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Report of the ANS Project Feasibility Workshop for a High Flux Isotope Reactor–Center for Neutron Research Facility

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July 1995

Advanced Neutron Source

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REPORT OF THE

ANS PROJECT FEASIBILITY WORKSHOP FOR A

HIGH FLUX ISOTOPE REACTOR-CENTER FOR NEUTRON RESEARCH FACILITY

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ACRONYMS

ANS	Advanced Neutron Source
CDR	conceptual design report
DOE	Department of Energy
HFIR	High Flux Isotope Reactor
HFIR-CNR	High Flux Isotope Reactor/Center for Neutron Research
ORNL	Oak Ridge National Laboratory
PIDAS	perimeter intrusion detection and assessment system
REDC	Radiological Engineering Development Laboratory
SANS	small angle neutron scattering
WBS	work breakdown structure

1. REASONS FOR THE WORKSHOP

The Advanced Neutron Source (ANS) Conceptual Design Report (CDR) and its subsequent updates provided definitive design, cost, and schedule estimates for the entire ANS Project.[1,2 *] A recent update to this estimate of the total project cost for this facility was $2.9 billion, as specified in the FY 1996 Congressional data sheet, reflecting a line-item start in FY 1995.

In December 1994, ANS management decided to prepare a significantly lower-cost option for a research facility based on ANS which could be considered during FY 1997 budget deliberations if DOE or Congressional planners wished. A cost reduction for ANS of about $1 billion was desired for this new option.

It was decided that such a cost reduction could be achieved only by a significant reduction in the ANS research scope and by maximum, cost-effective use of existing High Flux Isotope Reactor (HFIR) and Oak Ridge National Laboratory (ORNL) facilities to minimize the need for new buildings. However, two central missions of the ANS—neutron scattering research and isotope production—were to be retained.

The title selected for this new option was High Flux Isotope Reactor-Center for Neutron Research (HFIR-CNR) because of the project's maximum use of existing HFIR facilities and retention of selected, central ANS missions. Assuming this shared-facility requirement would necessitate construction work near HFIR, it was specified that HFIR-CNR construction should not disrupt normal operation of HFIR.

Additional objectives of the study were that it be highly credible and that any material that might be needed for U.S. Department of Energy (DOE) and Congressional deliberations be produced quickly using minimum project resources. This requirement made it necessary to rely heavily on the ANS design, cost, and schedule baselines. A workshop methodology was selected because assessment of each cost and/or scope-reduction idea required nearly continuous communication among project personnel to ensure that all ramifications of proposed changes were properly considered.

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* ANS provided the full research capability requested by the scientific community as specified in the Seitz-Eastman report, repeated reports from the Basic Energy Sciences Advisory Committee, the Kohn panel, and the National Steering Committee for the Advanced Neutron Source. The ANS design maximized performance of the research tool; that is, it provided the highest flux possible to the scientific instruments and facilities, while still meeting safety and availability requirements. Also, ANS was an entirely new facility located near but not dependent on the existing HFIR facility.

2. PURPOSE AND SCOPE OF THE WORKSHOP

2.1 PURPOSE

A primary purpose of this study was to provide a feasible design, schedule, and cost estimate for the HFIR-CNR that meets the assumptions and requirements in Sect 2.2. Results reported here may be used for comparison with a later, more detailed conceptual design and associated, bottom-up cost and schedule estimate.

2.2 REQUIREMENTS AND ASSUMPTIONS

The central mission of the ANS was retained. That is, HFIR-CNR should be a world-class neutron research facility that could support hundreds of "small science" users annually. It should provide a smooth and successful transition of research capabilities now present at HFIR and the High Flux Beam Reactor at Brookhaven National Laboratory. In addition, HFIR-CNR should represent a premier center for research using neutron beams, as well as for research using slow positron and radioactive ion beams. Specific requirements for research capabilities included the following:

- The world's most powerful source of steady-state cold neutron beams derived from a high-powered research reactor.
- Unique capabilities for thermal neutron research using supermirror guide systems.
- Production capabilities to meet the national need for ^{252}Cf, a portable neutron source with many industrial, medical, and security applications.
- A high-flux facility for materials irradiation studies.
- Hydraulic tube facilities for the production of key medical and industrial isotopes.
- Activation analysis facilities with an unprecedented thermal neutron flux.
- A positron research facility with a positron beam intensity substantially greater than any other available in the world.
- The necessary support facilities and staff to serve as a true user facility.

In addition to those requirements, some baseline assumptions were established. All costs were estimated from those presented in the ANS FY 1996 Congressional data sheet. Cost estimates included second-order effects as much as possible to help ensure the completeness of the estimate. The methodology used for estimating cost differences from an established baseline was developed in a previous cost-reduction trade study.[3]

The reactor power was established as 125 MW (f) compared with the ANS baseline value of 330 MW(f). The core design was essentially the same as the three-element core recently adopted for ANS. A minimum core life of 17 days and refueling time of 4 days were retained. Availability and predictability goals of the ANS were also retained.

Stringent core and safety parameter requirements were established to enhance licensability:

- The temperature of the fuel plate surfaces will be less than the saturation temperature of the cooling water ($T_{wall} < T_{sat}$) for all anticipated occurrences (i.e., occurrence frequency greater than or equal to 10^{-2} events per year).

- The critical heat flux condition is not exceeded, even assuming that normal heat transfer is lost on one side of a fuel plant, thereby forcing reliance upon single-sided fuel plate cooling. The goal here is no propagation of damage from plate to plate in the unlikely event of hot spot fuel damage.

- Aluminum structural components are kept below 100°C.

A 2-year compression of the ANS project schedule is desired, which would be feasible since less construction of buildings is required. A guest facility to be supplied by the state of Tennessee will house many of the users. This cost of this facility, estimated at $6 million, was not included in the cost estimate. Finally, it was assumed that the soil conditions, seismic conditions, and building foundation specifications are the same as for ANS.

2.3 APPROACH

The ANS staff was assembled and the goals, objectives, and constraints for the workshop were presented. Based upon this initial information, requirements for the HFIR-CNR were determined. Specific reference was made to the differences between this new facility and the ANS in generating requirements and engineering specifications.

To carry out the assignment, personnel responsible for each work breakdown structure (WBS) level-three element of the project documented design, cost, schedule, and project risk information consistent with the study objectives and new facility requirements. This material was compiled into the design report which, along with backup information, was transmitted as record material for traceability of the workshop study.[4] This transmitted design material formed the basis for the remainder of this report.

The first task was to determine the extent to which existing HFIR facilities could be used. A site plan for the facility was generated using the ANS principles of user-friendly research facilities and separation of research from operation and support facilities.

3. THE HFIR-CNR FACILITY

This section presents a summary of the site plan, facility design, cost, and schedule for the HFIR-CNR. Section 3.1 presents the overall site plan and indicates how HFIR facilities are expected to be used. Section 3.2 discusses the major design features of HFIR-CNR. In many instances, material in this section is presented in itemized form for clarity and ease of traceability. For those desiring more design details, a comparison of the HFIR-CNR facility with the ANS facility is presented in Appendix A and additional engineering and design details are in ref. 4.

Summary cost and schedule information is presented in the remainder of this section. More detailed cost and schedule information is presented in Appendix B and Appendix C, respectively. Scientific instruments included in HFIR-CNR are listed in Appendix D. Major contributors to the workshop are listed in Appendix E.

3.1 GENERAL SITE AND BUILDINGS

The HFIR-CNR would be located next to (west of) the present HFIR and Radiochemical Engineering Development Center (REDC) complex so that maximum use may be made of existing facilities and infrastructure. The site and building arrangements remain user-friendly and include features similar to features in the ANS design. A layout for the site is shown in Fig. 1. This layout allows for growth of HFIR-CNR and replacement of HFIR facilities in a logical and organized manner. The HFIR-CNR complex includes the following buildings and features:

- A 30-m-diameter reactor containment building that houses the HFIR-CNR reactor, the primary cooling system, the fuel handling and wet storage systems, and the cold source system. One year of spent fuel storage will be retained inside containment. Consistent with the ANS, a dry fuel storage facility with nominal 40-year capacity is not included, but space is available for it. Lower cost options for spent fuel storage may be considered.

- A guide hall housing the cold neutron guides and instruments. (See Fig. 2 for a layout of one guide hall and Appendix D for a list of instruments. Note that Fig. 1 shows the full complement of guide halls, and Fig. 2 shows only those included in the initial HFIR-CNR cost estimate.).

- A thermal guide hall housing thermal neutron scattering instruments. (See Fig. 2 for a layout of one guide hall and Appendix D for a list of instruments. Note that Fig. 1 shows the full complement of guide halls, and Fig. 2 shows only those included in the initial HFIR-CNR cost estimate.).

- A research support facility housing laboratories and shops needed to support research operations.

- A reactor support building housing equipment needed to operate the reactor and the refrigeration system needed to operate the cold source.

- An interface building used for access control, health physics monitoring and control, and security control.

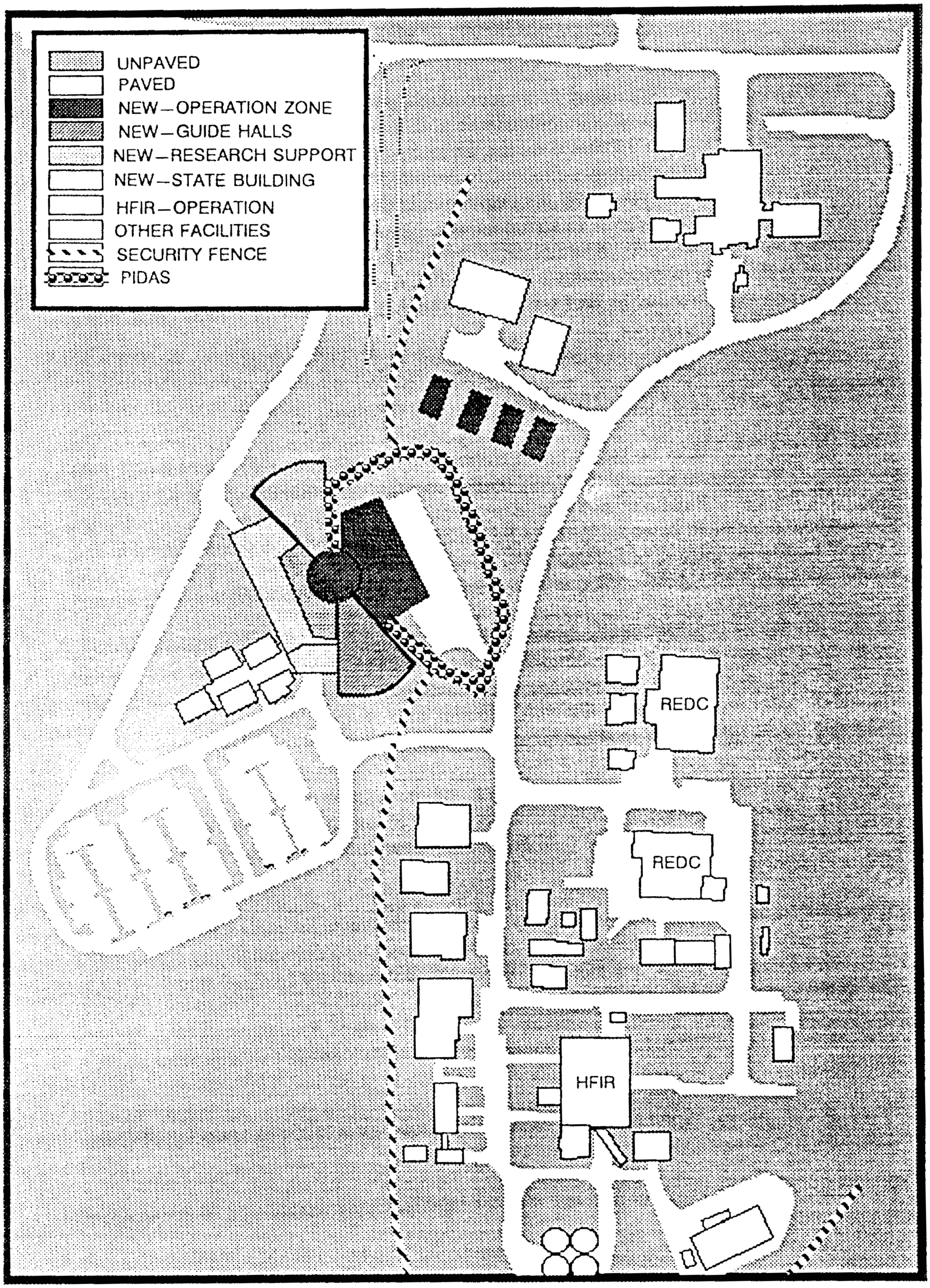

Fig. 1. A layout for the High Flux Isotope Reactor-Center for Neutron Research site.

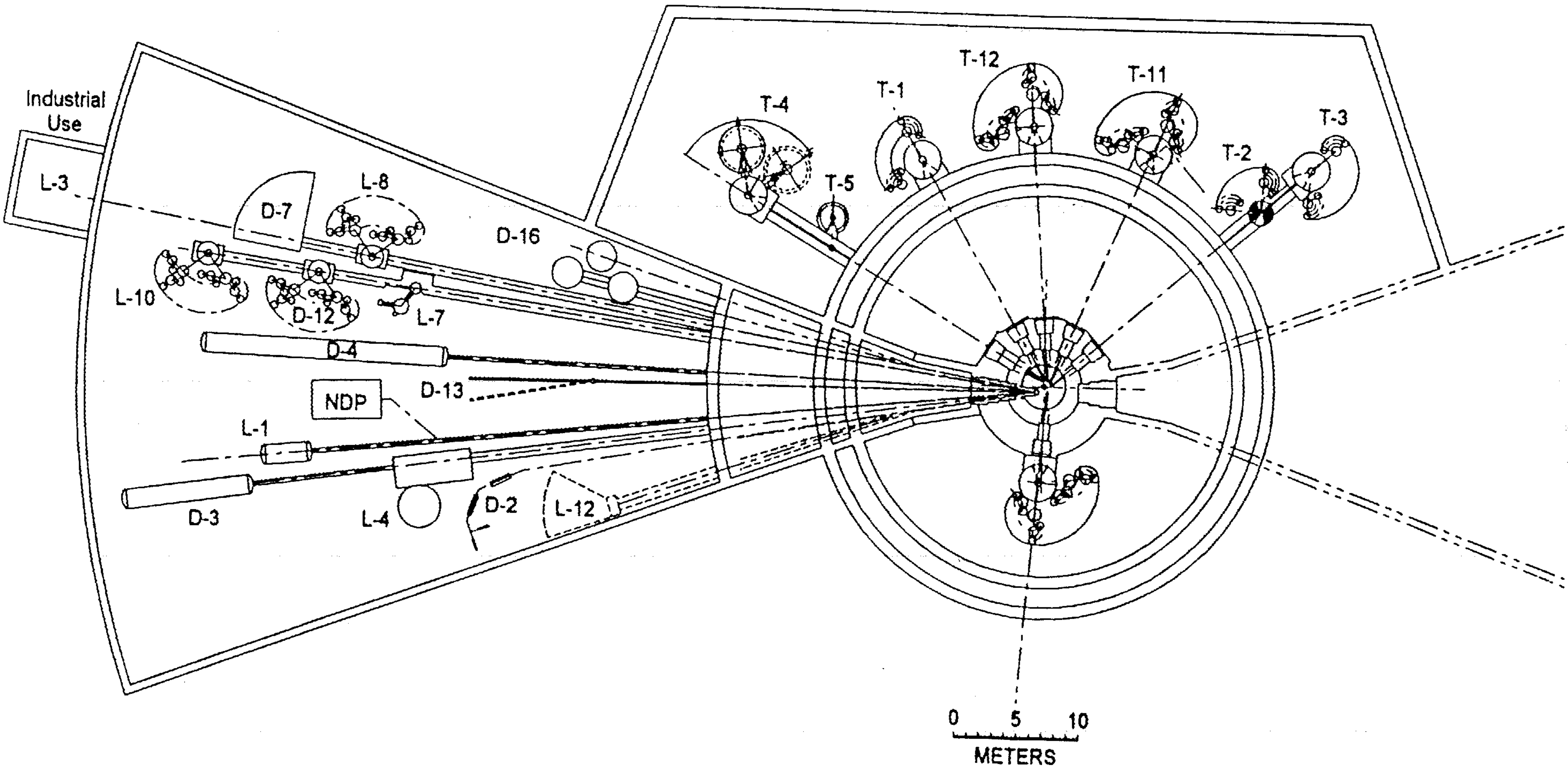

Fig. 2. A layout of the guide hall of the High Flux Isotope Reactor-Center for Neutron Research.

- Process and service buildings that house the heavy water upgrade and detritiation process equipment.

- Cooling towers, electrical substations, and other structures not available in the existing HFIR and REDC complex.

- Existing buildings in the HFIR and REDC complex are used to house the operations, maintenance, technical, quality, security, and health physics staff.

- Existing buildings in the HFIR and REDC complex provide the shops and warehouses needed to support HFIR-CNR operations and to house the HFIR-CNR mockup and other training facilities.

In developing this site plan, it was concluded that Buildings 7920, 7930, and adjoining structures, as well as the new office building under construction to the north of buildings 7914 and 7915, are not part of the HFIR complex and therefore cannot be used for HFIR-CNR. All research facilities are constructed northwest of the existing HFIR facility in what is now the parking lot area of HFIR outside the fence. The two guide halls and adjoining research support building will be included within the research zone. A small interface building of approximately 5400 ft^2 will include essential security and health physics monitoring and a general reception area. It was assumed that an adjoining $6 million facility will be funded by the state of Tennessee (and therefore not included in the design and cost summary), as was the case for ANS. This structure, a guest/user facility, will be a combination of office/dormitory wing, library and computers, lounge, break room, and user liaison/handling offices.

The HFIR-CNR is divided into two distinct security zones, as was the case for ANS. Unlike in ANS plans, only a portion of the dividing fence will be a perimeter intrusion detection and assessment system (PIDAS) because the areas enclosed by the PIDAS will be limited to the reactor building, reactor support building, and primary and secondary substations.

The present HFIR access road will be a utility service road. A new road for general access will be constructed west of the Molten Salt Reactor Experiment Building, over an existing service road. Some radiation clean-up work will be required, and underground piping will have to be displaced.

The new employee/guest parking lots will accommodate 205 new spaces for HFIR-CNR and 80 for analytical chemistry personnel. The initial estimate of personnel needed for HFIR-CNR is 320, based on personnel estimates of 559 for ANS and a present HFIR staff of 189.

3.2 SUMMARY SYSTEM DESCRIPTIONS

3.2.1 Reactor, Reactor Cooling System, and Containment

The HFIR-CNR neutron source is based on a 125 MW (f), heavy-water-cooled and -moderated, compact core reactor with the following features:

- A three-element core using low-or-medium-enriched uranium fuel, in the chemical form of U_3Si_2, within an aluminum matrix. The fuel is in the form of thin, curved plates that span between two concentric sideplates. Nominal values for core parameters include a fuel plate thickness of 1.27 mm, aluminum clad thickness of 0.254 mm, coolant channel gap of 1.27 mm, heated length of 418 mm, coolant velocity of 15 m/s, inlet pressure of 2.335 MPa, outlet pressure of 1.8 MPa, and maximum core inlet temperature of 45°C.

- A large heavy water reflector vessel that transports thermal neutrons to beam and irradiation facilities.

- A liquid deuterium cold source that slows the thermal neutrons down to low energies for transport in a cold neutron guide system to a guide hall located outside the reactor containment. Provisions are made in the design for adding a second cold source after the HFIR-CNR is constructed.

- Five containment penetrations for thermal guide systems that transport thermal neutrons to instruments in an experiment hall located outside the reactor containment.

- A reactor design that meets all Nuclear Regulatory Commission requirements for a licensed facility, in accordance with reactor safety requirements established by DOE.

- A reactor protection system that is redundant, diverse, and fully responsive to all challenges, including single-failure criteria and anticipated transients without scram of the primary shutdown system.

- Systems to refuel and maintain the reactor while maintaining barriers between light and heavy water.

- A cooling system that incorporates passive and inherent safety features. These include coolant upflow through the core, decay heat transport by natural circulation, passive accumulators for inventory control and to maintain pressure during postulated transients, and no reliance on electrical power for decay heat removal.

- A double-walled reactor containment structure with a filtered annulus. The design of the containment system is integrated with emergency planning activities so that realistic evacuation times are provided for occupants of the Oak Ridge Reservation, including ORNL, and no "immediate notification" of off-site residents is required after a postulated severe accident.

3.2.2 Beam, Instrument, Irradiation, and User Support Facilities

A layout of the guide hall is shown in Fig. 2. The HFIR-CNR complex provides the following research facilities:

- One cold source, seven cold guides with two or more split guides, five thermal guides, one remotely-operated thermal beam, and one slant beam tube. A second cold source and associated guides can be added later.

- Seven thermal and eleven cold neutron scattering instruments.

- A precision gamma-ray bolometer for nuclear physics. There is the potential to add a beam station and a radioactive ion beam facility in the future.

- Thirty target positions and a hydraulic rabbit tube for producing transuranic isotopes, especially ^{252}Cf.

- Five instrumented and five noninstrumented materials irradiation targets in a hard spectrum, with the necessary hot cell facilities to support their operation.

- Three hydraulic rabbit tube facilities for producing key medical and industrial isotopes, along with the necessary hot cell facilities to support their operation.

- Prompt gamma analysis and neutron depth profiling facilities on cold guides and four pneumatic rabbit tubes for activation analysis. Counting rooms, laboratories, and sample storage facilities needed to support the activation analysis facilities are also provided.

- A positron source and beam system based on irradiation of copper targets using a dedicated hydraulic rabbit tube.

- Facilities for instrument setup and maintenance, sample preparation, and data collection.

- User support facilities, including offices and temporary lodging, to be provided in a separate building to be constructed by the state of Tennessee.

3.2.3 Plant Systems

HFIR-CNR plant systems include the following:

- reliable electrical power systems;

- heating, ventilation and air conditioning systems that maintain habitability and that control tritium and other types of contamination;

- plant water, services, fire protection and waste systems, including the cryogenic helium refrigerator necessary for the operation of the cold source;

- a heavy water processing plant that removes tritium produced in the reactor heavy water and cold source deuterium and that removes light water contamination from all heavy water supplies;

- advanced control, data and communications systems, including a digital control room, a comprehensive data network, and a complete electronic technical and business data system.

3.3 COST ESTIMATE

Costs were developed using well-documented ANS cost estimates. Risks unique to HFIR-CNR that could increase its costs are documented in ref. 4. If these unique risks are avoided, then the accuracy of the HFIR-CNR cost estimate is similar to the accuracy of the ANS estimate. Remaining uncertainties in HFIR-CNR costs and in risks associated with its design, licensing, and construction have been adequately investigated and documented during the ANS conceptual design. Thus, the contingency percentages used for the HFIR-CNR were similar to those for ANS. Total project costs are summarized in Tables 1 and 2. Annual operating costs are summarized in Table 3.

3.4 SCHEDULE FOR CONSTRUCTION

The project schedule is success oriented, as was that of the ANS conceptual design. The most challenging schedule item is obtaining review and approval from DOE (or other regulating bodies) of environmental, safety, and licensing documentation in a timely manner. While we recognize that this may be difficult, we believe that if the project, DOE and the licensing body work as a team, the HFIR-CNR can be constructed on the schedule shown.

The following are key schedule dates:

Project authorization/begin Title I	October 1995
Industry team in place	October 1995
National Environmental Policy Act	
Record of decision issued	August 1997
Issue preliminary safety analysis report	October 1997
Begin early Title II design	December 1996
Start non-nuclear construction	December 1997
First nuclear concrete	November 1998
Complete Title II	December 1999
Issue final safety analysis report	January 2001
Initial core load	February 2002
Initial criticality	May 2002
Project complete	September 2002

3.5 METHOD OF ACCOMPLISHMENT

Both programmatic direction and funding from DOE will be provided by the Office of Energy Research, as is the case for their other large scientific facility projects (e.g., the Advanced Photon Source, the Relativistic Heavy Ion Collider). The project will be managed by Lockheed Martin Energy Systems. Industrial participation (architect engineer, reactor manufacturer, and construction manager) will be obtained and managed directly by Lockheed Martin Energy Systems.

Table 1. Total project cost for the High Flux Isotope Reactor-Center for Neutron Research (all types of funding included)

WBS element	FY 1992 dollars ($K)	As-spent dollars ($K)
1.1 Research and development	138,870	171,866
1.2 Project support	179,426	231,493
1.3 Reactor systems	114,226	144,768
1.4 Experiment systems	154,938	200,588
1.5 Site and buildings	188,590	239,015
1.6 Plant systems	321,082	415,277
1.7 Operations	128,660	178,727
1.8 DOE support	5,478	7,087
Total HFIR-CNR project cost[a]	1,231,270	1,588,821

[a] This figure does not include costs for the heavy water upgrade and detritiation facility (listed in Table 2).

Table 2. Total project cost for the High Flux Isotope Reactor-Center for Neutron Research heavy water upgrade and detritiation facility (all types of funding included)

WBS element	FY 1992 dollars ($K)	As-spent dollars ($K)
Detritiation buildings	7,165	9,081
Detritiation process	55,701	72,110
Total D_2O upgrade and detritiation project cost	62,866	81,191

Table 3. Annual operating costs for the High Flux Isotope Reactor-Center for Nuclear Research (HFIR-CNR) and for the heavy water upgrade and detritiation facility (thousands of FY 1995 dollars).

	35% enrichment	20% enrichment
HFIR-CNR reactor and plant operating cost	47,796	54,056
HFIR-CNR research staff cost	13,556	13,556
Total HFIR-CNR operations and research costs	61,352	67,612
Detritiation facility operating cost	1,671	1,739

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2. J. Peretz, et al., *Advanced Neutron Source Conceptual Design Summary*, ORNL/TM-12184, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, September 1992.

3. R. S. Booth, compiler, *ANS Project Workshop on Cost Reduction, ORNL/ANS/INT*-39, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, October 1992.

4. F. J. Peretz, , *Design Material from the Feasibility Workshop for a High Flux Isotope Reactor-Center for Neutron Research Facility*, ANS-1201-95-5, March 1995. This document was transmitted to the ANS records system via transmittal 95-054.

APPENDIXES

Appendix A

COMPARISON OF THE HFIR-CNR AND ANS FACILITIES

A.1 COMPARISON OF CAPABILITIES

1. The neutron flux distribution of the HFIR-CNR reactor is generally similar to that of the ANS reactor, but it is lower by the ratio of the fission power of the two designs. The power of the HFIR-CNR reactor, and therefore the flux available at most beam stations and irradiation facilities, is about 40% that of the corresponding ANS facility. In many cases, the research capability of the facility is directly proportional to the flux. In some cases, the lower flux may preclude certain types of experiments. The performance of some irradiation facilities (especially the transuranium production facilities) is proportional to the flux raised to some power above one, and thus the performance is reduced further than the simple ratio of flux.

2. The following neutron scattering instruments in the ANS complement, and their associated costs, have not been included in HFIR-CNR. The method of funding in the ANS Project cost estimate is also indicated. Instruments to be procured with line item funds were to be designed and installed as part of the ANS Project, whereas those procured with operating funds were in many cases to be designed and installed by other research organizations.

L-5	High resolution powder diffractometer	Operating
T-6	Diffuse scattering time-of-flight spectrometer	Line item
T-7	Diffuse scattering time-of-flight spectrometer	Operating
T-8	Time-of-flight spectrometer	Line item
D-1	Multichopper time-of-flight spectrometer	Line item
L-6	Time-focusing time-of-flight spectrometer	Operating
H-4	Triple-axis spectrometer	Line item
D-11	Triple-axis spectrometer	Operating
L-9	Triple-axis spectrometer	Operating
L-11	Double crystal small angle neutron scattering (SANS)	Operating
D-5	SANS 40m	Operating
L-2	SANS 20m	Operating
D-6	SANS 20m	Operating
H-2	General purpose liquids diffractometer	Line item
D-10	Backscattering spectrometer	Operating
V-1	Very cold neutron optical bench	Operating
U-1	Ultracold neutron turbine	Line item
C-1	Slant cold neutron station	Operating

3. The following nuclear and fundamental physics instruments in the ANS complement have not been included (the method of funding in the ANS Project is also indicated).

T-9	Through-tube loading station	Line item
T-10	Ultrahigh resolution gamma spectroscopy	Line item

D-8	Weak interaction physics	Operating
L-12	Parity violation	Line item
D-14	Nuclear structure	Operating
D-15	Nuclear spectroscopy	Operating
T-13	Isotope separation on-line	Line item

4. The two slant materials irradiation facilities included in the ANS design have been deleted.

5. The four vertical isotope production facilities included in the ANS design have been deleted.

6. Three of the seven pneumatic rabbit tubes provided for activation analysis in the ANS design have been deleted. The support facilities for activation analysis have been reduced by a corresponding amount.

7. Laboratories and shops that support research operations have been reduced in proportion to the number of instruments.

A.2 COMPARISON OF COST

The design and estimate for HFIR-CNR was generated using the exceptionally detailed (and independently verified) conceptual design and cost information developed for ANS. In using the ANS design information to generate the design and estimate for HFIR-CNR, the following changes were made to the ANS data:

A.2.2 Reactor, Reactor Cooling, and Containment Systems

1. The reflector vessel design is simplified with respect to the ANS design by the reduction in the number of beam and irradiation facility penetrations. This effect is offset by complications resulting from combining the primary and reflector cooling systems.

2. Because of the lower flux and heating rates in the HFIR-CNR reactor, a zirconium alloy is used for the core pressure boundary tube and possibly the beam tubes. Although this may increase the direct cost of the reactor components, it increases reactivity and core life and decreases the operating cost.

3. Because the reactor power is reduced considerably, many accident scenarios are less challenging for the HFIR-CNR reactor. Thus the required control rod response speed is less than in the ANS design, and the reactor control system costs are somewhat lower.

4. One primary and one secondary cooling system loop have been deleted. These loops were used as an on-line spare in the ANS design.

5. Cooling of the HFIR-CNR reflector is accomplished using the primary cooling loops. Thus the separate reflector cooling loops provided in the ANS design are deleted.

6. Plate heat exchangers are used instead of shell and tube designs to reduce the cost and size of the primary cooling loops in this lower pressure system.

7. Pony motors and separate emergency heat exchangers are not needed for the HFIR-CNR cooling systems.

8. All primary and secondary cooling system components are reduced in size and cost using appropriate power scaling factors.

9. The basic design of the reactor containment system remains the same. However, because of the lower power level of the HFIR-CNR, the containment structure is half the diameter of and somewhat lower in height than the ANS design. This reduces the size and cost of the containment ventilation and filtration systems. The containment is not normally occupied during operation; the size, number, and cost of airlocks has been reduced. The number of other penetrations in the containment has also been reduced. The reduced reactor power level [125 vs 330 MW (f)] allows reduction of the containment volume without an increase in the primary containment wall thickness. Thus the HFIR-CNR preserves the containment capability of the ANS conceptual design.

A.2.2 Research Facilities and User Support

1. One cold source and its associated cold neutron guides were deleted; but provision is made for adding them later, after operations have begun and the first guide hall is saturated.

2. Twenty-five beam instruments were deleted, as described under research capabilities.

3. Two slant materials irradiation facilities, four vertical isotope facilities, and three pneumatic tubes were deleted, as described under research capabilities.

4. Laboratories and shops needed to support research operations were scaled with the number of instruments. A research support structure encircles the thermal instrument room outside containment. User support is provided in a building that it is assumed will be built by the state of Tennessee.

A.2.3 Site, Buildings, and Plant Systems

1. The reactor containment building will have a diameter half that of the corresponding ANS building.

2. The reactor support building will be half the size of the corresponding ANS building.

3. The guide hall will be 60% of the size of the ANS guide hall. Provision will be made for the construction of a second guide hall at a later time.

4. The office building has been eliminated; many of its functions will be provided by a guest facility expected to be constructed by the state of Tennessee, and the rest will be provided by an interface building (see next item).

5. A new interface building has been added. This new 5400 ft^2 building replaces some of the functions of the ANS office building.

6. Operations support has been eliminated (existing HFIR facilities are to be used instead)

7. The mockup building has been eliminated (existing HFIR facilities are to be used instead)

8. The research support building will be 62% the size of the corresponding ANS building.

9. The detritiation buildings will be 80% of the size of the corresponding ANS buildings. The detritiation buildings are costed separately, so that the decision to construct the detritiation facility can be made separately from the decision to build HFIR-CNR.

10. The positron facility will be 34% of the size of the corresponding ANS building.

11. Most plant systems that support reactor operations are reduced in cost using an appropriate power scaling factor (See ref. 4).

12. The two independent 161-kV lines supplying the site with electrical power in the ANS design have been deleted. A second 13.8-kV line is brought to the HFIR site to improve the reliability of the existing HFIR power supply.

13. Emergency power loads have been greatly reduced, so Class 1E standby diesel generators are deleted; Class-1E battery systems will power the remaining emergency loads. Commercial grade standby generator sets have been added to supply non-Class 1E power during loss of off-site power. Emergency cooling of the main control room is provided by a passive design similar to that used in the ANS.

14. A processing plant is provided to remove tritium and light water contamination from the HFIR-CNR heavy water inventory. This plant will have other uses in the DOE complex as well. The detritiation process is costed separately so that the decision to construct the detritiation facility can be made separately from the decision to build HFIR-CNR.

15. The scope and thus cost of the plant control simulator has been reduced.

16. Since each fuel element cannot become supercritical as a result of any upset during refueling, the instrument and control equipment for refueling will not be Class 1E.

A.2.4 Project Cost

1. Research and development costs are reduced because of a substantial increase in thermal margins, the elimination of the hot source, the elimination of the need for neutron poisons in the refueling process, and numerous other simplifications in the reactor design.

2. Other project support cost elements (e.g., administration, quality assurance) have been reduced as appropriate to correspond to the 2-year reduction in the project schedule.

A.2.5 Summary Cost Estimates

Costs for HFIR-CNR were generally estimated by reviewing the ANS cost estimate data and changing costs to reflect the specific differences between ANS and HFIR-CNR. The key assumptions and methodology used are described in Ref. 4. The spreadsheet format developed to display the ANS costs over time were then used to summarize costs for HFIR-CNR. A summary of the escalated costs for ANS and HFIR-CNR, and the difference between them, is included in Tables A.1 and A.2.

A.3 COMPARISON OF SCHEDULE

The schedule for HFIR-CNR is 2 years shorter than for the much larger ANS Project. A key element of this shortened schedule is the assumption that the DOE office responsible for certification of HFIR-CNR will provide a staff co-located with the design team starting October 1, 1995, to ensure early and ongoing interaction and continual review of the design and safety program. It is also assumed that the certifying DOE office will take no more than one whole year to review the preliminary safety analysis report and one whole year to review the final safety analysis report.

Key schedule dates in the ANS and HFIR-CNR schedules compare as follows.

	ANS schedule	HFIR-CNR schedule
Project authorization/begin Title I	October 1995	October 1995
Industry team in place	October 1995	October 1995
Issue NEA record of decision	November 1996	August 1997
Issue preliminary safety analysis report	October 1997	October 1997
Begin early Title II design	October 1997	December 1996
Start non-nuclear construction	December 1997	December 1997
First nuclear concrete	November 1998	November 1998
Complete Title II	October 2001	December 1999
Issue final safety analysis report	January 2003	January 2001
Initial core load	March 2004	February 2002
Initial criticality	April 2004	May 2002
Project complete	September 2004	September 2002

Table A.1. Comparison of total costs for the Advanced Neutron Source and HFIR-CNR[a] projects (all types of funding included; escalated to year spent)

WBS element	ANS cost ($K)	HFIR-CNR ($K)	Cost reduction ($K)
1.1 Research & development	211,113	171,866	39,247
1.2 Project support	342,036	231,493	110,543
1.3 Reactor systems	178,497	144,768	33,729
1.4 Experiment systems	343,480	200,588	142,892
1.5 Site and buildings	502,695	239,015	263,680
1.6 Plant systems	792, 412	415,277	377,135
1.7 Operations	321,537	178,727	142,810
1.8 DOE support	9,120	7,087	2,033
Total project cost	2,700,890[b]	1,588,821[c]	1,122,069

[a] High Flux Isotope Reactor-Center for Neutron Research

[b] Does not include costs of the heavy water upgrade and detritiation facility or funds previously spent on the Advanced Neutron Source research and development and design. When heavy water upgrade and detritiation costs ($123 million) and prior year costs ($102 million) are added to the ANS Project cost, the total ANS cost comes to $2,925 million.

[c] Does not include heavy water upgrade and detritiation costs (listed in Table A.2).

Table A.2. Comparison of total costs for the ANS and HFIR-CNR heavy water upgrade and detritiation facilities (all types of funding included; escalated to year spent)

WBS element	ANS cost ($K)	HFIR-CNR ($K)	Cost reduction ($K)
Detritiation buildings	9,504	9,081	423
Detritiation process	113,191	72,110	41,081
Total project cost	122,695	81,191	41,504

Appendix B

HFIR-CNR COSTS BY WBS AND FUNDING TYPE

To simplify the task of developing a cost estimate for an upgraded HFIR, the present ANS WBS was used as a starting point. The ANS cost estimate baseline that is the basis for the FY 1996 Congressional data sheet (FY 1995 line-item start) was used as a starting point for evaluating and establishing cost estimates for activities, components, systems, subsystems, and/or structures. The estimating activities used FY 1992 constant year dollars, which are the basis for the ANS CDR and all other cost estimates since that time. After an estimate was established in fixed dollars, the estimate was spread in time based on the HFIR-CNR schedule for the activity using standard bell distributions or "S" curves, and then escalated from FY 1992 to actual year dollars.

The cost estimate for the HFIR-CNR was developed at WBS Level 3 and rolled up to establish the total estimated construction cost and total project cost. This established the line item construction budget, the operation expense budget for research and development and operations support, and the capital equipment budget that supports the research and development and operations activities.

The estimates were established by evaluating assumptions, scaling down or eliminating elements of the estimated cost, and comparing ANS function and HFIR-CNR function for all systems. Costs were developed through

- Eliminating an item, system or function entirely.
- Scaling down in area or size, which would then scale down the cost in a somewhat linear fashion.
- Scaling down as a function of the power: $(P_2/P_1)^{0.6}$
  where
  P_1 is the ANS power, 330 MW, and
  P_2 is the HFIR-CNR power, 125 MW.

  (See ref. 3 for more information on this expression.)

- Reducing level-of-effort activities by the ratio of the duration of the ANS schedule for the activity to the duration of the HFIR-CNR schedule for the activity

  Four tables are presented in this appendix (total project costs, pages B-3 to B-5; line item or capital costs, pages B-6 to B-8; operating expenses, pages B-9 to B-11; and capital equipment, pages B-12 to B-14). Costs are arranged by level 3 WBS numbers.

Total Project Cost April 1994 Baseline		ANS	HFIR-CNR	Distribution of Costs by Year							
		FY 1992	FY 1992	Actual Year $k							
WBS	TITLE	($K) Total	($K) Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.1.1	Reactor Core Development	22,604	18,267	2,686	3,997	4,029	4,598	3,846	2,438	1,389	22,983
1.1.2	Fuel Development	18,077	15,923	2,162	4,916	6,004	4,538	693	657	597	19,567
1.1.3	Corrosion Tests & Analysis	2,415	1,193	669	585	135	0	0	0	0	1,389
1.1.4	Core Flow Tests	39,388	21,675	1,924	5,108	9,423	6,641	3,696	0	0	26,792
1.1.5	Control Concepts	673	716	126	158	164	95	98	102	164	908
1.1.6	Critical Experiments	6,741	8,249	311	2,667	2,390	3,024	1,864	0	0	10,255
1.1.7	Matrls Data, Tests and Anly	20,519	21,614	5,120	8,754	5,341	4,441	1,718	670	136	26,180
1.1.8	Cold Source Development	8,970	9,324	1,310	2,411	2,012	1,947	1,297	1,242	1,556	11,774
1.1.9	Beam Tube, Guide, Inst Dev	16,472	15,389	1,030	2,099	3,903	5,282	3,860	1,766	1,716	19,656
1.1.10	Hot Source Development	8,438	0	0	0	0	0	0	0	0	0
1.1.11	Neutron Tranport & Shldng	6,138	5,419	1,250	1,399	1,438	1,477	1,074	0	0	6,637
1.1.12	I&C System Development	4,022	2,750	700	953	628	526	214	222	117	3,360
1.1.13	Facility Concepts	20,612	18,351	4,638	5,742	5,064	3,718	2,137	863	201	22,364
1.1 Research & Development		175,068	138,870	21,926	38,790	40,532	36,287	20,496	7,959	5,876	171,866
1.2.1	Proj Mgmt & Adminstn	147,881	79,841	3,016	9,055	16,469	24,876	26,969	18,278	4,342	103,005
1.2.2	Systems Engineering	21,747	11,720	307	1,163	2,373	3,714	4,107	2,840	669	15,173
1.2.3	Safety	58,578	58,578	1,533	5,812	11,862	18,561	20,529	14,192	3,345	75,834
1.2.4	Envrt & Waste Mgmt	5,991	3,349	1,297	1,040	454	627	496	130	0	4,044
1.2.5	Quality Assurance	27,089	20,393	526	2,002	4,104	6,452	7,168	4,978	1,179	26,409
1.2.6	Training	3,999	2,155	81	306	624	862	681	178	0	2,732
1.2.7	Test & Evaluation	6,288	3,389	127	480	982	1,355	1,071	280	0	4,295
1.2 Project Support		271,575	179,426	6,887	19,859	36,870	56,446	61,021	40,875	9,534	231,493
1.3.1	Reactor Assembly	27,295	27,295	1,025	3,869	7,906	10,915	8,624	2,254	0	34,594
1.3.2	Refueling	45,218	28,791	1,081	4,081	8,339	11,513	9,096	2,378	0	36,489
1.3.3	Reactor I&C	33,706	23,653	888	3,353	6,851	9,459	7,473	1,954	0	29,977
1.3.4	Fuel	2,984	4,038	152	572	1,170	1,615	1,276	334	0	5,118
1.3.5	Reactor Mockup	22,723	22,723	853	3,221	6,582	9,087	7,179	1,877	0	28,799
1.3.6	Maintenance	7,726	7,726	290	1,095	2,238	3,090	2,441	638	0	9,791
1.3 Reactor Systems		139,653	114,226	4,290	16,191	33,085	45,679	36,088	9,434	0	144,768

Total Project Cost		ANS	HFIR-CNR								
April 1994 Baseline		FY 1992	FY 1992	Distribution of Costs by Year							
		($K)	($K)	Actual Year $k							
WBS	TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.4.1	Neutron Transport	55,908	39,839	1,043	3,953	8,068	12,623	13,962	9,652	2,275	51,575
1.4.2	Neutron Scat Inst	84,402	40,352	1,056	4,004	8,172	12,786	14,141	9,776	2,304	52,239
1.4.3	Nuc & Fund Physics	15,034	3,413	89	339	691	1,081	1,196	827	195	4,418
1.4.4	Trans U Production	21,150	21,012	550	2,085	4,255	6,658	7,364	5,091	1,200	27,202
1.4.5	Materials Irrad. Facility	9,773	8,232	215	817	1,667	2,608	2,885	1,994	470	10,657
1.4.6	Isotope Prodtn Facility	6,634	3,951	103	392	800	1,252	1,385	957	226	5,115
1.4.7	Analytical Chem Fac	36,402	18,791	483	1,844	3,786	5,949	6,608	4,582	1,083	24,334
1.4.8	Instrument Supprt Fac	9,428	5,479	143	544	1,110	1,736	1,920	1,327	313	7,093
1.4.9	Comptr & Data Hndlg	4,492	2,059	54	204	417	652	722	499	118	2,666
1.4.10	Cold Source	17,966	11,810	309	1,172	2,392	3,742	4,139	2,861	674	15,289
1.4.11	Hot Source	1,856	0	0	0	0	0	0	0	0	0
1.4 Experiment Systems		263,045	154,938	4,046	15,353	31,357	49,087	54,320	37,567	8,857	200,588
1.5.1	Land Improvements	41,584	20,838	783	2,954	6,036	8,333	6,583	1,721	0	26,410
1.5.2	Reactor Building	136,569	52,554	1,974	7,449	15,222	21,016	16,604	4,341	0	66,606
1.5.3	React/Opns Suppt	79,161	52,554	1,974	7,449	15,222	21,016	16,604	4,341	0	66,606
1.5.4	GHall/Res Suppt	42,871	30,754	1,155	4,359	8,908	12,298	9,716	2,540	0	38,977
1.5.5	Office/Interface Bldg	32,529	1,090	41	155	316	436	344	90	0	1,381
1.5.6	Detritiation Building	7,704	7,165	269	1,016	2,075	2,865	2,264	592	0	9,081
1.5.7	Other Structures	32,581	8,837	332	1,253	2,560	3,534	2,792	730	0	11,200
1.5.8	Construction Support	21,963	21,963	825	3,113	6,362	8,783	6,939	1,814	0	27,836
1.5 Site & Buildings		394,963	195,755	7,351	27,748	56,700	78,282	61,846	16,168	0	248,096
1.6.0	Plant Systems Integration	2,858	1,225	46	174	355	490	387	101	0	1,553
1.6.1	Reactor Water Systems	115,962	53,370	1,397	5,296	10,808	16,910	18,703	12,930	3,047	69,092
1.6.2	Elec & Comm Systems	121,802	63,647	1,666	6,315	12,889	20,167	22,305	15,420	3,634	82,396
1.6.3	Environmental Systems	69,315	42,445	1,111	4,212	8,595	13,449	14,875	10,283	2,424	54,949
1.6.4	Plant Water Systems	91,437	44,831	1,173	4,448	9,079	14,205	15,711	10,861	2,560	58,037
1.6.5	Plant Service Systems	44,332	28,906	757	2,868	5,854	9,159	10,130	7,003	1,651	37,421
1.6.6	Plant Fire Protection	13,184	5,639	148	559	1,142	1,787	1,976	1,366	322	7,300
1.6.7	Plant Waste Systems	20,248	9,748	255	967	1,974	3,089	3,416	2,362	557	12,620
1.6.8	Heavy Water Dtrn & Upgd	87,385	55,701	1,458	5,527	11,280	17,649	19,520	13,495	3,181	72,110
1.6.9	Plant I, C & Data Systems	112,945	68,282	1,496	6,710	15,806	24,490	22,424	13,850	3,264	88,040
1.6.10	Maintenance & GPE	13,931	2,989	78	297	605	947	1,047	724	171	3,870
1.6 Plant Systems		693,398	376,783	9,585	37,373	78,386	122,341	130,496	88,397	20,810	487,387

Total Project Cost April 1994 Baseline		ANS FY 1992 ($K) Total	HFIR-CNR FY 1992 ($K) Total	Distribution of Costs by Year Actual Year $k							
WBS	TITLE			FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.7.1	Administrative Support	7,514	3,708	50	104	217	395	820	1,701	1,764	5,052
1.7.2	Management & Planning	11,343	10,674	368	573	1,588	2,273	2,577	3,340	3,463	14,181
1.7.3	Maintenance	12,319	6,868	0	0	0	470	489	1,715	6,975	9,649
1.7.4	Health&Safety	9,058	6,163	278	288	374	623	1,620	2,521	2,614	8,317
1.7.5	Training	6,825	1,623	0	14	60	181	377	782	811	2,225
1.7.6	QA	9,368	8,680	109	278	771	1,069	2,830	3,271	3,392	11,720
1.7.7	Utilities	3,687	8,476	0	0	0	778	889	922	9,317	11,907
1.7.8	Fuel	30,224	10,233	0	0	0	0	3,019	10,956	0	13,975
1.7.9	Replacing Equipt &Mods	0	1,000	0	0	0	319	332	344	357	1,352
1.7.10	Security	1,585	1,232	75	104	135	169	234	303	628	1,647
1.7.11	Reactor Operations	50,159	26,790	0	0	979	3,133	7,717	12,195	12,659	36,683
1.7.12	Rsrch Operations	75,341	33,793	0	0	0	4,016	8,299	16,786	17,421	46,522
1.7.13	Initial Purchases	8,256	9,420	569	437	147	639	3,319	4,818	5,567	15,496
1.7 Operations		225,681	128,660	1,449	1,798	4,272	14,065	32,520	59,654	64,969	178,727
1.8.1	DOE Support Subcontrctng	7,031	5,478	167	539	1,127	1,722	1,905	1,317	310	7,087
1.8 DOE Support		7,031	5,478	167	539	1,127	1,722	1,905	1,317	310	7,087
TOTAL		2,170,415	1,294,136	55,701	157,651	282,328	403,911	398,692	261,373	110,356	1,670,011

LINE ITEM As Spent $k April 1994 Baseline		ANS FY 1992 ($K) Total	HFIR-CNR FY 1992 ($K) Total	Distribution of Costs by Year Actual Year $k							
WBS	TITLE			FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.1.1	Reactor Core Development	8,945	12,803	1,195	2,606	2,755	3,203	3,177	2,029	1,325	16,289
1.1.2	Fuel Development	8,419	7,626	0	1,432	3,255	3,427	478	496	514	9,600
1.1.3	Corrosion Tests & Analysis	0	0	0	0	0	0	0	0	0	0
1.1.4	Core Flow Tests	0	0	0	0	0	0	0	0	0	0
1.1.5	Control Concepts	364	337	0	0	0	95	98	102	164	459
1.1.6	Critical Experiments	0	0	0	0	0	0	0	0	0	0
1.1.7	Matrls Data, Tests and Anly	2,308	3,988	188	528	1,413	1,471	1,018	340	86	5,043
1.1.8	Cold Source Development	3,114	3,090	183	0	0	672	924	991	1,409	4,179
1.1.9	Beam Tube, Guide, Inst Dev	2,486	1,317	0	0	0	0	231	523	1,089	1,843
1.1.10	Hot Source Development	1,847	0	0	0	0	0	0	0	0	0
1.1.11	Neutron Tranport & Shldng	5,447	5,316	1,195	1,399	1,438	1,407	1,074	0	0	6,512
1.1.12	I&C System Development	1,302	944	56	148	252	206	214	222	117	1,213
1.1.13	Facility Concepts	8,509	7,300	372	2,885	3,002	2,250	430	0	0	8,939
1.1 Research & Development		42,740	42,721	3,189	8,996	12,115	12,729	7,644	4,702	4,704	54,078
1.2.1	Proj Mgmt & Adminstn	138,104	74,429	1,948	7,385	15,072	23,583	26,084	18,032	4,250	96,355
1.2.2	Systems Engineering	21,747	11,720	307	1,163	2,373	3,714	4,107	2,840	669	15,173
1.2.3	Safety	42,967	42,967	1,125	4,263	8,701	13,614	15,058	10,410	2,453	55,624
1.2.4	Envrt & Waste Mgmt	2,911	1,569	59	222	454	627	496	130	0	1,989
1.2.5	Quality Assurance	24,055	17,965	470	1,783	3,638	5,692	6,296	4,353	1,026	23,257
1.2.6	Training	3,999	2,155	81	306	624	862	681	178	0	2,732
1.2.7	Test & Evaluation	6,288	3,389	127	480	982	1,355	1,071	280	0	4,295
1.2 Project Support		240,072	154,194	4,117	15,602	31,845	49,448	53,792	36,222	8,398	199,424
1.3.1	Reactor Assembly	27,295	27,295	1,025	3,869	7,906	10,915	8,624	2,254	0	34,594
1.3.2	Refueling	45,218	28,791	1,081	4,081	8,339	11,513	9,096	2,378	0	36,489
1.3.3	Reactor I&C	33,706	23,653	888	3,353	6,851	9,459	7,473	1,954	0	29,977
1.3.4	Fuel	2,984	4,038	152	572	1,170	1,615	1,276	334	0	5,118
1.3.5	Reactor Mockup	22,723	22,723	853	3,221	6,582	9,087	7,179	1,877	0	28,799
1.3.6	Maintenance	7,726	7,726	290	1,095	2,238	3,090	2,441	638	0	9,791
1.3 Reactor Systems		139,653	114,226	4,290	16,191	33,085	45,679	36,088	9,434	0	144,768

LINE ITEM		ANS	HFIR-CNR	Distribution of Costs by Year							
As Spent $k	April 1994 Baseline	FY 1992	FY 1992	Actual Year $k							
		($K)	($K)								
WBS	TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.4.1	Neutron Transport	55,908	39,839	1,043	3,953	8,068	12,623	13,962	9,652	2,275	51,575
1.4.2	Neutron Scat Inst	60,441	40,352	1,056	4,004	8,172	12,786	14,141	9,776	2,304	52,239
1.4.3	Nuc & Fund Physics	11,096	3,413	89	339	691	1,081	1,196	827	195	4,418
1.4.4	Trans U Production	21,150	21,012	550	2,085	4,255	6,658	7,364	5,091	1,200	27,202
1.4.5	Materials Irrad. Facility	9,773	8,232	215	817	1,667	2,608	2,885	1,994	470	10,657
1.4.6	Isotope Prodtn Facility	6,634	3,951	103	392	800	1,252	1,385	957	226	5,115
1.4.7	Analytical Chem Fac	33,547	18,446	483	1,830	3,735	5,845	6,464	4,469	1,053	23,880
1.4.8	Instrument Supprt Fac	9,428	5,479	143	544	1,110	1,736	1,920	1,327	313	7,093
1.4.9	Comptr & Data Hndlg	4,492	2,059	54	204	417	652	722	499	118	2,666
1.4.10	Cold Source	17,966	11,810	309	1,172	2,392	3,742	4,139	2,861	674	15,289
1.4.11	Hot Source	1,856	0	0	0	0	0	0	0	0	0
1.4 Experiment Systems		232,290	154,593	4,046	15,339	31,306	48,983	54,177	37,454	8,827	200,133
1.5.1	Land Improvements	41,584	20,838	783	2,954	6,036	8,333	6,583	1,721	0	26,410
1.5.2	Reactor Building	136,569	52,554	1,974	7,449	15,222	21,016	16,604	4,341	0	66,606
1.5.3	React/Opns Suppt	79,161	52,554	1,974	7,449	15,222	21,016	16,604	4,341	0	66,606
1.5.4	GHall/Res Suppt	42,871	30,754	1,155	4,359	8,908	12,298	9,716	2,540	0	38,977
1.5.5	Office/Interface Bldg	32,529	1,090	41	155	316	436	344	90	0	1,381
1.5.6	Detritiation Building	7,704	7,165	269	1,016	2,075	2,865	2,264	592	0	9,081
1.5.7	Other Structures	32,581	8,837	332	1,253	2,560	3,534	2,792	730	0	11,200
1.5.8	Construction Support	21,963	21,963	825	3,113	6,362	8,783	6,939	1,814	0	27,836
1.5 Site & Buildings		394,963	195,755	7,351	27,748	56,700	78,282	61,846	16,168	0	248,096
1.6.0	Plant Systems Integration	2,858	1,225	46	174	355	490	387	101	0	1,553
1.6.1	Reactor Water Systems	115,962	53,370	1,397	5,296	10,808	16,910	18,703	12,930	3,047	69,092
1.6.2	Elec & Comm Systems	121,802	63,647	1,666	6,315	12,889	20,167	22,305	15,420	3,634	82,396
1.6.3	Environmental Systems	69,315	42,445	1,111	4,212	8,595	13,449	14,875	10,283	2,424	54,949
1.6.4	Plant Water Systems	91,437	44,831	1,173	4,448	9,079	14,205	15,711	10,861	2,560	58,037
1.6.5	Plant Service Systems	44,332	28,906	757	2,868	5,854	9,159	10,130	7,003	1,651	37,421
1.6.6	Plant Fire Protection	13,184	5,639	148	559	1,142	1,787	1,976	1,366	322	7,300
1.6.7	Plant Waste Systems	20,248	9,748	255	967	1,974	3,089	3,416	2,362	557	12,620
1.6.8	Heavy Water Dtrn & Upgd	87,385	55,701	1,458	5,527	11,280	17,649	19,520	13,495	3,181	72,110
1.6.9	Plant I, C & Data Systems	93,031	57,166	1,496	5,672	11,576	18,113	20,034	13,850	3,264	74,006
1.6.10	Maintenance & GPE	13,931	2,989	78	297	605	947	1,047	724	171	3,870
1.6 Plant Systems		673,484	365,667	9,585	36,335	74,157	115,964	128,105	88,397	20,810	471,801

LINE ITEM		ANS	HFIR-CNR								
As Spent $k	April 1994 Baseline	FY 1992	FY 1992	Distribution of Costs by Year							
		($K)	($K)	Actual Year $k							
WBS	TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.7.1	Administrative Support										0
1.7.2	Management & Planning										0
1.7.3	Maintenance										0
1.7.4	Health&Safety										0
1.7.5	Training										0
1.7.6	QA										0
1.7.7	Utilities										0
1.7.8	Fuel										0
1.7.9	Replacing Equipt &Mods										0
1.7.10	Security										0
1.7.11	Reactor Operations										0
1.7.12	Rsrch Operations										0
1.7.13	Initial Purchases	8,256	7,020	285	142	0	639	2,655	2,065	3,426	9,211
1.7 Operations		8,256	7,020	285	142	0	639	2,655	2,065	3,426	9,211
1.8.1	DOE Support Subcontrctng	6,530	5,079	133	504	1,029	1,609	1,780	1,231	290	6,575
1.8 DOE Support		6,530	5,079	133	504	1,029	1,609	1,780	1,231	290	6,575
TOTAL		1,737,989	1,039,255	32,995	120,859	240,236	353,334	346,087	195,674	46,455	1,334,086

OPERATING EXPENSE		ANS	HFIR-CNR								
As Spent $k	April 1994 Baseline	FY 1992	FY 1992	Distribution of Costs by Year							
		($K)	($K)	Actual Year $k							
WBS	TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.1.1	Reactor Core Development	13,227	5,034	1,286	1,392	1,274	1,076	669	409	64	6,169
1.1.2	Fuel Development	9,658	8,297	2,162	3,485	2,749	1,112	215	161	83	9,966
1.1.3	Corrosion Tests & Analysis	2,415	1,193	669	585	135	0	0	0	0	1,389
1.1.4	Core Flow Tests	31,761	11,084	1,924	1,896	2,425	3,869	3,696	0	0	13,810
1.1.5	Control Concepts	309	379	126	158	164	0	0	0	0	449
1.1.6	Critical Experiments	6,741	8,249	311	2,667	2,390	3,024	1,864	0	0	10,255
1.1.7	Matrls Data, Tests and Anly	15,177	15,411	3,895	7,504	3,929	2,320	455	330	50	18,484
1.1.8	Cold Source Development	5,756	6,234	1,127	2,411	2,012	1,275	373	251	147	7,595
1.1.9	Beam Tube, Guide, Inst Dev	12,925	13,007	1,030	2,099	3,903	4,336	3,198	1,243	627	16,436
1.1.10	Hot Source Development	2,714	0	0	0	0	0	0	0	0	0
1.1.11	Neutron Tranport & Shldng	586	0	0	0	0	0	0	0	0	0
1.1.12	I&C System Development	1,951	1,806	644	806	377	321	0	0	0	2,147
1.1.13	Facility Concepts	10,102	9,951	3,961	2,802	1,416	1,137	1,707	863	201	12,088
1.1 Research & Development		113,322	80,645	17,136	25,804	20,773	18,469	12,177	3,257	1,172	98,789
1.2.1	Proj Mgmt & Adminstn	9,778	5,412	1,068	1,670	1,397	1,293	886	246	92	6,651
1.2.2	Systems Engineering										
1.2.3	Safety	15,612	15,612	409	1,549	3,161	4,947	5,471	3,782	891	20,211
1.2.4	Envrt & Waste Mgmt	3,080	1,780	1,238	818						2,056
1.2.5	Quality Assurance	3,034	2,428	56	220	466	759	872	626	153	3,152
1.2.6	Training										0
1.2.7	Test & Evaluation										0
1.2 Project Support		31,504	25,232	2,770	4,257	5,024	6,999	7,229	4,653	1,136	32,069
1.3.1	Reactor Assembly										
1.3.2	Refueling										
1.3.3	Reactor I&C										
1.3.4	Fuel										
1.3.5	Reactor Mockup										
1.3.6	Maintenance										
1.3 Reactor Systems											

OPERATING EXPENSE As Spent $k April 1994 Baseline	ANS FY 1992	HFIR-CNR FY 1992	Distribution of Costs by Year							
	($K)	($K)	Actual Year $k							
WBS TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.4.1 Neutron Transport										
1.4.2 Neutron Scat Inst	23,962	0		0	0	0	0	0	0	0
1.4.3 Nuc & Fund Physics	3,938	0		0	0	0	0	0	0	0
1.4.4 Trans U Production										
1.4.5 Materials Irrad. Facility										
1.4.6 Isotope Prodtn Facility										
1.4.7 Analytical Chem Fac	2,855	345		13	51	104	143	113	30	454
1.4.8 Instrument Supprt Fac										
1.4.9 Comptr & Data Hndlg										
1.4.10 Cold Source										
1.4.11 Hot Source										
1.4 Experiment Systems	30,755	345	0	13	51	104	143	113	30	454
1.5.1 Land Improvements										
1.5.2 Reactor Building										
1.5.3 React/Opns Suppt										
1.5.4 GHall/Res Suppt										
1.5.5 Office/Interface Bldg										
1.5.6 Detritiation Building										
1.5.7 Other Structures										
1.5.8 Construction Support										
1.5 Site & Buildings										
1.6.0 Plant Systems Integration										
1.6.1 Reactor Water Systems										
1.6.2 Elec & Comm Systems										
1.6.3 Environmental Systems										
1.6.4 Plant Water Systems										
1.6.5 Plant Service Systems										
1.6.6 Plant Fire Protection										
1.6.7 Plant Waste Systems										
1.6.8 Heavy Water Dtrn & Upgd										
1.6.9 Plant I, C & Data Systems	19,914	11,116		1,037	4,229	6,377	2,390			14,034
1.6.10 Maintenance & GPE										
1.6 Plant Systems	19,914	11,116	0	1,037	4,229	6,377	2,390	0	0	14,034

OPERATING EXPENSE		ANS	HFIR-CNR								
As Spent $k April 1994 Baseline		FY 1992	FY 1992	Distribution of Costs by Year							
		($K)	($K)	Actual Year $k							
WBS	TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.7.1	Administrative Support	7,514	3,708	50	104	217	395	820	1,701	1,764	5,052
1.7.2	Management & Planning	11,343	10,674	368	573	1,588	2,273	2,577	3,340	3,463	14,181
1.7.3	Maintenance	12,319	6,868	0	0	0	470	489	1,715	6,975	9,649
1.7.4	Health&Safety	9,058	6,163	278	288	374	623	1,620	2,521	2,614	8,317
1.7.5	Training	6,825	1,623	0	14	60	181	377	782	811	2,225
1.7.6	QA	9,368	8,680	109	278	771	1,069	2,830	3,271	3,392	11,720
1.7.7	Utilities	3,687	8,476	0	0	0	778	889	922	9,317	11,907
1.7.8	Fuel	30,224	10,233	0	0	0	0	3,019	10,956	0	13,975
1.7.9	Replacing Equipt &Mods		1,000	0	0	0	319	332	344	357	1,352
1.7.10	Security	1,585	1,232	75	104	135	169	234	303	628	1,647
1.7.11	Reactor Operations	48,904	25,596	0	0	979	2,904	7,285	11,727	12,160	35,055
1.7.12	Rsrch Operations	74,086	32,599	0	0	0	3,787	7,868	16,318	16,922	44,894
1.7.13	Initial Purchases		2,400	285	295	147	0	664	2,753	2,141	6,285
1.7 Operations		214,914	119,252	1,164	1,656	4,272	12,969	29,002	56,653	60,544	166,261
1.8.1	DOE Support Subcontrctng	457	356	9	35	72	113	125	86	20	461
1.8 DOE Support		457	356	9	35	72	113	125	86	20	461
TOTAL		410,865	236,945	21,080	32,803	34,422	45,031	51,067	64,763	62,901	312,067

CAPITAL EQUIPMENT As Spent $k April 1994 Baseline		ANS FY 1992 ($K) Total	HFIR-CNR FY 1992 ($K) Total	Distribution of Costs by Year Actual Year $k							
WBS	TITLE			FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.1.1	Reactor Core Development	432	430	205	0	0	319	0	0	0	524
1.1.2	Fuel Development		0	0	0	0	0	0	0	0	0
1.1.3	Corrosion Tests & Analysis		0	0	0	0	0	0	0	0	0
1.1.4	Core Flow Tests	7,626	10,591	0	3,212	6,998	2,772	0	0	0	12,982
1.1.5	Control Concepts		0	0	0	0	0	0	0	0	0
1.1.6	Critical Experiments		0	0	0	0	0	0	0	0	0
1.1.7	Matrls Data, Tests and Anly	3,035	2,215	1,037	722	0	650	244	0	0	2,653
1.1.8	Cold Source Development	100	0	0	0	0	0	0	0	0	0
1.1.9	Beam Tube, Guide, Inst Dev	1,060	1,065	0	0	0	945	431	0	0	1,377
1.1.10	Hot Source Development	3,878	0	0	0	0	0	0	0	0	0
1.1.11	Neutron Tranport & Shldng	105	103	55	0	0	70	0	0	0	125
1.1.12	I&C System Development	770	0	0	0	0	0	0	0	0	0
1.1.13	Facility Concepts	2,001	1,100	305	56	646	331	0	0	0	1,337
1.1 Research & Development		19,007	15,504	1,601	3,989	7,644	5,089	676	0	0	18,998
1.2.1	Proj Mgmt & Adminstn										
1.2.2	Systems Engineering										
1.2.3	Safety										
1.2.4	Envrt & Waste Mgmt										
1.2.5	Quality Assurance										
1.2.6	Training										
1.2.7	Test & Evaluation										
1.2 Project Support											
1.3.1	Reactor Assembly										
1.3.2	Refueling										
1.3.3	Reactor I&C										
1.3.4	Fuel										
1.3.5	Reactor Mockup										
1.3.6	Maintenance										
1.3 Reactor Systems											

CAPITAL EQUIPMENT		ANS	HFIR-CNR								
As Spent $k April 1994 Baseline		FY 1992	FY 1992	Distribution of Costs by Year							
		($K)	($K)	Actual Year $k							
WBS	TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.4.1	Neutron Transport										
1.4.2	Neutron Scat Inst										
1.4.3	Nuc & Fund Physics										
1.4.4	Trans U Production										
1.4.5	Materials Irrad. Facility										
1.4.6	Isotope Prodtn Facility										
1.4.7	Analytical Chem Fac										
1.4.8	Instrument Supprt Fac										
1.4.9	Comptr & Data Hndlg										
1.4.10	Cold Source										
1.4.11	Hot Source										
1.4 Experiment Systems											
1.5.1	Land Improvements										
1.5.2	Reactor Building										
1.5.3	React/Opns Suppt										
1.5.4	GHall/Res Suppt										
1.5.5	Office/Interface Bldg										
1.5.6	Detritiation Building										
1.5.7	Other Structures										
1.5.8	Construction Support										
1.5 Site & Buildings											
1.6.0	Plant Systems Integration										
1.6.1	Reactor Water Systems										
1.6.2	Elec & Comm Systems										
1.6.3	Environmental Systems										
1.6.4	Plant Water Systems										
1.6.5	Plant Service Systems										
1.6.6	Plant Fire Protection										
1.6.7	Plant Waste Systems										
1.6.8	Heavy Water Dtrn & Upgd										
1.6.9	Plant I, C & Data Systems										
1.6.10	Maintenance & GPE										
1.6 Plant Systems											

CAPITAL EQUIPMENT	ANS	HFIR-CNR								
As Spent $k April 1994 Baseline	FY 1992	FY 1992	Distribution of Costs by Year							
	($K)	($K)	Actual Year $k							
WBS TITLE	Total	Total	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	TOTAL
1.7.1 Administrative Support										
1.7.2 Management & Planning										
1.7.3 Maintenance										
1.7.4 Health&Safety										
1.7.5 Training										
1.7.6 QA										
1.7.7 Utilities										
1.7.8 Fuel										
1.7.9 Replacing Equipt &Mods										
1.7.10 Security										
1.7.11 Reactor Operations	1,256	1,194				229	431	468	500	1,628
1.7.12 Rsrch Operations	1,256	1,194				229	431	468	500	1,628
1.7.13 Initial Purchases										
1.7 Operations	2,511	2,388	0	0	0	457	863	936	999	3,256
1.8.1 DOE Support Subcontrctng	43	43	24		26					51
1.8 DOE Support	43	43	24	0	26	0	0	0	0	51
TOTAL	21,561	17,935	1,626	3,989	7,670	5,546	1,539	936	999	22,305

Appendix C

HFIR-CNR SCHEDULE

Individual systems were evaluated for the effect on the schedule of the following:

- reducing the plant power,
- reducing the number of experiments, and
- eliminating several facilities such as the office building, the maintenance support building, and the mockup building.

The project milestones and the schedule by WBS level 3 are indicated in the schedule in this appendix. Reducing the main plant schedule by approximately 25% is appropriate, based on reducing the size of the major facility approximately 33%. Specific reductions and assumptions are summarized in Appendix A.

Other schedule considerations:

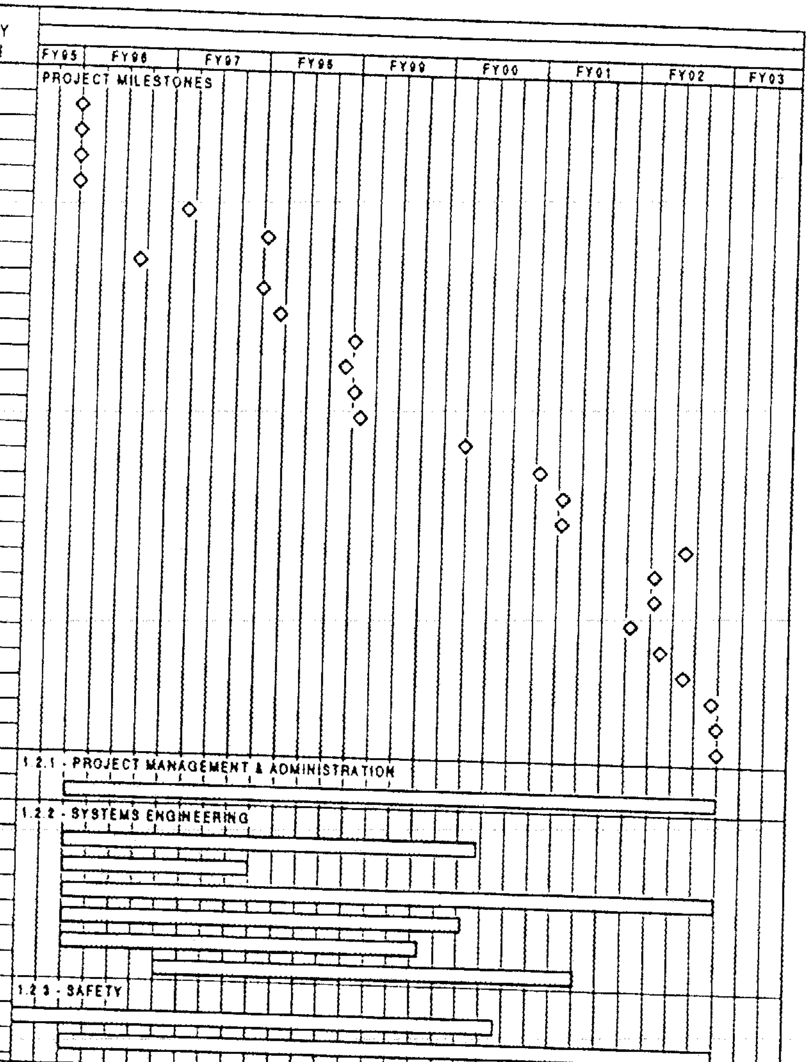
1. Regulatory restrictions on the schedule were eliminated based on establishing a close working relationship and continuous oversight rather than summary reviews at the end of the design.

2. Schedule ties between the main facility and the reactor mockup have been broken because the mockup will not be used to validate reactor vessel components before plant start-up. (It will not be used to validate the reflector vessel configuration; rather, it will be fabricated to the design and the mockup built in parallel for configuration validation after installation of the vessel.)

3. Schedule ties between the main facility and the detritiation facility have been broken because the heavy water will be processed at a non-ANS facility and provided "clean" to ANS.

4. Any contamination on the site or relocation of the waste line will be assumed to be cleaned up by another project before site clearing.

ACTIVITY ID	ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
100001	SCHEDULE START	0	2OCT95	
100014	CONTINUE R AND D	0	2OCT95	
100015	PROJECT AUTHORIZATION/BEGIN TITLE I	0	2OCT95	
100016	INDUSTRIAL TEAM IN PLACE	0	2OCT95	
100017	BEGIN EARLY TITLE II DESIGN	0	5DEC96	
100032	BEGIN PROJECT TITLE II DESIGN	0	15OCT97	
100020	BEGIN LONG LEAD PROCUREMENT	0	4JUN96	
100021	ISSUE PSAR	0		2OCT97
100024	START CONSTRUCTION NON-NUCLEAR	0	12DEC97	
100025	BEGIN TVA FEEDER DESIGN	0	8OCT98	
100026	COMPLETE TITLE I DESIGN	0		31AUG98
100040	DOE REVIEW OF PSAR COMPLETE	0		7OCT98
100045	FIRST NUCLEAR CONCRETE	0	3NOV98	
100047	COMPLETE TITLE II DESIGN	0		24DEC99
100056	COMPL INSTL/ALIGN REFLECTOR VESSEL	0	17OCT00	
100055	COLD SOURCE THIMBLE INSTALLED	0		18JAN01
100061	ISSUE FSAR	0		15JAN01
100062	MAJOR SYSTEMS TESTS COMPLETE	0		16MAY02
100064	DOE APPROVE FSAR/LOW POWER LICENSE	0		18JAN02
100071	DOE AUTHORIZATION TO LOAD FUEL	0	17JAN02	
100072	PROCUREMENT COMPLETE	0		17OCT01
100075	CORE LOAD	0	14FEB02	
100080	INITIAL CRITICALITY	0		16MAY02
100087	LOW POWER TESTING COMPLETE	0		6SEP02
100088	OPERATIONAL TESTING COMPLETE	0		29SEP02
100099	PROJECT COMPLETE	0		30SEP02
120106	CONSTRUCTION MGT SUPPORT	1828	2OCT95	30SEP02
120201	FUEL STORAGE DESIGN/CONFIGURATION M	1162	2OCT95	14MAR00
120202	CONSTRUCTION PLANNING	522	2OCT95	30SEP97
120203	SYSTEMS INTEGRATION	1828	2OCT95	30SEP02
120204	SYSTEMS REQUIREMENTS	1121	2OCT95	17JAN00
120208	SYSTEMS DESCRIPTIONS	1000	2OCT95	30JUL99
120212	OTHER CONSTRUCTION SUPPORT	1177	2OCT96	5APR01
120301	SAFETY CRIT REVIEW AND DEVELOPMENT	1220	2OCT94A	2JUN00
120302	ACCIDENT ANALYSIS	1828	2OCT95	30SEP02



Plot Date 14MAR95
Data Date 2OCT95
Project Start 1APR93
Project Finish 2OCT03

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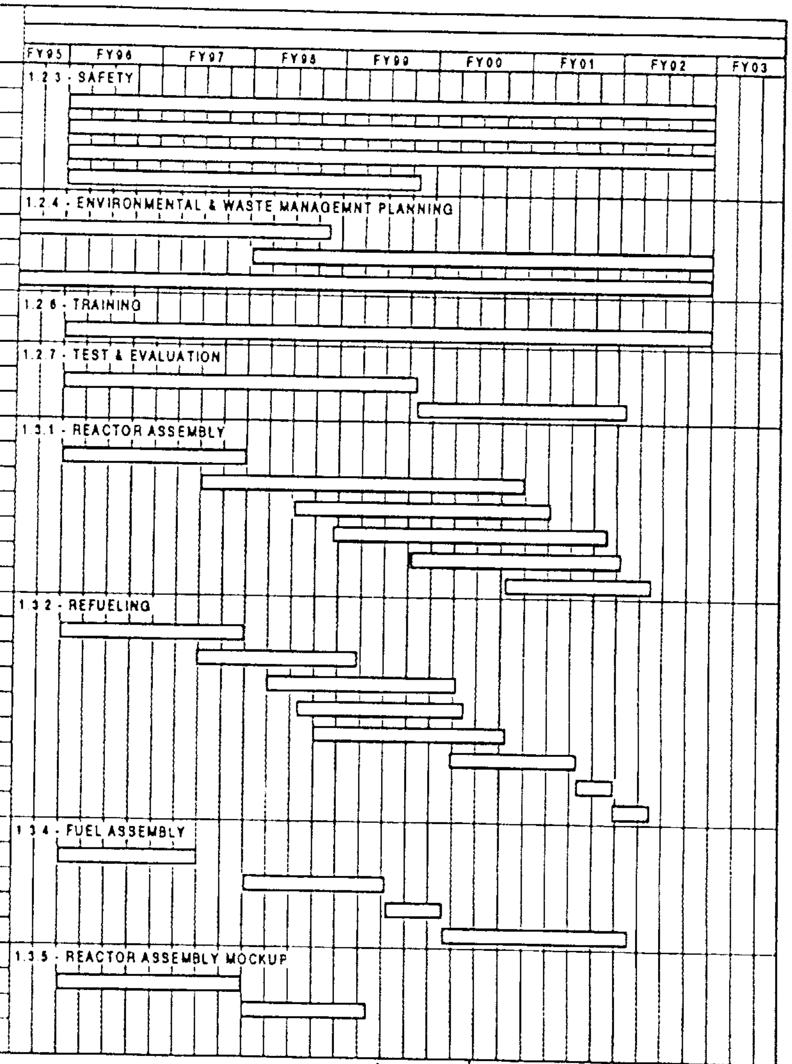
DOE / MARTIN MARIETTA ENERGY SYSTEMS
CENTER FOR NEUTRON RESEARCH
ACCELERATED SCHEDULE

Date	Revision	Checked	Approved

ACTIVITY ID	ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
120303	SAFETY ANALYSIS REPORT(SAR)	1828	2OCT95	30SEP02
120304	PROBABALISTIC RISK ASSESSMENT (PRA)	1828	2OCT95	30SEP02
120305	SEVERE ACCIDENT ANALYSIS	1828	2OCT95	30SEP02
120306	SAFETY REVIEWS	1000	2OCT95	30JUL99
120401	ENVIRONMENTAL PLANNING	1483	4JAN93A	14AUG98
120402	WASTE MANAGEMENT PLANNING	1300	1OCT97	2OCT02
120412	OTHER SYTEMS ENGR SUPPORT	2480	30MAR93A	30SEP02
120610	TRAINING	1828	2OCT95	30SEP02
120701	TEST & EVALUATION PLANNING	1000	2OCT95	30JUL99
120702	TEST & EVALUATION PLANNING	590	2AUG99	2NOV01
130101	TITLE I ENGINEERING	521	2OCT95	29SEP97
130102	TITLE II ENGINEERING	910	4APR97	29SEP00
130103	BID AND AWARD	720	9APR98	10JAN01
130104	VENDOR DESIGN	770	10SEP98	22AUG01
130105	VENDOR FABRICATION	590	15JUL99	17OCT01
130106	CONSTR AND FIELD ENGR SUP	415	17JUL00	15FEB02
130201	TITLE I ENGINEERING	521	2OCT95	29SEP97
130202	TITLE II ENGINEERING	451	27MAR97	17DEC98
130203	BID AND AWARD	532	30DEC97	12JAN00
130204	VENDOR DESIGN	488	1MAY98	11FEB00
130205	VENDOR FABRICATION	538	2JUL98	24JUL00
130206	CONSTR AND FIELD ENGR SUP	353	22DEC99	27APR01
130207	CONSTRUCTION TESTING	104	30APR01	20SEP01
130208	STARTUP TESTING	104	21SEP01	19FEB02
130401	TITLE I ENGINEERING	383	2OCT95	2APR97
130402	TITLE II ENGINEERING	400	1OCT97	18APR99
130403	BID AND AWARD	159	19APR99	29NOV99
130405	VENDOR FABRICATION	520	29NOV99	23NOV01
130501	TITLE I ENGINEERING	521	2OCT95	29SEP97
130502	TITLE II ENGINEERING	352	30SEP97	3FEB99



Plot Date	14MAR96
Data Date	2OCT95
Project Start	1APR93
Project Finish	2OCT02

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Activity Bar/Early Dates
Critical Activity
Milestone/Flag Activity

LV30

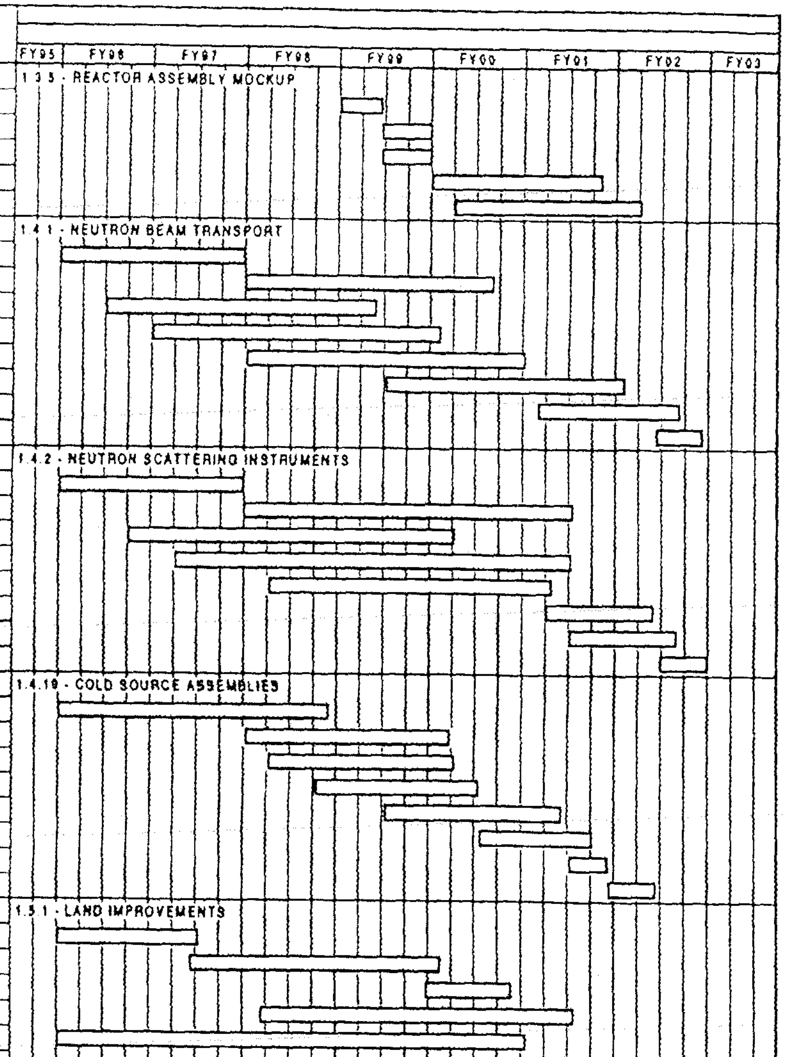
Sheet 1 of 1

DOE / MARTIN MARIETTA ENERGY SYSTEMS
CENTER FOR NEUTRON RESEARCH
ACCELERATED SCHEDULE

12/15/94

Date	Revision	Checked	Approved

ACTIVITY ID	ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
	1.3.5 - REACTOR ASSEMBLY MOCKUP			
130503	BID AND AWARD	120	5OCT98	19MAR99
130504	VENDOR DESIGN	140	22MAR99	1OCT99
130505	VENDOR FABRICATION	140	22MAR99	1OCT99
130506	CONSTR AND FIELD ENGR SUP	480	4OCT99	3AUG01
130508	STARTUP TESTING	525	4JAN00	7JAN02
	1.4.1 - NEUTRON BEAM TRANSPORT			
140101	TITLE I ENGINEERING	521	2OCT95	29SEP97
140102	TITLE II ENGINEERING	700	30SEP97	5JUN00
140103	BID AND AWARD	780	3APR96	2MAR99
140104	VENDOR DESIGN	810	4OCT96	11NOV99
140105	VENDOR FABRICATION	788	7OCT97	16OCT00
140106	CONSTR AND FIELD ENGR SUP	670	14APR99	6NOV01
140107	CONSTRUCTION TESTING	388	4DEC00	10JUN02
140108	STARTUP TESTING	130	11MAR02	9SEP02
	1.4.2 - NEUTRON SCATTERING INSTRUMENTS			
140201	TITLE I ENGINEERING	521	2OCT95	29SEP97
140202	TITLE II ENGINEERING	918	30SEP97	17APR01
140203	BID AND AWARD	917	4JUL96	7JAN00
140204	VENDOR DESIGN	1113	8JAN97	11APR01
140205	VENDOR FABRICATION	765	8JAN98	25JAN01
140206	CONSTR AND FIELD ENGR SUP	300	3JAN01	28FEB02
140207	CONSTRUCTION TESTING	300	6APR01	28MAY02
140208	STARTUP TESTING	132	13MAR02	30SEP02
	1.4.10 - COLD SOURCE ASSEMBLIES			
141001	TITLE I ENGINEERING	781	2OCT95	31AUG98
141002	TITLE II ENGINEERING	577	9OCT97	24DEC99
141003	BID AND AWARD	524	9JAN98	12JAN00
141004	VENDOR DESIGN	460	16JUL98	17APR00
141005	VENDOR FABRICATION	498	16APR99	8MAR01
141006	CONSTR AND FIELD ENGR SUP	315	24APR00	9JUL01
141008	STARTUP TESTING	118	9APR01	7SEP01
141009	FINAL STARTUP/PREOP TESTING	132	10SEP01	12MAR02
	1.5.1 - LAND IMPROVEMENTS			
150101	TITLE I ENGINEERING	400	2OCT95	11APR97
150102	TITLE II ENGINEERING	781	13MAR97	18NOV99
150108	VENDOR FABRICATION	240	23SEP99	23AUG00
150108	CONSTR AND FIELD ENGR SUP	880	12DEC97	28APR01
150112	OTHER ENGR SUPPORT	1318	2OCT95	18OCT00



Plot Date 14MAR95
Data Date 2OCT95
Project Start 1APR93
Project Finish 2OCT02

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Activity Bar/Early Dates
Critical Activity
Milestone/Flag Activity

LY30

DOE / MARTIN MARIETTA ENERGY SYSTEMS
CENTER FOR NEUTRON RESEARCH
ACCELERATED SCHEDULE

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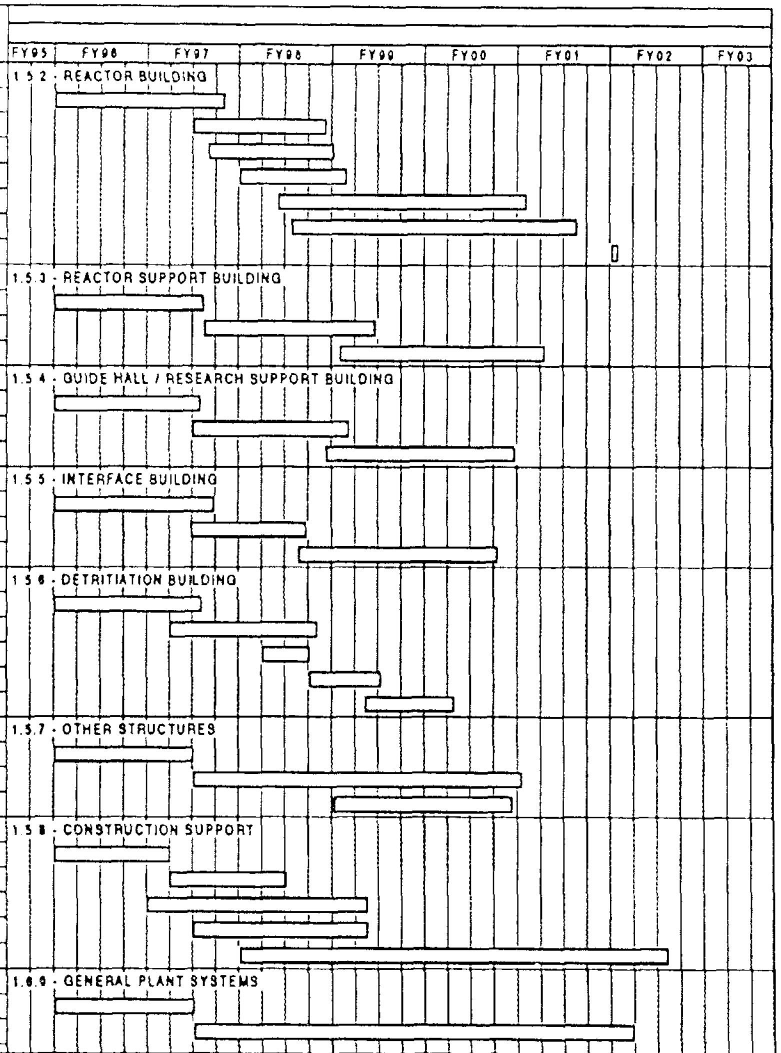
12/15/94

Date	Revision	Checked	Approved

C-5

ACTIVITY ID	ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
	1.5.2 - REACTOR BUILDING			
150201	TITLE I ENGINEERING	491	2OCT95	4AUG97
150202	TITLE II ENGINEERING	375	3APR97	9SEP98
150203	BID AND AWARD	352	4JUN97	9OCT98
150204	VENDOR DESIGN	330	9OCT97	27NOV98
150205	VENDOR FABRICATION	888	9MAR98	9NOV00
150206	CONSTR AND FIELD ENGR SUP	900	1MAY98	24MAY01
150208	STARTUP TESTING	15	12OCT01	1NOV01
	1.5.3 - REACTOR SUPPORT BUILDING			
150301	TITLE I ENGINEERING	425	2OCT95	16MAY97
150302	TITLE II ENGINEERING	482	16MAY97	23MAR99
150308	CONSTR AND FIELD ENGR SUP	574	5NOV98	18JAN01
	1.5.4 - GUIDE HALL / RESEARCH SUPPORT BUILDING			
150401	TITLE I ENGINEERING	415	2OCT95	2MAY97
150402	TITLE II ENGINEERING	443	3APR97	9DEC98
150408	CONSTR AND FIELD ENGR SUP	532	29SEP98	21SEP00
	1.5.5 - INTERFACE BUILDING			
150501	TITLE I ENGINEERING	455	2OCT95	27JUN97
150502	TITLE II ENGINEERING	324	28MAR97	24JUN98
150508	CONSTR AND FIELD ENGR SUP	590	28MAY98	17JUL00
	1.5.6 - DETRITIATION BUILDING			
150601	TITLE I ENGINEERING	413	2OCT95	6MAY97
150602	TITLE II ENGINEERING	418	2JAN97	8AUG98
150603	BID AND AWARD	132	5JAN98	7JUL98
150605	VENDOR FABRICATION	200	8JUL98	13APR99
150608	CONSTR AND FIELD ENGR SUP	250	11FEB99	28JAN00
	1.5.7 - OTHER STRUCTURES			
150701	TITLE I ENGINEERING	395	2OCT95	4APR97
150702	TITLE II ENGINEERING	922	7APR97	17OCT00
150708	CONSTR AND FIELD ENGR SUP	500	13OCT98	11SEP00
	1.5.8 - CONSTRUCTION SUPPORT			
150801	TITLE I ENGINEERING	329	2OCT95	2JAN97
150802	TITLE II ENGINEERING	327	3JAN97	9APR98
150803	BID AND AWARD	820	2OCT96	19FEB99
150805	VENDOR FABRICATION	490	4APR97	19FEB99
150808	CONSTR AND FIELD ENGR SUP	1200	7OCT97	13MAY02
	1.6.0 - GENERAL PLANT SYSTEMS			
160001	TITLE I ENGINEERING	398	2OCT95	7APR97
160002	TITLE II ENGINEERING	1233	8APR97	27DEC01



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Data Date 2OCT95
Project Start 1APR93
Project Finish 2OCT02

Activity Bar/Early Dates
Critical Activity
Milestone/Flag Activity

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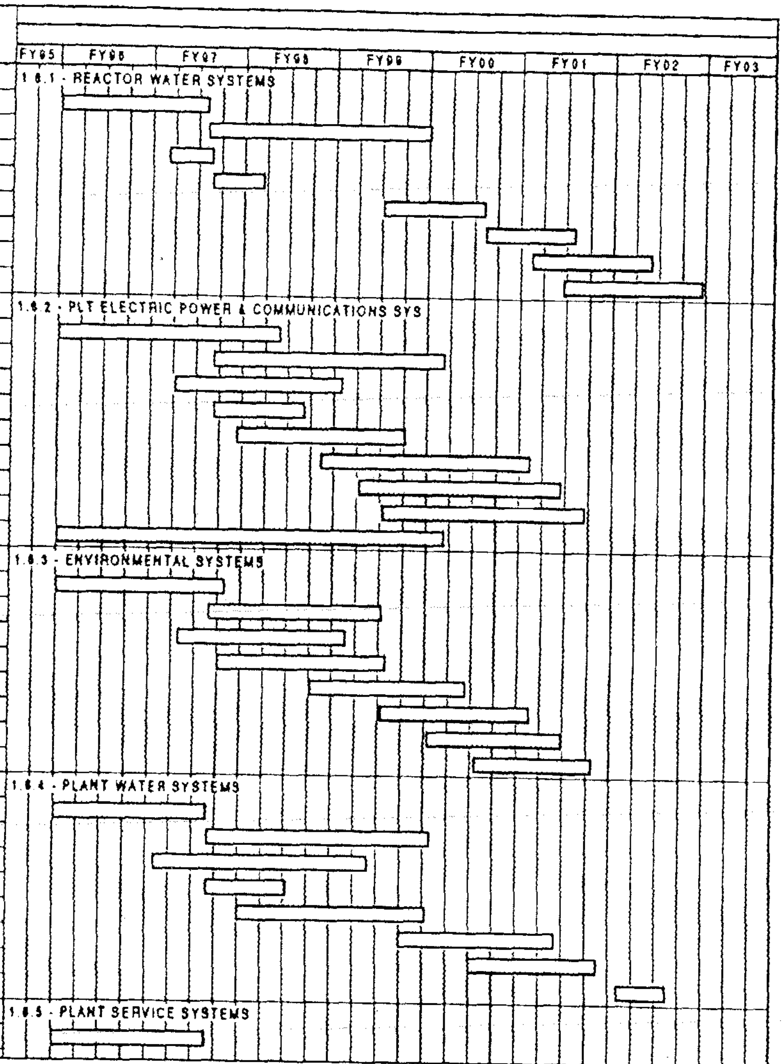
ACTIVITY ID	ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
	1.8.1 - REACTOR WATER SYSTEMS			
180101	TITLE I ENGINEERING	419	2OCT95	7MAY97
180102	TITLE II ENGINEERING	630	8MAY97	8OCT99
180103	BID AND AWARD	124	5DEC96	27MAY97
180104	VENDOR DESIGN	147	28MAY97	18DEC97
180105	VENDOR FABRICATION	280	5APR99	12MAY00
180106	CONSTR AND FIELD ENGR SUP	254	15MAY00	3MAY01
180107	CONSTRUCTION TESTING	339	15NOV00	4MAR02
180108	STARTUP TESTING	393	19MAR01	18SEP02
	1.8.2 - PLT ELECTRIC POWER & COMMUNICATIONS SYS			
180201	TITLE I ENGINEERING	630	2OCT95	27FEB98
180202	TITLE II ENGINEERING	655	9JUN97	10DEC99
180203	BID AND AWARD	477	6JAN97	3NOV98
180204	VENDOR DESIGN	280	9JUN97	5JUN98
180205	VENDOR FABRICATION	478	3SEP97	8JUL99
180206	CONSTR AND FIELD ENGR SUP	580	13AUG98	15NOV00
180207	CONSTRUCTION TESTING	575	5JAN99	19MAR01
180208	STARTUP TESTING	570	12APR99	15JUN01
180212	OTHER ENGR SUPPORT	1096	2OCT95	10DEC99
	1.8.3 - ENVIRONMENTAL SYSTEMS			
180301	TITLE I ENGINEERING	478	2OCT95	30JUL97
180302	TITLE II ENGINEERING	488	30MAY97	13APR99
180303	BID AND AWARD	477	28JAN97	26NOV98
180304	VENDOR DESIGN	478	1JUL97	29APR99
180305	VENDOR FABRICATION	440	8JUL98	10MAR00
180306	CONSTR AND FIELD ENGR SUP	420	14APR99	21NOV00
180307	CONSTRUCTION TESTING	380	18OCT99	28MAR01
180308	STARTUP TESTING	330	18APR00	23JUL01
	1.8.4 - PLANT WATER SYSTEMS			
180401	TITLE I ENGINEERING	424	2OCT95	29MAY97
180402	TITLE II ENGINEERING	530	30MAY97	28OCT99
180403	BID AND AWARD	597	31OCT96	26FEB99
180404	VENDOR DESIGN	227	30MAY97	13APR98
180405	VENDOR FABRICATION	539	1OCT97	12OCT99
180406	CONSTR AND FIELD ENGR SUP	440	25JUN99	5MAR01
180407	CONSTRUCTION TESTING	380	31MAR00	18AUG01
180408	STARTUP TESTING	140	2NOV01	16MAY02
	1.8.5 - PLANT SERVICE SYSTEMS			
180501	TITLE I ENGINEERING	434	2OCT95	29MAY97



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Project Start 1APR93
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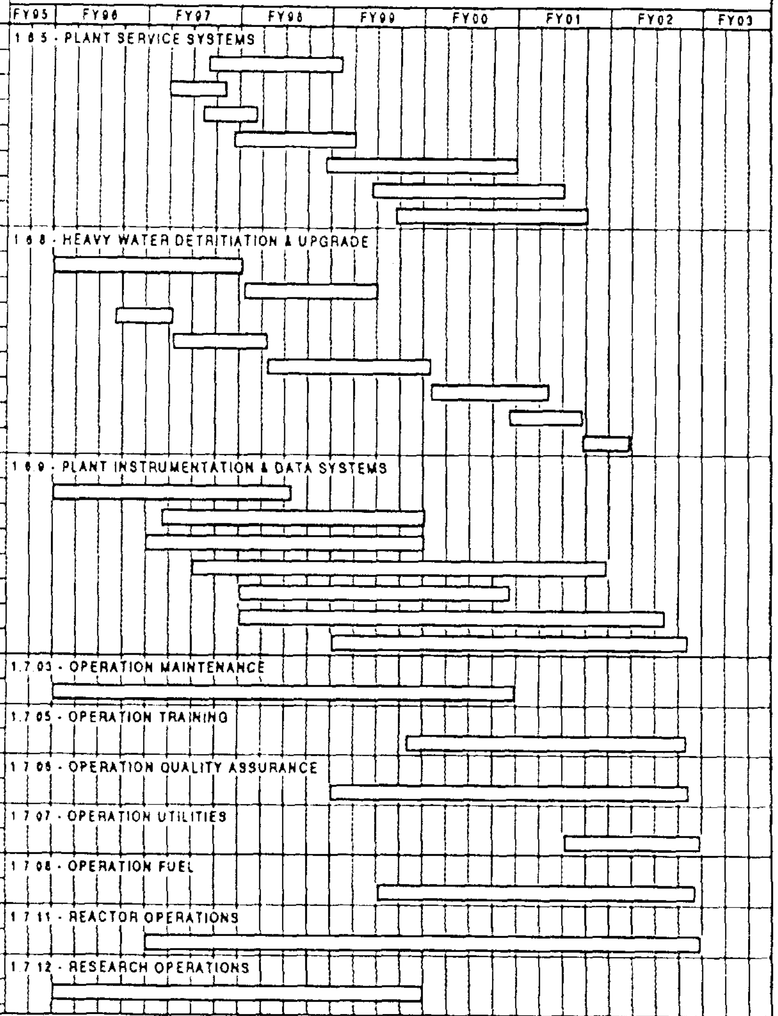
ACTIVITY ID	ACTIVITY DESCRIPTION	ORIG DUR	EARLY START	EARLY FINISH
	1.6.5 - PLANT SERVICE SYSTEMS			
180502	TITLE II ENGINEERING	379	30MAY97	10NOV98
180503	BID AND AWARD	161	27DEC96	8AUG97
180504	VENDOR DESIGN	152	9MAY97	8DEC97
180505	VENDOR FABRICATION	348	9SEP97	4JAN99
180506	CONSTR AND FIELD ENGR SUP	540	9SEP98	30OCT00
180507	CONSTRUCTION TESTING	540	12MAR99	5APR01
180508	STARTUP TESTING	540	14JUN99	6JUL01
	1.6.8 - HEAVY WATER DETRITIATION & UPGRADE			
180801	TITLE I ENGINEERING	532	2OCT95	14OCT97
180802	TITLE II ENGINEERING	378	23OCT97	5APR99
180803	BID AND AWARD	161	4JUN96	14JAN97
180804	VENDOR DESIGN	267	16JAN97	23JAN98
180805	VENDOR FABRICATION	482	23JAN98	1NOV99
180806	CONSTR AND FIELD ENGR SUP	330	2NOV99	5FEB01
180807	CONSTRUCTION TESTING	205	5SEP00	18JUN01
180808	STARTUP TESTING	132	18JUN01	19DEC01
	1.6.9 - PLANT INSTRUMENTATION & DATA SYSTEMS			
180901	TITLE I ENGINEERING	674	2OCT95	30APR98
180902	TITLE II ENGINEERING	741	5DEC96	7OCT99
180903	BID AND AWARD	788	2OCT96	8OCT99
180905	VENDOR FABRICATION	1185	3APR97	18SEP01
180906	CONSTR AND FIELD ENGR SUP	781	8OCT97	4SEP00
180907	CONSTRUCTION TESTING	1200	8OCT97	10MAY02
180908	STARTUP TEST	1000	7OCT98	8AUG02
	1.7.03 - OPERATION MAINTENANCE			
170310	MAINTENANCE	1305	2OCT95	29SEP00
	1.7.05 - OPERATION TRAINING			
170510	TRAINING	764	2AUG99	1AUG02
	1.7.06 - OPERATION QUALITY ASSURANCE			
170610	QUALITY ASSURANCE	1004	6OCT98	8AUG02
	1.7.07 - OPERATION UTILITIES			
170710	UTILITIES	382	10APR01	23SEP02
	1.7.08 - OPERATION FUEL			
170810	FUEL	880	7APR99	3SEP02
	1.7.11 - REACTOR OPERATIONS			
171110	REACTOR OPERATIONS	1590	2OCT96	24SEP02
	1.7.12 - RESEARCH OPERATIONS			
171210	EXPERIMENT OPERATIONS	1043	2OCT95	29SEP99



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Appendix D

SCIENTIFIC INSTRUMENTS

Scientific instruments included in the HFIR-CNR are listed in Table D.1 by WBS number. Also shown is the funding category associated with each instrument. The distribution is consistent with the capabilities of the facility and input from the scientific community.

D.1. Experiment systems instrument list/funding category

Instrument	Instrument Number	Funding category
1.4.2 Neutron scattering instruments		
1.4.2.1 Single-crystal instruments		
Single-crystal diffractometer	T-1	Line item
Single-crystal diffractometer	T-2	Line item
Polarized single-crystal diffractometer	T-3	Line item
Protein crystal diffractometer	L-10	Line item
1.4.2.2 Powder diffractometers		
High-resolution powder diffractometer	T-4	Line item
High-intensity powder diffractometer	T-5	Line item
1.4.2.3 Time-of-flight (TOF) spectrometers		
Time-focusing TOF spectrometer	D-9	Line item
1.4.2.4 Triple-axis spectrometers		
Triple-axis spectrometer	T-11	Line item
Triple-axis spectrometer	T-12	Line item
Triple-axis spectrometer	D-12	Line item
Triple-axis spectrometer	L-8	Line item
1.4.2.5 Small-angle neutron scattering (SANS)		
SANS—10 m	L-1	Line item
SANS—20 m (biology)	D-3	Line item
SANS—40 m	D-4	Line item
1.4.2.7 High-resolution spectroscopy		
Neutron spin echo spectrometer	D-2	Line item
Backscattering spectrometer	L-4	Line item
1.4.2.8 Neutron optical instruments		
Interferometer	L-7	Line item
Reflectometer	D-13	Line item
1.4.2.9 Ultracold neutron (UCN) facilities		

Instrument	Instrument Number	Funding category
UCN turbine converter	V-2	Line item
Neutron storage bottle	U-2	Operating expense
Neutron microscope	U-3	Operating expense
Electric dipole moment	U-4	Operating expense
UCN station	U-5	Operating expense
1.4.2.10 Development scattering instruments		
General purpose area detector	L-3	Operating expense
1.4.3 Nuclear and fundamental physics instruments		
1.4.3.2 Polarized nuclear physics		
Precision gamma-ray bolometer	D-7	Line item
1.4.7 Analytical chemistry facilities		
1.4.7.1 Materials analysis facilities		
Prompt-gamma activation analysis multibeam facility	D-16	Line item
Neutron depth profiling facility	C-2	Line item
Gamma irradiation facility		Operating expense
Positron detectors		Operating expense

Appendix E

PRINCIPAL CONTRIBUTORS

1. Overall guidance and direction	C. D. West/J. E. Cleaves
1.2 Scientific requirements	J. B. Hayter
1.2 Design summary	F. J. Peretz
2. Overall requirements and key design parameters	
2.1 Plant design requirements	R. S. Booth
2.2 Core design parameters	D. L. Selby/G. L. Yoder
3. Reactor systems	
3.1 Reactor assembly	C. C. Queen Jr.
3.2 Refueling and maintenance	K. K. Chipley
3.3 Reactor control	R. E. Battle
3.4 Fuel element assemblies	C. C. Queen Jr.
4. Experiment systems	
4.1 Neutron beam transport	T. J.McManamy
4.2 Neutron scattering instruments	T. J. McManamy
4.3 Nuclear and fundamental physics instruments	T. J. McManamy
4.4 Transuranium production	T. J. McManamy A. E. Williams
4.5 Materials irradiation	T. J. McManamy A. E. Williams
4.6 Isotope production	C. C. Eberle
4.7 Analytical chemistry and positron research	C. C. Eberle
4.10 Cold source	A. Lucas/D. H. Vandergriff
5. Site and buildings	
5.1 General site and buildings	H. B. Shapira W. W. Bowman/N. E. Stone
5.2 Positron spectroscopy facility	C. C. Eberle
6. Plant systems	
6.1 Reactor water systems	G. R. McNutt
6.2 Electrical and communication systems	M. E. Mathews/J. T. Cleveland
6.3 Environmental control	C. W. Parker
6.4 Plant water systems	J. P. Schubert
6.5 Plant service systems	J. P. Schubert
6.6 Fire protection	J. P. Schubert
6.7 Plant waste systems	J. R. Joplin/W. R. Reed
6.8 Heavy water detritiation and upgrade facility	J. R. DeVore
6.9 Instrumentation and data systems	J. E. Cleaves
7. Operations	M. M. Houser/W. E. Hill

8. Research and development	D. L. Selby
9. Safety and regulatory compliance	D. L. Moses/R. M. Harrington
10. Quality assurance	M. L. Gildner
11. Summary cost estimate	R. L. Johnson
12. Summary schedule	R. A. Brown

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