, as success cannot come without a first-rate user program. Thus, the SNS should be deeply involved in the planning and implementation of the user program at the HFIR and vice versa. It is clear that the user programs at ORNL should be merged into one user group. Thorn Mason is the appropriate contact point, and he along with his counterpart at the HFIR should work to get the best information about successful approaches at other neutron and photon facilities (IPNS, ISIS, ILL, NIST, NSLS, SSRL, ESRF, . . .). Success will require a change of philosophy at the HFIR and a strong user focus in the planning and hiring of staff for both facilities. The staffing strategy should reflect the needs of both facilities and should anticipate poorly represented areas at the HFIR and ORNL neutron group that have significant potential for growth and offer expanded opportunities, e.g., biological structure. While the permanent staff must have their own scientific agenda, they also must be fully committed to a successful user program, with well-defined duties and responsibilities in both areas.

HFIR also needs to continue building its interfaces to other programs at ORNL. Such efforts help build on existing strengths and will lead to mutually beneficial impact on the HFIR and the other programs. Specifically, isotope processing and target decanning demands the necessity of an ongoing REDC facility and a strong interface between the REDC and HFIR programs. In addition, other interfaces are also critical to the future of the HFIR user and science programs. The Metals and Ceramics materials research programs would benefit from stronger ties to the scattering facilities at HFIR and ultimately SNS. The HFIR science program includes high quality soft matter scattering programs, but this is almost exclusively focused on condensed matter science issues. The new facilities will have a significant impact on the biological community so HFIR management and the new user group need to anticipate this opportunity and aggressively pursue it. These interfaces need to be addressed immediately so as not to waste the opportunity of involving the broad community in planning instrumentation for both the HFIR and SNS. For example, an upcoming report by the BERAC Subcommittee on structural biology will likely indicate that a quasi-Laue biological diffractometer, as proposed for the end station for one of the cold neutron guides, is probably not the instrument of choice. The quality of diffraction data from synchrotron sources has improved to the point where neutron diffraction for biological systems has a much less important role. As such it is important for the neutron effort at both the HFIR and SNS to focus on those issues where the impact of neutrons complement the science done at the synchrotron light sources. User input on instrument development and priorities for instrument implementation are critical. This community may call for the construction of a second SANS instrument targeted for biological and soft materials users.

RECOMMENDATIONS:

The Review Committee feels that certain issues should be specifically addressed immediately. These critical issues along with a few additional concerns are outlined below. In addition, the Committee has raised numerous concerns and calls for action throughout the body of this report and many will not be repeated here. The specific recommendations appearing below address the most grievous issues and appear in prioritized order. Following these recommendations, a few important concerns where action is required are also highlighted. The Review Committee has not tried to assess the cost of implementing each recommendation and feels that such issues are better dealt with by DOE in cooperation with ORNL and with appropriate input from standing advisory committees within DOE and other ad hoc review committees as required.

<u>CRITICAL RECOMMENDATIONS:</u>

1. **ORNL should develop a plan to address the long-term reliability of the HFIR that identifies the amount and source of the necessary resources.**

The Committee has referred to reliability issues many times in the body of this report and reliable operation is the critical underpinning to any successful user program. The infrastructure needs should be defined and prioritized. The necessary resources to accomplish the program goals should be defined. Issues of reactor reliability need to be addressed as an integral part of the upgrade plan. The investment in upgraded instrumentation and user facilities will represent a dubious investment if the reactor reliability issue is not addressed in a timely manner. It is obvious that the poor reliability record over the last two years has negatively impacted all sectors of the user communities.

2. ORNL should develop a coherent vision of the expected outcome of the ongoing upgrades, and develop and implement a management plan to reach that goal.

The present activities at ORNL are being managed as a collection of small projects. However, the total funding commitment and the importance of this project dictate that these activities should now become a full-scale project with a clearly defined project manager and steering committee. There are reactor reliability and operation issues, user program issues, instrument development and sighting issues, staffing issues, scientific breath issues, and many others that must be addressed in an organized fashion. Concerns were raised with regard to the positioning of the new instruments and the impact this has on the signal to noise (S/N) ratio due to the increased levels of background radiation close to the reactor vessel. This issue and the others raised above are interrelated and cannot be treated as separate concerns or projects. Along with addressing the various issues and concerns raised by in this report, a prioritized execution plan needs to be developed. If HFIR is to fully meet the national expectations, then a much more organized and committed effort must be forthcoming. Without it, the opportunity will be missed and the investment in the upgrade will be questionable. The project manager should be charged to develop a comprehensive plan that addresses the issues listed above. When such an implementation plan has been developed, another review would be appropriate.

3. ORNL should develop a viable plan to develop a high quality user program at the upgraded HFIR that is tightly coordinated with development of the user program at the SNS.

Access to neutron facilities remains an important national issue. Access to the HFIR remains based on a collaborative philosophy and continuation of this approach cannot be justified with the upgrade investment. There needs to be a cultural change in attitudes toward users. The upgrade to the HFIR facilities and the construction of the SNS offer the user community an unprecedented opportunity to stabilize and greatly improve the availability of neutrons in this country. In order to ensure the most effective use of these resources, ORNL must develop a plan that integrates these two national facilities into one cohesive unit with a common user group and user advisory committee. A strong plan for a capable user program needs to be developed at the HFIR in collaboration with the SNS.

4. ORNL should consult the relevant communities and develop a plan for staffing that takes into account the need to broaden the existing science program.

The breadth of the existing scientific program is relatively narrowly focused, as is appropriate for the program and resources in the past. This will not be adequate for the future envisioned at the HFIR, and a broader science program must be considered in all staffing decisions for the future. For example, the HFIR science program needs to take steps to strengthen its research program in biological areas. This could be implemented through a combined effort to involve possible external users in planning the facilities and through developing closer associations with the biological programs at ORNL and region universities. Strengthening in broader areas of materials science, like technologically important advanced structural materials, is also warranted.

5. In developing the plans for increased utilization of the HFIR, ORNL should work closely with the irradiation and isotope communities to ensure that their needs are met to the maximum possible extent.

Materials irradiation and isotope production are very important parts of the HFIR contribution to science and engineering. The upgrade of facilities also needs to include these communities in their planning. In particular, the Review Committee supports efforts to install a hot cell in the reactor area and again stresses the importance of addressing the reliability problems. These two communities are particularly hard hit by unscheduled shutdowns.

CONCERNS:

- It is anticipated that the biological community will represent a major new community presently not served by the HFIR. It is also anticipated that this community and the general SANS users will continue to find the HFIR as the neutron source of preference after the completion of the SNS. Thus, in addition to the new 35m SANS machine to be located in the new cold guide hall, the planners should strive to add a second SANS instrument.

- The HFIR needs to support the development of standardized/user friendly data handling and modeling software packages that can run on most common computer platforms.

- The HFIR and SNS should develop a series of workshops on the applications of neutrons to materials science and biological sciences issues, which will help to stimulate interest from university researchers. Both HFIR and SNS need to be concerned about the development of the next generation of scientists interested in using neutron facilities.

- Some issues have been raised relative to the present allocation of beam time at the HFIR. At present, the process for allocating beam time involves submitting a proposal to a beamline scientist with the beam time ultimately scheduled by the section head after external peer review is received. It is highly desirable to organize the review process so that proposals come to a central office and are judged by a panel of reviewers familiar with the field of the proposal.

APPENDIX A:

Charge Letter

Appendix A: Charge Letter

EPRI

Electric Power
Research Institute *Powering Progress through Innovative Solutions*

June 23rd, 1998

Dr. Jack Crow
National High Magnetic Field Laboratory
1800 E. Paul Dirac Drive
Tallahassee, Florida 32310

Jack
Dear Dr. Crow:

The Basic Energy Sciences Advisory Committee (BESAC) has been asked by Dr. Martha Krebs to review the activities and the user program at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory. I am very grateful that you have agreed to chair this review panel.

The review should consider the full range of activities at HFIR regardless of whether they are supported by the BES program. The review panel should therefore include experts in neutron scattering, isotope production, and materials irradiation. It should also include members who will be able to address the effectiveness of the user program; user support; proposal review mechanisms; and availability, dependability, and reliability of the facility for neutron scattering, isotope production, and materials irradiation. As part of the panel's work, it should visit the reactor and meet with members of the management, staff, and the user community.

We would like to be able to report our progress toward this review to BESAC at its next meeting, which is scheduled for July 29-30, 1998. In particular, we would like to report to BESAC that we have empaneled a review team and have scheduled the review. We would like to have the review completed by September 30, 1998, and to have a final report by October 30, 1998. It is likely that BESAC will meet in November, 1998, at which time you will be asked to present the report of the review panel to BESAC.

We would specifically like the review panel to address the following issues and questions:

1. What has been the scientific and technological impact of the High Flux Isotope Reactor during the past decade, and what is it expected to be during the next decade?
2. What is the level of user demand for the reactor, and how is it changing? How does the current shutdown of the High Flux Beam Reactor at Brookhaven National Laboratory affect the user demand at HFlR?
3. Are the full range of user issues currently being adequately addressed with respect to the current operating schedule?
4. From the user perspective, evaluate the availability, dependability, and reliability of the reactor.
5. What is the relationship of the HFIR to other activities at the ORNL, e.g., the planned Spallation Neutron Source and the Radiochemical Engineering Development Center?

Headquarters: 3412 Hillview Avenue, Post Office Box 10412, Palo Alto. CA 94303, USA • (415)855-2000 • SR&D Fax: (415)855-2287

Washington Ofiice: 2000 L Street, NW, Suite 805. Washington, DC 20036, USA • (202) 872-9222 • Fax: (202) 293-2697

Because the Basic Energy Sciences (BES) program is making significant investments to upgrade capabilities for both cold and thermal neutron scattering at HFIR, this facility is very important to the BES program and to the neutron science community. Thank you again for agreeing to chair this review panel, and I look forward to your report.

With best wishes,

John Stringer
Executive Technical Fellow
Materials Performance
EPRI;
Chairman, Basic Energy Sciences Advisory Committee

APPENDIX B:

Review Committee Members

Appendix B: Department of Energy, Basic Energy Sciences Review Committee High Flux Isotope Reactor, ORNL, List of Members

Dr. Jack E. Crow (Chair)
National High Magnetic Field Laboratory
1800 E. Paul Dirac Road
Tallahassee, FL 32310
Phone: (850) 644 0850
Fax: (850) 644 9462
E-mail: crow@magnet.fsu.edu

Dr. John Stringer (Co-Chair)
Executive Technical Fellow
EPRI
3412 Hillview Avenue
P. 0. Box 10412
Palo Alto, CA 94303
Phone: (650) 855 2472
Fax: (650) 855 2002
E-mail: jstringe@epri.com

Dr. Frank Bates
Department of Chemical Engineering and Materials Science
University of Minnesota
421 Washington Ave. SE
Minneapolis, MN 55455
Phone: (612) 625 6606
Fax: (612) 626 1686
E-mail: bates@cems.umn.edu

Dr. Martin Blume
American Physical Society
1 Research Road
Ridge, NY 11961
Phone: (516) 591 4000
Fax: (516) 591 4155
E-mail: blume@aps.org

Professor Robert M. Briber
Department of Materials and Nuclear Engineering
University of Maryland
2100 Marie Mount Hall
College Park, MD 20742-2115
Phone: (301) 405 7313
Fax: (301) 314 9601
E-mail: rbriber@eng.umd.edu

Mr. Hugh W. Evans
AEA Technology-QSA
2636 S. Clearbrook Drive
Arlington Heights, IL 60005
Phone: (847) 593 6300, ext. 418
Fax: (847) 593-8091
E-mail: hugh.evans@us.nvcomed-amersham.com

Dr. Thomas M. Holden
National Research Council of Canada
Chalk River, ON K0J1J0
Canada
Phone: (613) 584 3311, ext. 3991
Fax: (613) 584 4040
E-mail: holdent@aecl.ca

Dr. Robert G. Odette
Department of Mechanical and Environmental Engineering
University of California-Santa Barbara
Santa Barbara, CA 93106
Phone: (805) 893 3525
Fax: (805) 893 4731
E-mail: odette@engineering.ucsb.edu

Dr. J. Michael Rowe
NIST Center for Neutron Research
Reactor Building (235), Room A104
Gaithersburg, MD 20899
Phone: (301) 975 6210
Fax: (301) 869 4770
E-mail: j.rowe@nist.gov

Dr. Jill Trewhella
Laboratory Fellow
Bioscience and Biotechnology Group
Mail Stop G758
Chemical Science and Technology Division
Los Alamos National Laboratory
Los Alamos, NM 87545
Phone: (505) 667 2031
Phone: (505) 667 5324 (Sec.)
Fax: (505) 667 0110
E-mail: jtrewhella@lanl.gov

APPENDIX C:

Agenda

Appendix C: Agenda

BESAC Review of HFIR

August 31-September 1, 1998

Agenda

7:30 a.m. Meet at Garden Plaza Hotel and travel to ORNL

(Monday, August 31, 1998, Conference Room, 7917)

Introduction

8:00	Welcome (Al Trivelpiece)
8:15	Overview (Jim Ball)

Neutron Scattering Program

8:45	Neutron scattering overview (Herb Mook)
9:30	HFIR upgrades (Jim Roberto)
10:15	*Break*
10:45	User program (Herb Mook)
11:15	User presentations: "Spin Dynamics in Linear Chain Antiferromagnets" (Andrey Zheludev, BNL) "Vibrational Entropy of Alloy Phases" (Brent Fultz, Cal Tech) "Superparamagnetic Properties of Spinel Nanoparticles" (John Zhang, Ga Tech) "Microstructure and Dynamics of Solutions of Giant Worm-like Micelles" (Lee Magid, UT-Knoxville)
12:15 p.m.	Lunch (committee with users)
1:00	*Committee executive session*

HFIR Operations

1:30	HFIR overview (George Flanagan)
2:15	Tour of HFIR (George Flanagan and Emory Collins [gallery], Ken Thorns [materials irradiation], David Glascow [NAA], Herb Mook [beam room], Jim Ball and Jim Roberto) HFIR posters: "Subthermal Triple-Axis Research (STAR) Instrument" (Stephen Nagler) "Cold Neutron Guide System and 35m SANS" (George Wignall) "Thermal Neutron Guide System and Instruments" (Lee Robertson) "Neutron Activation Analysis at HFIR" (David Glasgow)
3:30 p.m.	*Break and committee executive session*

Materials Irradiation Programs

4:00 Materials irradiation (Everett Bloom)
4:45 *Committee executive session*
5:30 Adjourn and travel to Garden Plaza Hotel

(Monday evening, August 31, 1998, Garden Plaza Hotel)

6:30 Reception with user posters:
“Aggregation of Carbon Particles in Diesel Oils” (Min Lin, Exxon)
“SANS Investigations of Polymers in Supercritical CO_2” (Sharon Wells, UNC-Chapel Hill)
“What Is a Model Liquid Crystal Polymer?” (Mark Dadmun, UT-Knoxville)
“Surfactant Adsorption on Crystalline Surfaces” (Jamie Schulz, Univ. of Sydney)
“Residual Stress Studies of Boiler Tube Cracking” (Jim Keiser, ORNL)
“Lattice Dynamics of CMR Materials” (Jiandi Zhang, Florida International Univ.)
“Superconducting Borocarbides” (Jerel Zarestky, Ames Laboratory)
“The Vortex Lattice in High-T, Superconductors” (Mohana Yethiraj, ORNL)
“Universal Behavior of Spin Fluctuations in High-T, Superconductors” (Pengcheng Dai, ORNL)
“Vibration Entropy in Alloys” (Heather Frase, Cal Tech)
“Magnetic Excitations in Cr” (Hal Lee, ORNL and Univ. of Missouri)
“Spin Dynamics in CMR Manganites” (Hazuki Kawano, ORNL and ISSP-Japan)
“Lower Dimensional Quantum Magnets” (Garrett Granroth, ORNL and Univ. of Florida)
“Phonons in High-T, Superconductors” (Rob McQueeney, LANL and Univ. of Pennsylvania)
“Materials Irradiation Experimental Facilities at HFIR” (Ken Thorns, ORNL)
“Structure and Lattice Expansion of Ti_3SiC_2” (M.W. Barsoum, Drexel; Claudia Rawn, ORNL)
“Effects of Low Temperature Neutron Irradiation on Deformation Behavior of Austenitic Stainless Steel” (J. P. Robertson, A. F. Rowcliffe, D. J. Alexander, M. L. Grossbeck, ORNL; K. Shiba, Japan Atomic Energy Research Institute)

7:30 Dinner with users
SNS overview (Thorn Mason, SNS Scientific Director)

7:30 a.m. Depart Garden Plaza Hotel for ORNL

(Tuesday, September 1, 1998, Conference Room, 7917)

Isotope Programs

8:00 Transplutonium isotopes (Bob Wham)

8:30 User presentation: "Transplutonium Isotope Research at LLNL and LBNL" John Wild (LLNL)

9:00 Medical isotopes (Jerry Klein)

9:30 User presentation: "The Use of HFIR Produced Radioisotopes for the Inhibition of Coronary Restenosis" (Dr. Neal Eigler, M.D., Cedars Sinai Medical Center, Los Angeles)

10:00 Tour of REDC and isotope posters (Bob Wham):

"HFIR Produced Radioisotopes Will Play an Important Role in Restenosis Therapy" (Jerry Klein)

"Transuranium Element Production" (D. E. Benker)

"Production, Uses, and Users of Cf-252" (C. M. Simmons, J. B. Knauer, and J. E. Bigelow)

"Biomedical Neutron Research at the Californium User Facility" (R. C. Martin, T. E. Byrne (UT-Knoxville), and L. F. Miller (UT-Knoxville)

11:00 *Committee executive session*

11:45 General discussion session (all HFIR missions)

12:15 *Lunch (committee executive session)*

1:00-3:00 p.m. *Committee working session*

3:00 Closeout with ORNL management

3:45 Adjourn and depart for airport