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IFMIF
International Fusion Materials Irradiation Facility Conceptual Design Activity Cost Report

Compiled by M.J. Rennich
Oak Ridge National Laboratory

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LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
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IFMIF
International Fusion Materials Irradiation Facility
Conceptual Design Activity
Cost Report

IFMIF CDA Team

Report compiled by

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Oak Ridge, Tennessee, U.S.A.

An activity of:
The International Energy Agency (IEA)
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Preface

The IFMIF cost report documents the estimate for the International Fusion Materials Irradiation Facility described in the Conceptual Design Activity Final Report. It was jointly prepared by the design team and has substantial input from the participating institutes and industry representatives from the collaborating countries. The costing data was not changed or edited during the compilation of this document without the concurrence of the originating party.

The results of the IFMIF CDA are documented in a set of two reports:

"IFMIF- International Fusion Materials Irradiation Facility, Conceptual Design Activity, Final Report", IFMIF-CDA Team edited by M. Martone, ENEA Frascati Report, RT/ERG/FUS/96/11 (December, 1996)

"IFMIF- International Fusion Materials Irradiation Facility, Conceptual Design Activity, Cost Report", IFMIF-CDA Team compiled by M. J. Rennich, ORNL/M-5502 (December, 1996)

A complete list of the project documentation is included in the final report.

Table of Contents

Acronyms and Definitions

1.0 Introduction
- 1.1 Cost Summaries
- 1.2 Integration of an International Cost Estimate

2.0 Costing Methodology
- 2.1 Scope
- 2.2 Organization
- 2.3 Costing Structure
- 2.4 Costing Techniques
- 2.5 Allowance for Indeterminates
- 2.6 Industrial Participation
- 2.7 Personnel Costs
- 2.8 Siting Considerations
- 2.9 Items Not Included in Cost Estimate
- 2.10 Cost Estimate Verification
- 2.11 Shortcomings in Cost Estimate

3.0 Cost Estimate Format
- 3.1 Worksheets
- 3.2 Explanation of Cost Categories
- 3.3 Explanation of Cost Rows

4.0 Cost Estimate Definitions
- 4.1 Project Management (WBS 1.0)
- 4.2 Facility Design and Construction (WBS 2.0-6.0)
- 4.3 Startup and Commissioning (WBS 7.0)
- 4.4 Operating Costs

5.0 Cost Estimate Analysis
- 5.1 Distribution of Costs by WBS
- 5.2 Distribution of Costs by Type
- 5.3 Allowance for Indeterminates
- 5.4 Industrial Participation
- 5.5 Expenditure Location
- 5.6 Management Distributions

References

Appendices
- A Summary Cost Estimate
- B Work Breakdown Structure (WBS)
- C Annual IFMIF Operating Costs
- D Cost Estimating Worksheets

Acronyms and Definitions

- AFI: Allowance for Indeterminates
- CDA: Conceptual Design Activity
- Conventional Facilities: The balance of plant elements grouped under WBS 2.5
- Ecu: European Currency Units
- EDI: Engineering Design and Inspection
- FMIT: Fusion Materials Irradiation Test
- ITER: International Thermonuclear Experimental Reactor
- ICF: IFMIF Currency Factor; the unit of accounting used uniquely in this estimate.
- Off-site: Activities and charges occurring away from the IFMIF facility.
- On-site: Activities and charges occurring at the IFMIF facility.
- Operating Costs: The cost of operating the facility after the completion of the construction project. These costs do not show in the TPC.
- TEC: Total Estimated Cost: A summary estimate which includes the cost of design, fabrication, testing, installation and all project management costs from project approval to the beginning of facility startup and commissioning.
- Technical Facilities: The major process facilities of IFMIF; Test, Target, Accelerator and Central I&C.
- TPC: Total Project Cost: A summary estimate which includes the TEC as well as development and, startup and commissioning costs. The CDA costs are not included
- WBS: Work Breakdown Structure; complete listing in Appendix 5-A

1.0 Introduction

This report documents the cost estimate for the International Fusion Materials Irradiation Facility (IFMIF) at the completion of the Conceptual Design Activity (CDA). The estimate corresponds to the design documented in the Final IFMIF CDA Report [1].

In order to effectively involve all the collaborating parties in the development of the estimate, a preparatory meeting was held at Oak Ridge National Laboratory in March 1996 to jointly establish guidelines to insure that the estimate was uniformly prepared while still permitting each country to use customary costing techniques. These guidelines are described in Section 4.

A preliminary cost estimate [2] was issued in July, 1996 based on the results of the Second Design Integration Meeting, May 20-27, 1996 at JAERI, Tokai, Japan. This document served as the basis for the final costing and review efforts culminating in a final review during the Third IFMIF Design Integration Meeting, October 14-25, 1996, ENEA, Frascati, Italy.

The present estimate is a baseline cost estimate which does not apply to a specific site. A revised cost estimate will be prepared following the assignment of both the site and all the facility responsibilities.

1.1 Cost Summaries

1.1.1 Construction Cost Estimate Summary

The following costs summarize the important budgetary numbers in the estimate. A more detailed summary of the cost estimate is provided in Appendix A which also includes various charts which compare and analyze the cost data. Information about the currency units and how the elements are defined and costed is included in the description below.

WBS	System	TEC Estimate
1.0	Project Management	52,000 kICF
2.0	Test Facilities	107,000
3.0	Target Facilities	115,000
4.0	Accelerator Facilities	409,000
5.0	Conventional Facilities-EU/US [JP]	90,000 [195,000]
6.0	Central Control and Common Instr.	24,000
Total Estimated Construction Cost (TEC):		797,000
7.0	Start-up and Commissioning	63,000 (avg.)*
	Engineering Validation Phase	49,000
Total Project Cost (TPC):		910,000

* Differences in electric power costs result in a range of start-up and commissioning estimates between 54,000 and 79,000 kICF

The TEC includes a total Allowance for Indeterminates of 168,000 kICF or 27% of the TEC; the base TEC is therefore 629,000 kICF.

1.1.2 Operating Cost Estimate

The estimated cost of operating the IFMIF facility in a normal year including electric power, utilities, maintenance and miscellaneous costs associated with operating the facility will be between 56,000 and 78,000 kICF. The electric power and personnel costs dominate the total number and only the differences in electric power result in the range of site costs.

1.2 Integration of an International Cost Estimate

The IFMIF cost estimate was prepared jointly by the collaborating countries for a generic site within a project defined schedule. Consequently, the costs do not apply to a specific site or country. However, the goal of providing a comprehensive base estimate on which a specific estimate could be prepared was accomplished. In particular, the division of the work packages and the costing assumptions have been carefully documented along with the costs, enabling each participant to analyze costs based on local considerations.

In order to evaluate the differences between countries a few elements were costed by more than one country, notably the accelerator, conventional facilities and operating costs. Based on these cost comparisons it appears that the cost of manufactured items including complex one-of-a-kind machinery is driven by international competition among industrial firms. Therefore, the cost of procured items such as power supplies, accelerator and target components and test cell equipment can be estimated by different countries within a similar range of uncertainty. On the other hand, the cost of conventional construction and operation is more difficult to generalize since each country must satisfy national requirements for building codes and standards, safety and environmental considerations and rules for construction of facilities on government sites. As a result of this difference, a separate Japanese cost estimate for the conventional facilities is appended to the base estimate which is more representative of the cost of these facilities in the US or EU. The operating and start-up and commissioning estimates also include a range of electric power costs to account for differences in siting.

2.0 Costing Methodology

2.1 Scope

Costs have been developed for the IFMIF project over its entire cycle beginning with the Engineering Validation Phase (EVP) scheduled for 1997, through facility construction, startup and plant commissioning. The anticipated cost of normal annual operations has also been estimated.

2.2 Organization

2.2.1 Work Breakdown Structure (WBS)

All project costs, except operation and decommissioning estimates, are organized in accordance with the IFMIF WBS attached in Appendix B. The WBS listing was completed to the most detailed level possible to insure that the estimate is both comprehensive and does not include overlap between Facilities. Costing was performed at the WBS level determined appropriate by the estimating group, usually levels four or five, and summarized at level three.

2.2.2 Project Schedule

The preliminary IFMIF master schedule developed for the CDA as shown in Figure 2-1 was used as the time basis for the estimate. Recognizing the effect of regulatory/licensing requirements on program cost, the master schedule was configured to contain suitable time to obtain approval for IFMIF.

A key provision included in the schedule assumes approval to begin the bidding process for major contracts, particularly the accelerator, one year ahead of final project approval in CY-2000. This advanced effort will save approximately one year in the overall project timetable.

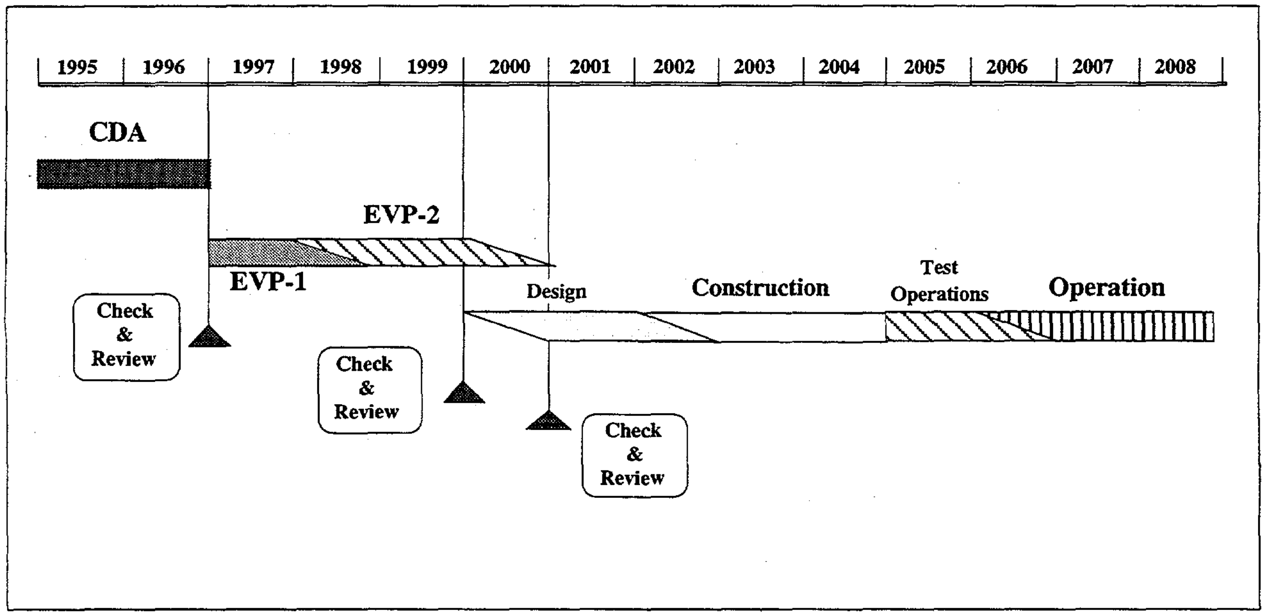

Figure 2-1. Top Level IFMIF Construction Schedule.

2.2.3 Coordination

The cost estimate incorporates information from all parties and provides a summary reference cost for planning and budgeting in all the collaborating countries based on coordinated, common cost input. Thus, while each party developed costs using customary internal methods, a common-format detailed worksheets were used to report costs. The worksheets are attached as Appendix D .

2.2.4 Costing Responsibilities

The cost estimate has input from all parties as described in Table 2.2-1. In most cases, individual items of the cost estimate were not estimated by more than one party; however, top level cross checking was completed as previously described.

Table 2-1. General costing responsibilities.

Project Management	(WBS 1.0)	All parties
Test Facilities	(WBS 2.0)	European Union
Target Facilities	(WBS 3.0)	Japan
Accelerator Facilities	(WBS 4.0)	United States
Conventional Facilities	(WBS 5.0)	EU/US
Central Cont. and Instru.	(WBS 6.0)	Japan
Startup & Commissioning	(WBS 7.0)	All parties
Operating Costs		All parties

2.3 Costing Structure

2.3.1 Accounting

Each party reported costs in US dollars or the local currency; for example the Europeans used European Currency Units (Ecu's). To provide a uniform cost summary, the estimates from the Facility groups were converted to a unit unique to this estimate called the IFMIF Conversion Factor (ICF). Conversions for the local currencies as of January 1996 are shown in Table 2.3-1.

Table 2-2. Currency conversion factors

1 ICF	= 1.00 U.S. $	(Jan 1996)
	= 105 ¥	(Jan 1996)
	= 0.807 Ecu	(Jan 1996)

2.3.2 Inflation

The cost estimate is reported in January 1996 currency values, inflation is not considered.

2.4 Costing Techniques

Estimators, in general, used four basic types of estimating techniques:

Industrial: Detailed quotes or industrial estimates based on exact equipment specifications or requirements. Approximately 75% of the technical facilities were estimated by industry.

Scaling: The use of known costs for existing equipment and adjusting the costs to account for different sizes, years of construction etc. to estimate costs for items such as buildings, hot cells, ventilation systems, offices, site preparation and utilities. Roughly 10% of the estimate was completed using this estimate

Factoring: The use of percentages of known equipment or labor costs to estimate contingency and personnel costs such as project management and construction management which amount to approximately 10% of the estimate.

Engineering Judgment: Educated guesses were used for the remaining 5% of the estimate for which the other estimating techniques were not possible. For example, the cost of maintenance during the two years of startup and commissioning is impossible to derive quantitatively at this stage of the project.

2.5 Allowance for Indeterminates

IFMIF is in the earliest stages of design, consequently there are assumed to be many unknowns, thus each Facility group provided an additional cost referred to as the Allowance for Indeterminates (AFI) based on such factors as:

(i) design maturity,
(ii) technological risk,
(iii) historical cost growth in estimates performed at the conceptual design phase.

AFI was applied in the manner customary to the estimating party, at the lowest level possible to prevent subsequent doubling of AFI when summarizing costs across WBS elements. For example, where factoring was used to derive costs, notably Project Management, AFI was not added again since the base numbers included the allowance.

2.6 Industrial Participation

The estimate reflects the decision that virtually all design, fabrication and installation functions will be performed by commercial companies operating under the direction of the responsible government sponsored institutes. This approach recognizes that, in general, the IFMIF design is based on conventional or proven technologies which can be easily procured from several vendors. It also provides for the most cost efficient method of building the facility through established design-to-cost and procurement-to-cost techniques. The funding implication of this division of is tracked at all levels of the estimate.

2.7 Personnel Costs

Personnel labor costs appear primarily in two places in the cost estimate. First, industrial labor used to manufacture and assemble facility components and construct the facility. And Second, technical staff required to startup and operate the facility. Of necessity, each has been treated differently.

2.7.1 Manufacturing and Assembly Labor

In keeping with the division of the estimate into separate facilities which are fully estimated inaccordance with the procedures customary for the responsible party, the industrial labor rates are specific to the individual countries involved. This allowed each party to evaluate total fabrication costs within the framework customary to that country and avoided the confusion resulting from imposing an international standard for specific types of labors.

2.7.2 Startup and Operating Personnel

Since a site has not been designated, all the parties contributed to the startup and operating cost estimates. Specifically, each party provided annual rates for a designated list of personnel from which average rates were computed as shown in Table 2-3. The unit cost for characteristic types of personnel (i.e. technicians, managers, engineers and maintenance shop labor) includes all burdens and overheads. The US figures are based on rates at Oak Ridge National Laboratory and those used by Northrop Grumman in similar estimates. The EU rates were provided by Frascati and FZK, and the Japanese rate by JAERI. Since the labor rates for all the countries are comparable within the accuracy of the overall estimate a single average rate structure was used for Project Management, Operations and Startup & Commissioning.

Table 2.3. Average Annual Personnel Costs (Jan 96 kICF)

	Rate (kICF/yr)				
	US	Japan	Italy	Ger.	**Average**
Administration					
Plant Manager	195	234	198	152	**195**
Office Support	50	144	91	88	**93**
Engineers					
Engineers	173	165	154	152	**161**
Technicians	150	145	154	121	**143**
Operations					
Shift Superintendent	149	187	154	152	**161**
Central Control Operators	94	144	154	121	**128**
Plant Operators	94	119	91	121	**106**
Plant Protection	94	119	91	121	**106**
Safety Officer	164	144	154	152	**153**
HP Technicians	156	119	154	121	**137**
Maintenance					
Maintenance Manager	111	178	154	152	**149**
Shop Labor	92	119	91	88	**98**
Experimental Operations					
Hot Cell Operators	94	119	91	88	**98**
Data Acquisition	111	144	154	88	**124**

2.8 Siting Considerations

The cost estimate structure segragates work performed “on-site” in the host country from work which could be done “off-site” in other countries or locations. This arrangement, shown in Figure 2-2 represents an extreme case in which the maximum amount which could be spent “off-site” is established. In a more realistic scenario, the host country would center work at the designated site out of convenience, thus the amount of “on-site” expense will probably be higher than that shown in this cost study.

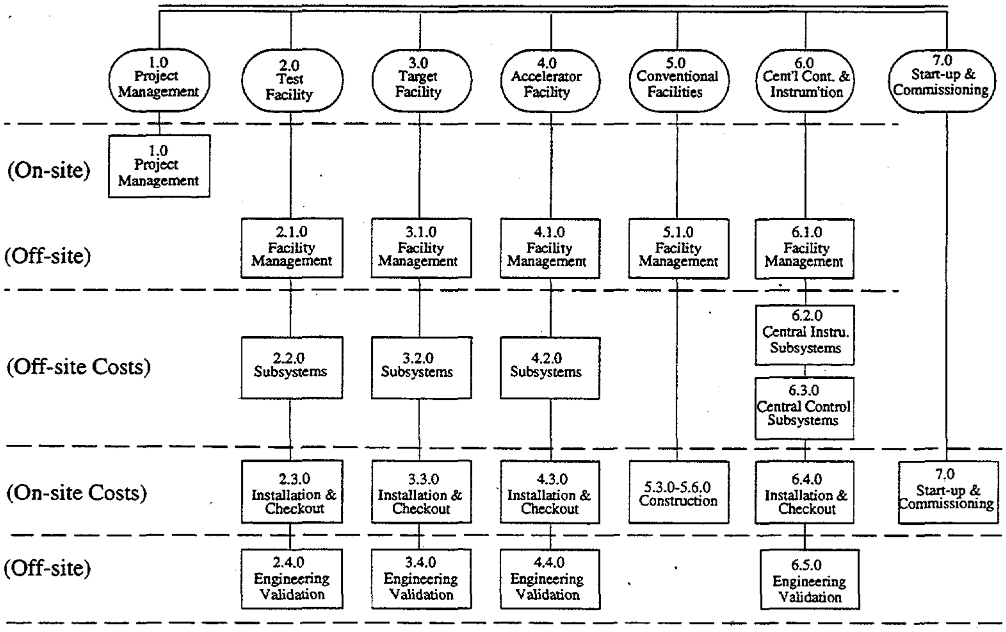

Figure 2-2. Cost Estimate Structure showing separation of off-site and on-site costs.

2.8.1 Site Specific Costing

Different sites may have significant variations in construction and operating costs. The cost drivers depend on elements which cannot be easily normalized, such as licensing, labor, electricity and utilities, and to a lesser extent the cost of contaminated waste disposal. The segregation of on and off site costs will ultimately allow for a reasonable determination of a more accurate site specific cost estimate. This division will also enable the design team to more easily develop future cost estimates following official site selection.

2.8.2 Site Support Assumptions

The cost estimate is based on locating IFMIF within an existing nuclear research facility. This assumption presumes that certain basic support functions are available through the central infrastructure of the parent facility and are therefore not included in the IFMIF construction or operations costs as separate items. The costs for these services are assumed to be included in the "overhead" burden applied to the operating personnel costs (~48%). These include:

- Fire protection,
- Security management (but not on-site guards),
- Procurement,
- Accounting and budgeting,
- Computing and networks,
- Shipping and receiving control,
- Plant engineering,
- Waste management,
- Waste processing facilities, and
- Governmental interface.

The cost of procuring additional services from the parent facility (e.g., design engineering, computer repair) are costed under "Miscellaneous" in the operating budget.

2.9 Items Not Included In Cost Estimate

Items not included in the estimate are:

- The cost of land is not included because the host is assumed to provide the land.
- The costs of various services to the boundary of the site and associated land, such as roads, water, electricity, sewers, are not included because the host is assumed to provide such services. Such services on the site are included in the estimate in WBS 5.
- The direct costs associated with the regulatory process, i.e., preparing the required reports in the native language, reviewing the reports and obtaining the necessary approvals, are not included.
- The costs for disposing of IFMIF operational wastes (except high level radioactive material) once they leave the site are not included in the operations cost.
- Costs associated with decommissioning and disassembly of the IFMIF after it has completed its operational life are not considered.

2.10 Cost Estimate Verification

2.10.1 Referencing to Existing Facility Costs

The most reliable sources of information for verifying the IFMIF cost estimate are the actual costs incurred in the construction of similar facilities. The ITER cost estimate has many of this type of cost factors for major elements such as buildings, waste management, site preparation etc. In addition, FZK has recently completed a hot cell facility similar to that proposed in IFMIF thus providing a reliable cost comparison for this portion of this portion of the facility.

2.10.2 Referencing to FMIT Cost Estimate

A facility similar to IFMIF, the Fusion Materials Irradiation Test (FMIT), was partially completed before being terminated in 1984. The cost estimate and actual costs of that facility are only slightly relevant to IFMIF because significant physical and operating differences added to the 12 year time lapse make cost comparisons very difficult and tenuous, consequently, a cost comparison was not completed.

2.11 Shortcomings of the Cost Estimate

The final cost estimate has three weaknesses of which the most important is that it is based on a conceptual design with all the unknowns inherent to that level of understanding. This problem has been compensated with the use of added Allowance For Indeterminates (AFI) based on historical data. A second weakness, the limited amount of cross-checking between facility groups, results from the minimum amount of funding available to accomplish the CDA activities. Independent, top-level reviews by other groups served as a modest substitute for complete, duplicate estimates. Finally, a full analysis of labor rates has not been completed. This reflects the directive to have each country estimate using domestic rates; however, it also opens the possibility of significantly different overhead and burden assumptions at the detailed level of the estimate. Given the nature of these shortcomings, the CDA estimate is considered to be a good basis for planning and preparation of the construction project.

3.0 Cost Estimate Format and Results

The overall IFMIF cost estimate is documented in two forms; first costs are accumulated in a spreadsheet format as summarized in Appendix A "Summary Cost Format" . Second, the individual costs for each row of the estimate are documented in detailed worksheets as provided in Appendix D and described in Section 3.1 below. Figure 3-1 shows the standard spreadsheet format used to categorize costs. Note that the sheet follows the requirements to segment off-site and on-site costs; industry and institutional costs; allowance for indeterminates (AFI); management and engineering validation.

3.1 Worksheets

Standard form worksheets where prepared by the responsible parities at levels 3, 4 and 5 as appropriate. The worksheets are linked to the summary cost sheet to enable direct tracking of costs by a single tabular row in the same format as the spreadsheet. The rest of the worksheet provides information to capture lower level costs and the details of the content and approach, employed to reach the final figures. The standard worksheet format is as follows:

A. Summary Cost Estimate:

A single costing row in the format of the overall spreadsheet appears at the top of the worksheet. The WBS level of the entry is identified at the top of the sheet and the currency units are identified under the row.

B. Description:

A written description of the items included in the element being costed is provided. This includes as much quantitative information such as sizes, quantities and materials as practical. Special considerations and procedures may also be identified.

C. Detailed WBS Listing:

A continuation of the WBS at levels below the subject row is provided. The additional detail has been added to the overall IFMIF WBS.

D. Costing Rational:

An explanation of how all costs were derived (scaling, factoring, bottoms-up or engineering judgment) and the origin of the basic cost numbers used (e.g. industrial quote, previous construction, reference book, catalogue). The Allowance For Indeterminates (See Section 4.3.2 below) factor used may also be explained.

E. Detailed Costing:

As much of the detailed costing data as required to explain the costs to an independent reviewer is included.

3.2 Explanation of Costs

The top level costs of the IFMIF Cost Estimate are tabulated in the Introduction and defined in Figure 3-1 and as follows:

- The Total Estimated Cost (TEC) includes the cost of design, fabrication, testing, installation and all project management costs from project approval to the beginning of facility startup and commissioning.

- The Total Project Cost (TPC) includes the TEC as well as development and, startup and commissioning costs. The CDA costs are not included

- The lower level cost categories are explained in Section 4.0 below

		Total Project Cost (TPC)															
		Total Estimated Capital Cost (TEC)															
				Off-IFMIF Site					On-Site At IFMIF								
				Industry		Instit'al			Const. Contractor		Instit'al						
		Proj Man.	Facil. Manag.	Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total		EVP	St&Comm	
WBS	Element	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
1.0	Proj. Managem't	TBE	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	=a	TBE	nc	=n+m
2.0	Test Facilities	nc	TBE	TBE	TBE	TBE	TBE	=c+d+e+f	TBE	TBE	TBE	TBE	=h+i+j+k	=b+g+l	TBE	nc	=n+m
3.0	Target Facilities	nc	TBE	TBE	TBE	TBE	TBE	=c+d+e+f	TBE	TBE	TBE	TBE	=h+i+j+k	=b+g+l	TBE	nc	=n+m
4.0	Accelerator Facil's	nc	TBE	TBE	TBE	TBE	TBE	=c+d+e+f	TBE	TBE	TBE	TBE	=h+i+j+k	=b+g+l	TBE	nc	=n+m
5.0	Convent'l Facil's	nc	TBE	nc	nc	nc	nc	nc	TBE	TBE	TBE	TBE	=h+i+j+k	=b+l	TBE	nc	=n+m
6.0	Central I&C Syst's	nc	TBE	TBE	TBE	TBE	TBE	=c+d+e+f	TBE	TBE	TBE	TBE	=h+i+j+k	=b+g+l	TBE	nc	=n+m
7.0	Startup	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	TBE	=o
														TEC			TPC

Abreviations

nc No Cost in this element

TBE To Be Estimated by Facility Groups

AFI Allowance for Indeterminates

Figure 3-1. Detail structure of IFMIF cost estimate spreadsheet.

4.0 Cost Estimate Definitions

This section describes major elements of the cost estimate as tabulated in the WBS and summary format.

4.1 Project Management and Administration (WBS 1.0)

This element includes all project management costs for the management, administration and control of the overall project (column “a” in Figure 3-1). The management of the Facility design, testing and installation activities are included in the Facility costs. The management team will begin to form in 1998 and disband following Commissioning. The peak employment years will be between Project Approval at the beginning of the year 2000 and the completion of the major construction elements at the end of the year 2004. Note, project management is considered an "on-site" cost since it is assumed that it will be performed in the host country.

This element includes the following items:

- Project Management and Administration: includes costs for activities such as overall administration, cost control and scheduling, and documentation. Also included are administrative support, meetings, and publications.
- Systems Engineering: costs for engineering beginning after the IFMIF is approved as an official project required to ensure the facility functions are properly coordinated including interfaces, RAM and safety.
- Environmental, Safety and Health (ES&H): includes cost of personnel responsible for establishing and maintaining procedures in accordance with the regulations of the country responsible for the Facility.
- Quality Assurance (QA): includes cost of personnel responsible for establishing and maintaining a quality assurance program for the overall project.
- Construction Management; coordination of construction activities for all Facilities, development of construction specifications, oversight of contracts. It is assumed that the construction management activities will be performed by a commercial contractor.

The history of large projects shows that all Management and Administration costs, including WBS 1.0 and related costs in each Facility WBS X.1.0, should be between 10 and 15% depending on the complexity of the project. For IFMIF the reduced technical complexity is somewhat off-set by the difficulties of coordination of an international facility. Consequently, the total factor is assumed to be approximately 12.0% of the TEC. Thus, since the individual facilities estimates included a factor of 5.5% of the total the remaining 6.5% was assigned to WBS 1.0. The specific management costs for each Facility are detailed in the appropriate worksheets.

4.2 Facility Design and Construction (WBS 2 through 6)

Each of the four WBS elements describing the Technical Facilities of IFMIF include subelements for program management, subsystems, installation and checkout and subsystem development. The scope and content of each of these subelements is described below. Because the WBS structure for the Technical Facilities is uniform at level 2; all the elements at that level are discussed together.

4.2.1 Facility Management (WBS X.1)

All the management activities required to directly support and complete each Facility are included in this element (column “b” in Figure 3-1). The facility management staff is also expected to coordinate all activities with the overall project management staff (WBS 1.0). The subelements are the same as WBS 1.0 and have the same description as applies to the individual facility.

- Project Management and Administration: basic management costs such as administration, cost control and scheduling, and documentation. Under each of these categories factors such as administrative support, meetings, and publishing are included.

- Systems Engineering: costs for Engineering after the IFMIF is approved as an official project will be estimated based upon anticipated activities needed to support the procurement of elements of the Facility. Engineering will include the following elements:

    - preparation of major system specifications,
    - preparation of preliminary design documentation,
    - vendor and contractor oversight,
    - verification testing oversight,
    - installation planning and coordination,
    - installation oversight,
    - startup oversight.

- Environmental, Health and Safety Documentation: support for personnel responsible for establishing and maintaining procedures in accordance with the regulations of the country responsible for the Facility.

- Quality Assurance: support for personnel responsible for establishing and maintaining the quality assurance program for the individual facility. Also included will be activities to coordinate the QA program will the project office.

4.2.2 Technical Facility Design, Fabrication, Installation and Testing (WBS X.2)

This element includes the cost for work begun following project approval and performed off-site. It includes the following items:

Column "c" [Industry Mat'l/Lab.]:
- material,
- equipment fabrication,
- fabrication labor,
- factory assembly labor,
- factory verification testing,
- shipment to the IFMIF site,
- special maintenance systems

Column "d" [Industry Engin'g]:
- vendor provided design engineering,
- vendor provided inspection engineering,

Column "e" [Institutional Engin'g]:

- Manpower (engineering, labor and technical) provided by the responsible institute presented in currency units rather than hours.

Column "f" Allowance for Indeterminates [AFI]:

An Allowance for Indeterminates (AFI)is added to account for:
(i) design maturity,
(ii) technological risk,
(iii) historical cost growth in estimates performed at the conceptual design phase.

Column "g" [Total]:

The total of columns c, d, e and f should give all costs associated with the off-site fabrication, testing and design of the technical facilities.

4.2.3 Installation and Checkout (WBS X.3)

This element includes all work to install and perform verification testing of the individual technical facilities at the IFMIF site. All costs following the acceptance of facilities for operation are included in WBS 7.0.

The Equipment Installation and checkout cost estimate includes the following elements:

Column "h" [Construction Contractor Mat'l/Lab]:
- construction contractor provided installation labor,
- construction contractor provided supervision,
- verification testing labor and support.

Column "i" [Construction Contractor Engin'g]:
- construction contractor provided installation engineering,
- on-site support by fabricating industry labor and technicians.

Column "j" [Institutional Engin'g]:
- On-site support of responsible institute personnel.

Column "k" [AFI]: See explanation of column "f".

4.2.4 Engineering Validation (WBS X.4)

This element includes the costs for the Engineering Validation Phase of the project, starting in calendar year 1997. The costs are explained in the IFMIF Engineering Validation Phase plan [3].

All EVP costs are reported in Column "n"

4.2.5 Facility Construction (WBS 5.0)

IFMIF construction was estimated differently than the technical facilities because all work is performed on-site. Since IFMIF uses construction techniques similar to those proposed for ITER, costs are generally based on factors developed for the ITER cost estimate.

Column "h" [Construction Contractor Mat'l/Lab]:
- construction contractor provided installation labor,
- construction contractor provided supervision,
- verification testing labor and support,
- material,
- purchased equipment.

Column "i" [Construction Contractor Engin'g]:
- construction contractor provided installation engineering,
- construction contractor design engineering.

Column "j" [Institutional Engin'g]:
- On-site support of responsible institute personnel.

Column "k" [AFI]: See explanation of column "f".

4.3 Startup and Commissioning (WBS 7.0)

This element includes the costs for start-up and commissioning of the IFMIF facility. This includes operations and material costs from the startup of the accelerator through the commissioning of the plant.

4.3.1 Indeterminates:

This WBS element provides a best estimate of the cost of starting IFMIF regardless of site location. The actual startup and commissioning costs will depend on many imponderable factors including the type of organization responsible for the construction phase, the extent or sharing of vendor responsibilities, and the necessary level of interaction with regulatory bodies.

4.3.2 Personnel Rates:

Operating personnel will be hired during the Startup and Commissioning phase of the project to assist with operations and training. The personnel costs as shown in Table 2-3 include all overheads and burdens.

4.3.3 Electrical Power:

Electric power costs include the power required for the operating equipment and power consumption during various levels of non-operation. This is accounted for in assumptions for a reasonable two-year startup plan. Power costs were developed for Europe, US and Japan, and reported for IFMIF as an average and as a range.

4.3.4 Maintenance:

A percentage factor of the TEC cost was used to cover capital improvements, spare parts and maintenance costs.

4.3.5 Waste Disposal:

The volume and cost of waste disposal was reviewed at the Second Design Integration meeting with a resulting average cost based on engineering judgement. .

4.4 Operating Costs

An estimate of the normal facility annual operating costs is included in Appendix C. The same basic factors of electric power, personnel, maintenance, waste disposal and utilities are included.

5.0 Cost Estimate Analysis

The overall IFMIF cost estimate has been analyzed through a series of charts which provide a relative comparison of many factors which are common to all facilities of this type.

5.1 Distribution of Costs by WBS

Chart 5-1 shows a percentage distribution of the TPC by WBS level two elements. Note that the accelerator accounts for approximately half of the total project cost, a common "rule of thumb" for accelerator based facilities. Also note that the relatively low cost of central control and instrumentation assumes a configuration in which each technical facility provides a stand-alone control capability which is included in the individual facility cost estimates.

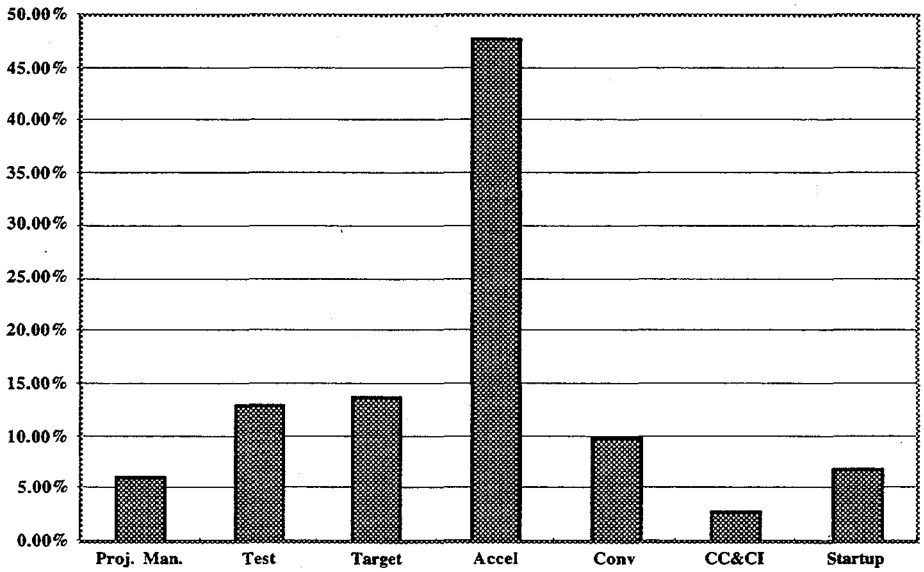

Figure 5-1. Distribution of TPC by WBS level 2 elements.

5.2 Distribution of Costs by Type

Chart 5-2 shows a percentage distribution of the TPC by major types of costs which is close to that expected for a large construction project. The engineering numbers appear low, however, the IFMIF WBS includes a substantial amount of engineering in project management, EVP and Startup and Commissioning. Thus the actual total engineering cost will be closer to the expected value of 30 to 35%.

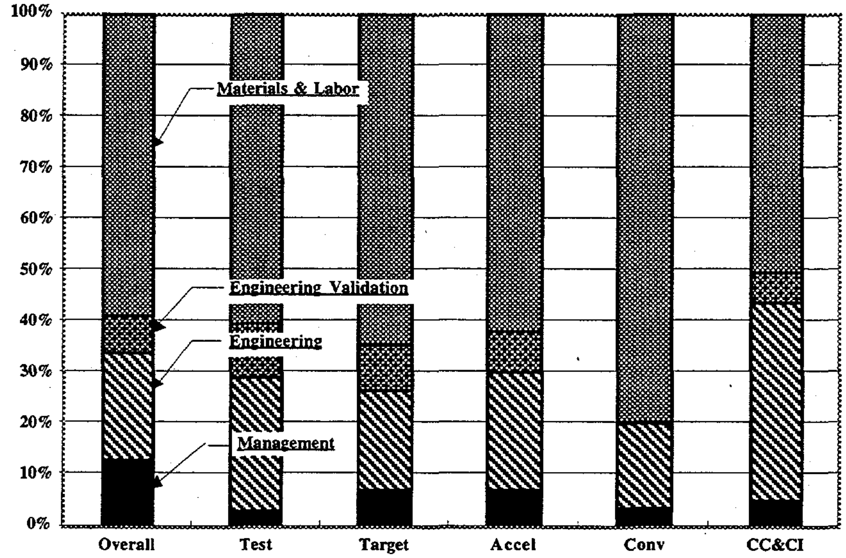

Figure 5-2. Distribution of basic cost types

5.3 Allowance for Indeterminates

Figure 5-3 shows the distribution of AFI for the total system and each major WBS element. The overall value of 27% seems reasonable since the IFMIF configuration is well established from the FMIT project. Note that the majority of the AFI is determined by the relatively complex accelerator faculty which has an AFI factor of 35%.

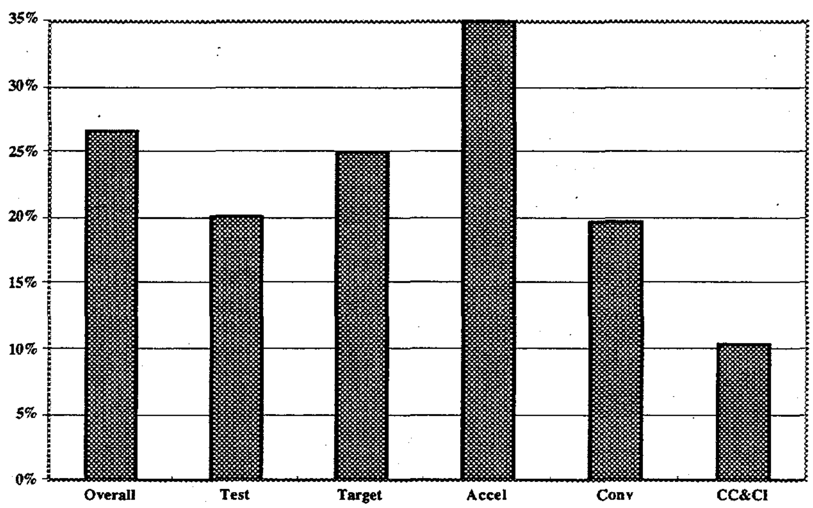

Figure 5-3. Distribution of TEC Allowance for Indeterminates

5.4 Industrial Participation

The estimate shows that up to 85% of the IFMIF cost could be contracted to commercial vendors as shown in Figure 5-4. This value includes Project Management; if only the individual facilities are considered, the factor would be more than 90%.

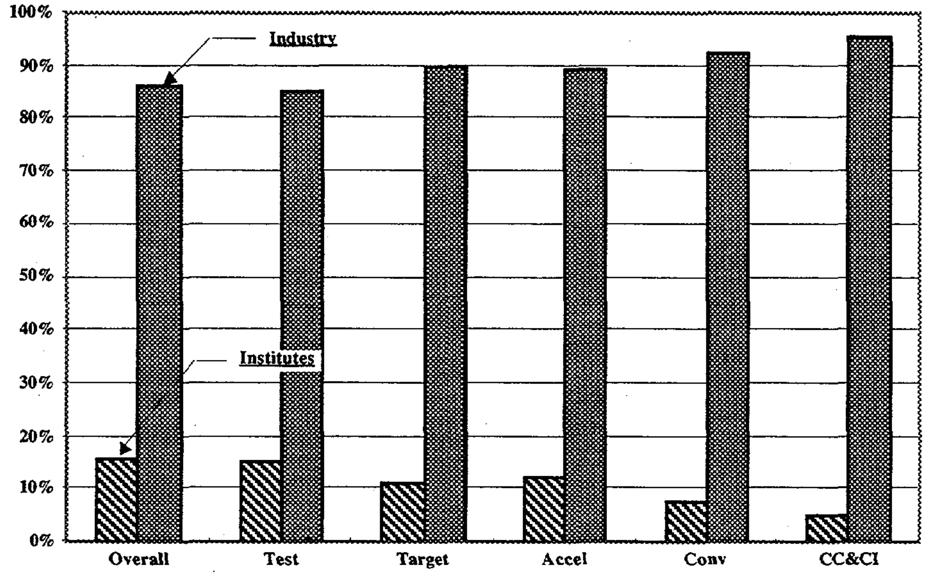

Figure 5-4 Industrial-Laboratory distribution

5.5 Expenditure Location

The estimate shows that up to 70% of the IFMIF cost could ideally be spent "off-site" as shown in Figure 5-5. A more realistic value will probably be lower when a specific site has been selected and additional construction and management functions are located at the IFMIF site.

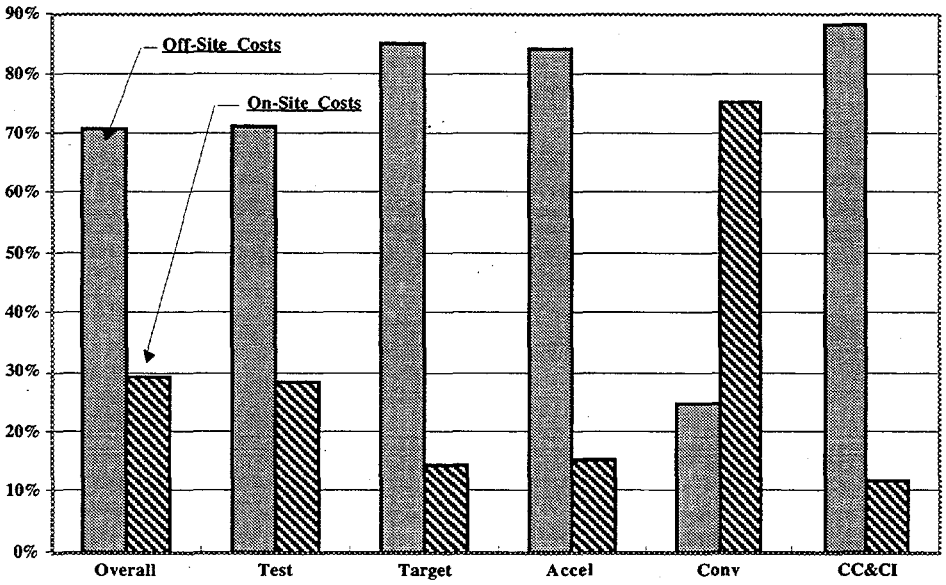

Figure 5-5. "On-site"-"off-site" distribution

5.6 Management Distributions

Figure 5-6 shows the percentage of TPC costs for the management of both the overall project and each facility. The "Overall" figure is a combination of both the WBS 1.0 Project Management total and the sum of all the Facility management costs. It is based on historical values for large projects while the facilities management costs were estimated individually by each responsible party. The Target and Accelerator systems are considered the most complex and thus have relatively high management costs. Conventional facilities are to be managed by the Construction Manager which is costed in WBS 1.0 once construction begins thus the value is relatively low.

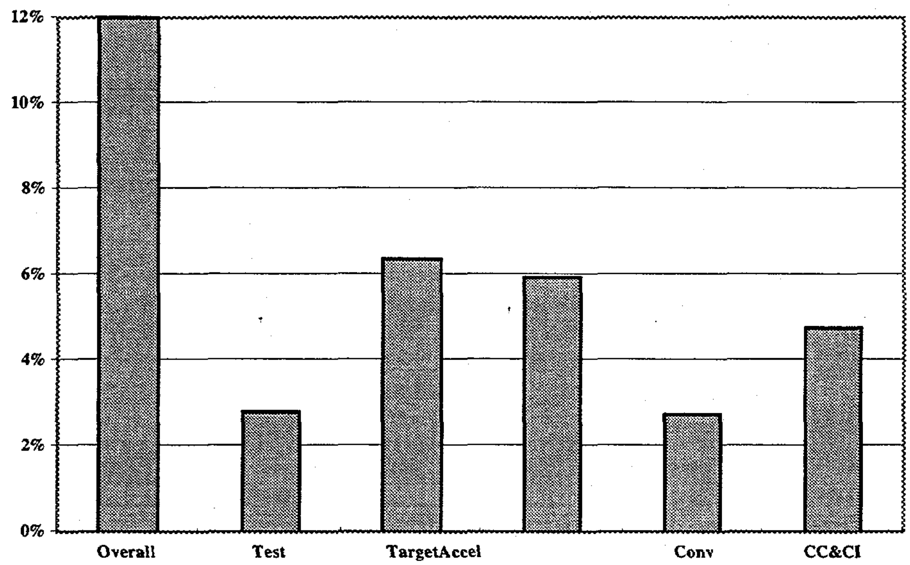

Figure 5-6. Management cost distribution

References:

1. IFMIF Conceptual Design Activity Final Report, IFMIF CDA Team, Edited by M. Martone, ENEA, Frascati Italy, No. RT/ERG/FUS/96/11, December, 1996

2. IFMIF Conceptual Design Activity Preliminary Cost Report, Compiled by M. J. Rennich, Oak Ridge National Laboratory, ORNL/M-5230, July 1995, [Limited Distribution].

3. Proposed Tasks for International Fusion Materials Irradiation Facility - Engineering Validation Phase, IFMIF-CDA Team, JAERI-memo 08-173, August 1996

Appendix 5-A

Summary Of Preliminary IFMIF Construction and Startup Cost Estimate

December 1996, Final IFMIF Summary Cost Estimate

Currency Units=kilo IFMIF Currency Factor

WBS	Element	Total Project Cost (TPC)															
		Total Estimated Capital Cost (TEC)															
				Off-IFMIF Site					On-Site At IFMIF								
		On-site	Off-Site	Industry		Instit'al		Off-site	Const. Contractor		Instit'al		On-site				
		Proj Man.	Facil. Manag.	Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total		EVP	St&Comm	
	Project Totals	**52,000**	**38,347**	**291,605**	**93,672**	**17,401**	**122,554**	**525,232**	**114,138**	**21,489**	**11,770**	**34,203**	**181,601**	**797,179**	**49,323**	**63,034**	**909,536**
1 0 0	**Project Management**	**52,000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**52,000**	**2,800**	**0**	**54,800**
2 0 0	**Test Facilities**	**0**	**3,000**	**46,720**	**10,697**	**4,562**	**11,296**	**73,275**	**13,635**	**4,550**	**5,985**	**6,197**	**30,367**	**106,642**	**10,460**	**0**	**117,102**
1 0	**Test Facility Management**	**0**	**3,000**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3,000**	**0**	**0**	**3,000**
2 0	**Test Facility Subsystems**	**0**	**0**	**46,720**	**10,697**	**4,562**	**11,296**	**73,275**	**10,635**	**4,550**	**5,985**	**6,197**	**27,367**	**100,642**	**0**	**0**	**100,642**
1	Vertical Test Assemblies for Test Cell I			3,465	661	2,008	1,045	7,179	105	0	390	99	594	7,773			
2	Test Cell I			3,198	0	928	825	4,951	222	0	72	59	353	5,304			
3	Test Cell Technology Room I			342	0	127	94	563	155	18	231	81	485	1,048			
4	Vertical Test Assemblies for Test Cell II			3,465	66	201	668	4,400	105	0	39	29	173	4,573			
5	Test Cell II			3,198	0	93	658	3,949	222	0	7	46	275	4,224			
6	Test Cell Technology Room II			342	0	13	71	426	155	2	54	42	253	679			
7	Test Facility Control room			872	0	103	195	1,170	4	0	291	59	354	1,524			
8	Access Cell			5,710	0	375	1,217	7,302	690	0	909	320	1,919	9,221			
9	Service Cell			1,546	0	0	309	1,855	2,549	0	625	635	3,809	5,664			
10	Test Module Handling Cell			1,457	0	0	291	1,748	838	0	346	237	1,421	3,169			
11	PIE Hot Cell			3,288	0	0	658	3,946	3,382	0	559	788	4,729	8,675			
12	Shielded Glove Box Laboratory			8,970	0	0	1,794	10,764	0	0	311	62	373	11,137			
13	Tritium Laboratory			10,867	9,970	715	3,471	25,023	238	4,530	1,560	3,228	9,556	34,579			
14	Maintenance Systems			0	0	0	0	0	1,970	0	591	512	3,073	3,073			
3 0	**System Installation and Checkout**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3,000**	**0**	**0**	**0**	**3,000**	**3,000**	**0**	**0**	**3,000**
1	Installation																
2	Facility Verification Testing																
4 0	**Subsystem Development**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10,460**	**0**	**10,460**

December 1996, Final IFMIF Summary Cost Estimate

Currency Units=kilo IFMIF Currency Factor

		Total Project Cost (TPC)															
		Total Estimated Capital Cost (TEC)															
				Off-IFMIF Site					On-Site At IFMIF								
		On-site	Off-Site	Industry		Instit'al		Off-site	Const. Contractor		Instit'al		On-site				
WBS	Element	Proj Man.	Facil. Manag.	Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total		EVP	St&Comm	
3 0 0	**Target Facility**	**0**	**7,374**	**53,648**	**12,929**	**2,795**	**21,629**	**91,001**	**11,914**	**4,007**	**80**	**800**	**16,801**	**115,176**	**8,950**	**0**	**124,126**
1 0	**Subsystem Management**	**0**	**7,374**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	7,374			**7,374**
1	Project Management and Administration		2,143					0	0	0	0	0	0	2,143			**2,143**
2	Systems Engineering		2,327					0	0	0	0	0	0	2,327			**2,327**
3	ES&H Documentation		400					0	0	0	0	0	0	400			**400**
4	Quality Assurance		1,830					0	0	0	0	0	0	1,830			**1,830**
5	Other Costs		674					0	0	0	0	0	0	674			**674**
2 0	**Subsystems**			**53,648**	**11,823**	**2,773**	**21,545**	**89,788**	**4,775**	**0**	**0**	**239**	**5,014**	**94,802**			**94,802**
1	Lithium Target System			3,608	603	680	2,445	7,336	574	0	0	29	603	7,939			
2	Lithium Cooling System			16,113	3,462	929	3,956	24,460	2,296	0	0	115	2,411	26,871			
3	Lithium Purification & Monitoring System			7,234	2,154	1,051	3,792	14,231	866	0	0	43	909	15,140			
4	Lithium Recovery System			10	2	1	7	20	0	0	0	0	0	20			
5	Control System			6,334	915	18	727	7,994	1,039	0	0	52	1,091	9,085			
6	Ventilation System			6,291	629	13	1,519	8,452	0	0	0	0	0	8,452			
7	Maintenance Systems			14,058	4,058	81	9,099	27,296	0	0	0	0	0	27,296			
3 0	**Installation and Checkout**			**0**	**1,106**	**22**	**85**	**1,213**	**7,139**	**4,007**	**80**	**561**	**11,787**	**13,000**			**13,000**
1	Installation			0	553	11	56	620	6,267	2,801	56	456	9,580	10,201			
2	Verification Testing			0	181	4	9	194	291	291	6	29	617	811			
3	Test Operations			0	372	7	19	398	581	915	18	76	1,590	1,988			
4 0	**Subsystem Development**			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	8,950		**8,950**
4 0 0	**Accelerator Facility**	**0**	**24,330**	**169,364**	**59,053**	**9,222**	**83,487**	**321,126**	**38,271**	**5,678**	**3,044**	**16,520**	**63,513**	**408,969**	**25,684**	**0**	**434,653**
1 0	**Accelerator Facility Management**		**24,330**										**0**	**24,330**			**24,330**
2 0	**Subsystems**			**169,364**	**59,053**	**9,222**	**83,487**	**321,126**	**0**	**0**	**0**	**0**	**0**	**321,126**			**321,126**
1	Accel. Equip. Prel. Design				11,621	2,905	5,084	19,610					0	19,610			**19,610**
2	Accelerator Equipment Physics				4,944	2,119	2,472	9,535					0	9,535			**9,535**
3	Accelerator #1 (Castor)			85,498	28,465	3,644	41,182	158,789					0	158,789			**158,789**
4	Accelerator #2 (Pollux)			78,050	6,162	0	29,766	113,978					0	113,978			**113,978**
5	Beam Calibration Dumps			5,133	994	412	2,291	8,830					0	8,830			**8,830**
6	Accelerator System Control			683	4,581	142	1,892	7,298					0	7,298			**7,298**
7	Accelerator Support Systems				2,286	0	800	3,086					0	3,086			**3,086**
8	Maintenance Systems					0	0	0					0	0			**0**
3 0	**Subsystem Installation and Checkout**			**0**	**0**	**0**	**0**	**0**	**38,271**	**5,678**	**3,044**	**16,520**	**63,513**	**63,513**		0	**63,513**
1	Accelerator #1 (Castor)					0	0	0	20,715	3,036	1,499	8,909	34,159	34,159		0	**34,159**
2	Accelerator #2 (Pollux)					0	0	0	17,556	2,642	1,545	7,611	29,354	29,354		0	**29,354**
4 0	**Subsystem Development**													0	25,684		**25,684**

December 1996, Final IFMIF Summary Cost Estimate

Currency Units=kilo IFMIF Currency Factor

		Total Project Cost (TPC)															
		Total Estimated Capital Cost (TEC)															
				Off-IFMIF Site					On-Site At IFMIF								
		On-site	Off-Site	Industry		Instit'al		Off-site	Const. Contractor		Instit'al		On-site				
WBS	Element	Proj Man.	Facil. Manag.	Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total		EVP	St&Comm	
5 0 0	**Conventional Facilities (EU/US)**	0	2,500	11,677	3,267	822	4,052	19,817	48,845	5,971	2,661	10,629	68,105	90,422	0	0	90,422
1 0	**Conventional Facility Management**		2,500											2,500			2,500
2 0	**Buildings**								35,902	2,760	132	6,436	45,229	45,229			45,229
1	Accelerator Complex			0	0	0	0	0	20,959	1,257	132	3,350	25,698	25,698			
2	Target Complex								6,456	717	0	1,435	8,608	8,608			
3	Test and Examination Complex								3,652	366	0	730	4,747	4,747			
4	Building High Bay								3,777	378	0	756	4,911	4,911			
5	Support Facilities								1,058	42	0	165	1,265	1,265			
3 0	**Plant Services**			11,677	3,267	822	4,052	19,817	11,938	3,191	2,529	4,093	21,751	41,568			41,568
1	HVAC			7,207	1,153	0	1,254	9,614	7,207	288	0	1,024	8,519	18,133			
2	Power System Substation			1,611	0	35	330	1,975	384	0	36	83	503	2,478			
3	Heat Rejection System			0	0	0	0	0	3,847	385	0	769	5,001	5,001			
4	Service Water System								500	25	0	79	604	604			
5	Radioactive Waste Treatment Systems			2,859	2,114	787	2,468	8,228	0	2,493	2,493	2,138	7,124	15,352			
4 0	**Site Improvements**			0	0	0	0	0	1,005	20	0	100	1,125	1,125			1,125
1	Roads and Parking			0	0	0	0	0	0	0	0	0	0	0			
2	Grading and Landscaping			0	0	0	0	0	0	0	0	0	0	0			
3	Storm Drainage			0	0	0	0	0	0	0	0	0	0	0			
5 0 0	***Conventional Facilities (Japan)***	*0*	*11,926*	*0*	*0*	*0*	*0*	*0*	*152,779*	*0*	*0*	*30,555*	*183,334*	195,405	*0*	*0*	195,405
1 0	***Management***		*11,926*											*11,926*	*0*		*11,926*
2 0	***Construction***			*0*	*0*	*0*	*0*	*0*	*83,989*	*0*	*0*	*16,798*	*100,787*	*100,787*	*0*		*100,787*
1	*Buildings*			*0*	*0*	*0*	*0*	*0*	*55,775*	*0*	*0*	*11,155*	*66,930*				
2	*Special Equipment*			*0*	*0*	*0*	*0*	*0*	*28,214*	*0*	*0*	*5,643*	*33,857*				
3 0	***Plant Services***			*0*	*0*	*0*	*0*	*0*	*39,259*	*0*	*0*	*7,852*	*47,111*	*47,111*	*0*		*47,111*
1	*HVAC*			*0*	*0*	*0*	*0*	*0*	*14,483*	*0*	*0*	*2,897*	*17,380*				
2	*Service Water System*			*0*	*0*	*0*	*0*	*0*	*5,506*	*0*	*0*	*1,101*	*6,607*				
3	*Cooling Water Utilities*			*0*	*0*	*0*	*0*	*0*	*10,643*	*0*	*0*	*2,129*	*12,771*				
4	*Special Equipment*			*0*	*0*	*0*	*0*	*0*	*8,627*	*0*	*0*	*1,725*	*10,352*				
4 0	***Electric Utilites***			*0*	*0*	*0*	*0*	*0*	*29,531*	*0*	*0*	*5,906*	*35,437*	*35,437*	*0*		*35,437*
1	*Electric Service*			*0*	*0*	*0*	*0*	*0*	*5,220*	*0*	*0*	*1,044*	*6,264*				
2	*Electric System*			*0*	*0*	*0*	*0*	*0*	*23,178*	*0*	*0*	*4,636*	*27,813*				
3	*Special Equipment*			*0*	*0*	*0*	*0*	*0*	*960*	*0*	*0*	*192*	*1,152*				
4	*Outside Electrical Utilites*			*0*	*0*	*0*	*0*	*0*	*173*	*0*	*0*	*35*	*208*				
5 0	***Radioactive Waste Treatment Systems***			*28*	*20*	*7*	*23*	*78*	*0*	*23*	*23*	*21*	*67*	*145*	*0*		*145*
1	*Exhaust Gas Detritiation System*			*9*	*4*	*2*	*6*	*21*	*0*	*9*	*9*	*8*	*26*				
2	*Temporary Exhaust Gas Detrit. System*			*3*	*3*	*1*	*3*	*10*	*0*	*4*	*4*	*4*	*12*				
3	*Liquid Waste Treatment System*			*4*	*4*	*1*	*4*	*13*	*0*	*6*	*6*	*5*	*17*				
4	*Solid Waste Treatment System*			*12*	*9*	*3*	*10*	*34*	*0*	*4*	*4*	*4*	*12*				

December 1996, Final IFMIF Summary Cost Estimate

Currency Units=kilo IFMIF Currency Factor

WBS	Element	On-site Proj Man.	Off-Site Facil. Manag.	Off-IFMIF Site: Industry Mat'l/Lab	Industry Engin'g	Instit'al Engin'g	AFI	Off-site Total	On-Site At IFMIF: Const. Contractor Mat'l/Lab	Const. Contractor Engin'g	Instit'al Engin'g	AFI	On-site Total	Total Estimated Capital Cost (TEC)	EVP	St&Comm	Total Project Cost (TPC)
6 0 0	**Central Cont. and Common Instr.**	**0**	**1,143**	**10,196**	**7,726**	**0**	**2,091**	**20,012**	**1,473**	**1,284**	**0**	**57**	**2,814**	**23,969**	**1,429**	**0**	**25,398**
1 0	**Facitity Management**		**1,143**											**1,143**	**0**	**0**	**1,143**
2 0	**Common Instrumentation Subsystems**			**5,348**	**983**	**0**	**628**	**6,960**	**713**	**598**	**0**	**57**	**1,368**	**8,328**	**1,429**	**0**	**9,757**
1	Beam Instrumentation			876	0	0	263	1,139	0	171	0	51	222	1,361	1,143		
2	Radiation Monitoring			2,616	69	0	52	2,737	140	422	0	6	568	3,305			
3	Video Monitoring			744	229	0	109	1,081	200	0	0	0	200	1,281	286		
4	Access Control			275	229	0	62	565	133	0	0	0	133	698			
5	Announciator			214	229	0	56	499	80	0	0	0	80	579			
6	Information Display Stations			530	229	0	87	846	160	0	0	0	160	1,006			
7	Safety and Emergency Equipments			93	0	0	0	93	0	5	0	0	5	98			
3 0	**Central Control Subsystems**			**4,848**	**6,514**	**0**	**1,462**	**12,824**	**760**	**0**	**0**	**0**	**760**	**13,584**	**0**	**0**	**13,584**
1	Central Control			846	1,829	0	359	3,034	67	0	0	0	67	3,100			
2	LAN			486	229	0	83	798	160	0	0	0	160	958			
3	Interlock Logic			410	914	0	178	1,502	200	0	0	0	200	1,702			
4	Central Display Panel			1,587	114	0	176	1,878	133	0	0	0	133	2,011			
5	Sequence Synchronizer			1,187	229	0	153	1,568	133	0	0	0	133	1,702			
6	Dummy Substation			331	914	0	170	1,416	67	0	0	0	67	1,482			
7	Operation and Configuration Control			0	2,286	0	343	2,629	0	0	0	0	0	2,629			
4 0	**System Installation and Checkout**			**0**	**228**	**0**	**0**	**228**	**0**	**686**	**0**	**0**	**686**	**914**	**0**	**0**	**914**
1	Installation and Test			0	114	0	0	114	0	343	0	0	343	457			
2	System Verification Testing			0	114	0	0	114	0	343	0	0	343	457			
7 0 0	**Operational Startup and Commiss.**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**63,034**	**63,034**
1 0	Personnel & Overhead								0	0	32,918	3,292	36,210			36,210	
2 0	Electrical Power								22,509	0	0	2,251	24,760			24,760	
3 0	Utilities								578	0	0	58	636			636	
4 0	Maintenance								1,000	0	0	100	1,100			1,100	
5 0	Waste Disposal								298	0	0	30	328			328	

APPENDIX 5-B

Complete Listing Of The IFMIF Work Breakdown Structure

IFMIF Work Breakdown Structure (November, 1996)

1.	*2.*	*Level*
1.	**0.**	**Project Management**
	1.	**Project Management and Administration**
	2.	**Systems Engineering**
	3.	**Environmental, Safety & Health Documentation**
	4.	**Quality Assurance**
2.	**0.**	**Test Facilities**
	1.	**Test Facility Management**
	2.	**Test Facility Subsystems**
	3.	**Test Facility System Installation and Checkout**
	4.	**Test Facility Subsystem Development**
3.	**0.**	**Target Facility**
	1.	**Target Facility Management**
	2.	**Subsystem**
	3.	**System Installation and Checkout**
	4.	**Subsystem Development**
4.	**0.**	**Accelerator Facility**
	1.	**Accelerator Facility Management**
	2.	**Subsystems**
	3.	**Subsystem Installation and Checkout**
	4.	**Subsystem Development**
5.	**0.**	**Conventional Facilities**
	1.	**Conventional Facility Management**
	2.	**Buildings**
	3.	**Plant Services**
	4.	**Site Improvements**
6.	**0.**	**Common Instrumentation and Central Control Systems**
	1.	**System Management**
	2.	**Common Instrumentation Subsystems**
	3.	**Central Control Subsystems**
	4.	**System Installation and Checkout**
7.	**0.**	**Operational Startup and Commissioning**
	1.	**Personnel & Overhead**
	2.	**Electrical Power**
	3.	**Utilities**
	4.	**Maintenance**
	5.	**Waste Disposal**

IFMIF Work Breakdown Structure

1. 2. 3. 4. 5. 6. 7. Level

1. 0. 0. 0. 0. 0. 0. Project Manag.

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1. 0. 0. 0. 0. 0. Project Manag. and Administration
1. 0. 0. 0. 0. Administration
2. 0. 0. 0. 0. Cost Control
3. 0. 0. 0. 0. Schedule
4. 0. 0. 0. 0. Development Oversight
5. 0. 0. 0. 0. Construction Manag.
6. 0. 0. 0. 0. Doc.

2. 0. 0. 0. 0. 0. Systems Engineering
1. 0. 0. 0. 0. Design Integration
2. 0. 0. 0. 0. Systems Analysis
3. 0. 0. 0. 0. Requirements/Specs
4. 0. 0. 0. 0. RAM Analysis

3. 0. 0. 0. 0. 0. Envir., Safety & Health Doc.

4. 0. 0. 0. 0. 0. Quality Assurance

2. 0. 0. 0. 0. 0. 0. Test Facilities

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1. 0. 0. 0. 0. 0. Test Facility Manag.
1. 0. 0. 0. 0.Project Manag. and Administration
1. 0. 0. 0.Administration
2. 0. 0. 0.Cost Control
3. 0. 0. 0.Schedule
4. 0. 0. 0.Doc.
2. 0. 0. 0. 0.Systems Engineering
1. 0. 0. 0.Design Integration
2. 0. 0. 0.Systems Analysis
3. 0. 0. 0.Requirements/Specs
4. 0. 0. 0.RAM Analysis
3. 0. 0. 0. 0.Envir., Safety & Health Doc..
1. 0. 0. 0.Envir., Safety & Health Doc..
2. 0. 0. 0.Licenses
4. 0. 0. 0. 0.Quality Assurance
5. 0. 0. 0. 0.Other Costs

2. 0. 0. 0. 0. 0.Test Facility Subsystems
1. 0. 0. 0. 0.Vertical Test Assemblies
1. 0. 0. 0.VTA1-NaK
2. 0. 0. 0.VTA1-He
3. 0. 0. 0.VTA2-NaK
4. 0. 0. 0.VTA2-He
1. 0. 0.VTA2-He Concept 1
2. 0. 0.VTA2-He Concept 2
5. 0. 0. 0.VIT-System
6. 0. 0. 0.Shield Plug
2. 0. 0. 0. 0.Test Cell 1
1. 0. 0. 0.Test Cell Cover
2. 0. 0. 0.Test Cell Liner
3. 0. 0. 0.Heat shield
4. 0. 0. 0.Seal Plate
5. 0. 0. 0.Camera System
6. 0. 0. 0.Neutron Source Diagnostics
7. 0. 0. 0.Test Cell Diagnostics
8. 0. 0. 0.Emergency Shutdown System
3. 0. 0. 0. 0.Test Cell Technology Room 1
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Cooling System
3. 0. 0. 0.Vacuum Pumping System
4. 0. 0. 0.Ar backfill System
5. 0. 0. 0.Diagnostics and Controls
6. 0. 0. 0.Subsystem Power
4. 0. 0. 0. 0.Test Cell 2
1. 0. 0. 0.Test Cell Cover
2. 0. 0. 0.Test Cell Liner
3. 0. 0. 0.Heat shield
4. 0. 0. 0.Seal Plate
5. 0. 0. 0.Camera System
6. 0. 0. 0.Neutron Source Diagnostics
7. 0. 0. 0.Test Cell Diagnostics
8. 0. 0. 0.Emergency Shutdown System
5. 0. 0. 0. 0.Test Cell Technology Room 2
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Cooling System
3. 0. 0. 0.Vacuum Pumping System
4. 0. 0. 0.Ar backfill System
5. 0. 0. 0.Diagnostics and Controls
6. 0. 0. 0.Subsystem Power
6. 0. 0. 0. 0.Test Facility Control Room
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Data Acq - VTA 1 - NaK
3. 0. 0. 0.Data Acq - VTA-1 - He
4. 0. 0. 0.Data Acq. - Creep Fatigue
5. 0. 0. 0.Data Acq - Tritium Release
6. 0. 0. 0.Data Acq - VIT
7. 0. 0. 0.Supervisory Computer
8. 0. 0. 0.Subsystem Power
7. 0. 0. 0. 0.Access Cell
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Cell Structure
3. 0. 0. 0.Universal Robot
4. 0. 0. 0.Manipulator System
5. 0. 0. 0.Maintenance Support Equipment
6. 0. 0. 0.Infrastructure
8. 0. 0. 0. 0.Service Cell
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Cell Structure
3. 0. 0. 0.Transfer System
4. 0. 0. 0.Manipulator Systems
5. 0. 0. 0.Bridge Crane
6. 0. 0. 0.Maintenance Support Equip
7. 0. 0. 0.Infrastructure
9. 0. 0. 0. 0.Test Module Handling Cell
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Cell Structure
3. 0. 0. 0.Manipulator Systems
4. 0. 0. 0.Bridge Crane
5. 0. 0. 0.Maintenance Support Equip
6. 0. 0. 0.Infrastructure

10. 0. 0. 0. 0.PIE Hot Cell
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Cell Structure
3. 0. 0. 0.Manipulator Systems
4. 0. 0. 0.Bridge Crane
5. 0. 0. 0.Infrastructure
6. 0. 0. 0.Examination Equipment
11. 0. 0. 0. 0.Shielded Glove Box Laboratory
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Structure and Support Systems
3. 0. 0. 0.Examination Equipment
12. 0. 0. 0. 0.Tritium Laboratory
1. 0. 0. 0.Assembly and Testing
2. 0. 0. 0.Components
2. 0. 0. 0.Tritium Retention
13. 0. 0. 0. 0.Maintenance System

3. 0. 0. 0. 0.Test Facility System Install. and Checkout
1. 0. 0. 0. 0.Install.
2. 0. 0. 0. 0.Facility Verification Testing

4. 0. 0. 0. 0.Test Facility Subsystem Development
1. 0. 0. 0. 0. Project Manag. and Administration
1. 0. 0. 0. Administration
2. 0. 0. 0. Cost Control
3. 0. 0. 0. Schedule
4. 0. 0. 0. Doc.
2. 0. 0. 0. 0. Systems Engineering
1. 0. 0. 0. Design Integration
2. 0. 0. 0. Systems Analysis
3. 0. 0. 0. Requirements/Specs
4. 0. 0. 0. RAM Analysis
3. 0. 0. 0. 0. Envir., Safety & Health Doc.
4. 0. 0. 0. 0. Quality Assurance

3. 0. 0. 0. 0. 0. 0. Target Facility

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1. 0. 0. 0. 0. 0.Target Facility Manag.
1. 0. 0. 0. 0.Project Manag. and Administration
1. 0. 0. 0.Administration
2. 0. 0. 0.Cost Control
3. 0. 0. 0.Schedule
4. 0. 0. 0.Doc.
2. 0. 0. 0. 0.Systems Engineering
1. 0. 0. 0.Design Integration
2. 0. 0. 0.Systems Analysis
3. 0. 0. 0.Requirements/Specs
4. 0. 0. 0.RAM Analysis
3. 0. 0. 0. 0.Envir., Safety & Health Doc..
1. 0. 0. 0.Envir., Safety & Health Doc..
2. 0. 0. 0.Licenses
4. 0. 0. 0. 0.Quality Assurance
5. 0. 0. 0. 0.Other Costs

2. 0. 0. 0. 0. 0.Subsystem
1. 0. 0. 0. 0.Lithium Target System
1. 0. 0. 0.Assembly and Testing
1. 0. 0.Assembly
2. 0. 0.Testing
2. 0. 0. 0.Components
1. 0. 0.Target Assembly
1. 0.Li Inlet Piping
2. 0.Flow Straightener
3. 0.Nozzle
4. 0.Replaceable Backwall
5. 0.Downstream Diffuser
6. 0.Downstream Baffles
7. 0.Mechanical Connectors
8. 0.Li System Target Assembly Interface
9. 0.Measuring System
2. 0. 0.Beam-Target Interface
1. 0.Beam-Target Interface Structure
2. 0.Evacuation System
3. 0.Emergency Shutdown System
3. 0. 0.Target-Test Cell Interface
1. 0.Target-Test Cell Interface Structure
2. 0. 0. 0. 0.Lithium Cooling System
1. 0. 0. 0.Assembly and Testing
1. 0. 0.Assembly
2. 0. 0.Testing
2. 0. 0. 0.Components
1. 0. 0.Main Lithium Loop
1. 0.EM Pump
2. 0.Valves
3. 0.Flow Meters
4. 0.Piping
5. 0.Quench Tank
6. 0.Dump Tank
7. 0.Surge Tank
8. 0.Trace Heating
9. 0.Insulation
10. 0.Argon/Vacuum System
11. 0.Instrumentation and Control
12. 0.Lithium Metal
13. 0.Radiation Shielding
2. 0. 0.Primary Heat Removal System
1. 0.Primary Heat Exchanger(Li to Organic)
2. 0.Piping
3. 0.Pump
4. 0.Valves
5. 0.Flow Meters
6. 0.Organic Dump Tank
7. 0.Instrumentation and Control
8. 0.Radiation Shielding
9. 0.Organic Oil
10. 0.Organic Heater
3. 0. 0.Secondary Heat Removal System
1. 0.Secondary Heat Exchanger (Organic to Water)
2. 0.Piping
3. 0.Pump
4. 0.Valves
5. 0.Flow Meters
6. 0.Instrumentation and Control
4. 0. 0.Tertiary Heat Exchanger(Water Cooling)
3. 0. 0. 0. 0.Purification and Impurity Monitoring System
1. 0. 0. 0.Assembly and Testing

1. 0. 0.Assembly
2. 0. 0.Testing
2. 0. 0. 0.Components
1. 0. 0.Lithium Purification System
1. 0.Cold Trap
2. 0.Hot Trap #1
3. 0.Hot Trap #2
4. 0.EM Pump
5. 0.Cold Trap Cooler
6. 0.Piping
7. 0.Valves
8. 0.Trace Heating
9. 0.Insulation
10. 0.Instrumentation and Control
11. 0.Radiation Shielding
12. 0.Flow Meters
13. 0.Economizer
2. 0. 0.Impurity Monitoring System
1. 0.On-Line Meters
2. 0.Off-Line Monitors
3. 0.Flow Meters
4. 0.Piping
5. 0.Valves
6. 0.Main Heater
7. 0.Economizer
8. 0.Trace Heating
9. 0.Insulation
10. 0.Instrumentation and Control
11. 0.Radiation Shielding
12. 0.EM Pump
4. 0. 0. 0. 0.Lithium Recovery System
1. 0. 0. 0.Leaked Lithium Recovery System
2. 0. 0. 0.Leaked Lithium Detection System
3. 0. 0. 0.Lithium Fire Control System
5. 0. 0. 0. 0.Target Facility Control System
1. 0. 0. 0.Normal Operation Control System
2. 0. 0. 0.Emergency Control System
6. 0. 0. 0. 0.Maintenance Systems
1. 0. 0. 0.Maintenance Procedure Development
2. 0. 0. 0.Special Purpose Tooling
3. 0. 0. 0.Remote Handling Equipment
1. 0. 0.For Target Assembly
2. 0. 0.For Purification Components
4. 0. 0. 0.Mockup Facilities and Testing

3. 0. 0. 0. 0. 0.System Install. and Checkout
1. 0. 0. 0. 0.Install.
1. 0. 0. 0.Lithium Target System
2. 0. 0. 0.Lithium Cooling System
3. 0. 0. 0.Lithium Recovery System
4. 0. 0. 0.Target Facility Control System
5. 0. 0. 0.Target Facility Ventilation System
6. 0. 0. 0.Target Facility Power System
7. 0. 0. 0.Other Support Facilities
8. 0. 0. 0.Maintenance Systems
2. 0. 0. 0. 0.Verification Testing
3. 0. 0. 0. 0.Startup

4. 0. 0. 0. 0. 0.Subsystem Development

4. 0. 0. 0. 0. 0. 0. Accelerator Facility

1. 0. 0. 0. 0. 0.Accelerator Facility Manag.
1. 0. 0. 0. 0.Project Manag. and Administration
2. 0. 0. 0. 0.Systems Engineering
3. 0. 0. 0. 0.Envir. Safety & Health Doc.
4. 0. 0. 0. 0.Quality Assurance

2. 0. 0. 0. 0. 0.Subsystems
1. 0. 0. 0. 0.Accelerator Equipment Preliminary Design (injector thru HEBT)
2. 0. 0. 0. 0.Accelerator Equipment Physics (injector thru HEBT)
3. 0. 0. 0. 0.Accelerator #1 (Castor)
1. 0. 0. 0.Injector System
1. 0. 0.Final Design labor
2. 0. 0.Procurement support/Seller Surveillance
3. 0. 0.Purchased Material
1. 0.Source and RF power supply
2. 0.LEBT
3. 0.Power supplies
4. 0.Operational Controls & Software
5. 0.Vacuum Equipment & Services
6. 0.Thermal Control Equip & Services
7. 0.Structure and Shielding
4. 0. 0.Fabrication Labor
5. 0. 0.Sustaining Engineering
2. 0. 0. 0.Radio Frequency Quadrupole System
1. 0. 0.Cold Model Design & Test
2. 0. 0.Final Design labor
3. 0. 0.Procurement support/Seller Surveillance
4. 0. 0.Purchased Material
1. 0.Copper
2. 0.Vacuum System Equipment & Services
3. 0.Drive Loops
4. 0.Electro-forming
5. 0.Miscellaneous Hardware
5. 0. 0.Fabrication Labor
6. 0. 0.Sustaining Engineering
3. 0. 0. 0.Drift Tube Linac System
1. 0. 0.Cold Model Design & Test
2. 0. 0.Final Design Tanks #1-8
3. 0. 0.Tank #1
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware

3. 0.Fabrication Labor

4. 0. 0.Tank #2

1. 0.Procurement support/Seller Surveillance

2. 0.Purchased Material

1.Drift Tubes

2.Drift tube magnets

3.Vacuum system equipment & Services

4.OFHC Copper for tank shell

5.Endwalls with magnets

6.Tank support system

7.Tuners

8.RF drive loops

9.Post couplers

10.Drift tube support girder

11.Focusing quadrupole package

12.Miscellaneous hardware

3. 0.Fabrication Labor

5. 0. 0.Tank #3

1. 0.Procurement support/Seller Surveillance

2. 0.Purchased Material

1.Drift Tubes

2.Drift tube magnets

3.Vacuum system equipment & Services

4.OFHC Copper for tank shell

5.Endwalls with magnets

6.Tank support system

7.Tuners

8.RF drive loops

9.Post couplers

10.Drift tube support girder

11.Focusing quadrupole package

12.Miscellaneous hardware

3. 0.Fabrication Labor

6. 0. 0.Tank #4

1. 0.Procurement support/Seller Surveillance

2. 0.Purchased Material

1.Drift Tubes

2.Drift tube magnets

3.Vacuum system equipment & Services

4.OFHC Copper for tank shell

5.Endwalls with magnets

6.Tank support system

7.Tuners

8.RF drive loops

9.Post couplers

10.Drift tube support girder

11.Focusing quadrupole package

12.Miscellaneous hardware

3. 0.Fabrication Labor

7. 0. 0.Tank #5

1. 0.Procurement support/Seller Surveillance

2. 0.Purchased Material

1.Drift Tubes

2.Drift tube magnets

3.Vacuum system equipment & Services

4.OFHC Copper for tank shell

5.Endwalls with magnets

6.Tank support system

7.Tuners

8.RF drive loops

9.Post couplers

10.Drift tube support girder

11.Focusing quadrupole package

12.Miscellaneous hardware

3. 0.Fabrication Labor

8. 0. 0.Tank #6

1. 0.Procurement support/Seller Surveillance

2. 0.Purchased Material

1.Drift Tubes

2.Drift tube magnets

3.Vacuum system equipment & Services

4.OFHC Copper for tank shell

5.Endwalls with magnets

6.Tank support system

7.Tuners

8.RF drive loops

9.Post couplers

10.Drift tube support girder

11.Focusing quadrupole package

12.Miscellaneous hardware

3. 0.Fabrication Labor

9. 0. 0.Tank #7

1. 0.Procurement support/Seller Surveillance

2. 0.Purchased Material

1.Drift Tubes

2.Drift tube magnets

3.Vacuum system equipment & Services

4.OFHC Copper for tank shell

5.Endwalls with magnets

6.Tank support system

7.Tuners

8.RF drive loops

9.Post couplers

10.Drift tube support girder

11.Focusing quadrupole package

12.Miscellaneous hardware

3. 0.Fabrication Labor

10. 0. 0.Tank #8

1. 0.Procurement support/Seller Surveillance

2. 0.Purchased Material

1.Drift Tubes

2.Drift tube magnets

3.Vacuum system equipment & Services

4.OFHC Copper for tank shell

5.Endwalls with magnets

6.Tank support system

7.Tuners

8.RF drive loops

9.Post couplers

10.Drift tube support girder

11.Focusing quadrupole package

12.Miscellaneous hardware

3. 0.Fabrication Labor

4. 0. 0. 0.HEBT System

1. 0. 0.Final Design labor
2. 0. 0.Procurement support/Seller Surveillance
3. 0. 0.Purchased Material
1. 0.Beam Tube, Flanges, Bellows, etc
2. 0.RF Cavities
3. 0.Support/Alignment Structure
4. 0.Quadrupole magnets: 6" long x 5" dia bore
5. 0.Quadrupole magnets: 16" long x 5" dia bore
6. 0.Quadrupole magnets: 24" long x 5" dia bore
7. 0.Octupole magnets: 16" long x 3.5" dia bore
8. 0.Dipole (45°) magnets: 5" gap
9. 0.Dipole (10°) magnets: 5" gap
10. 0.Energy Spread Monitors
11. 0.Phase Spread Monitors
12. 0.Video Profile Monitor
13. 0.Microstriplines
4. 0. 0.Fabrication Labor
5. 0. 0. 0.RF Drive Loop
1. 0. 0.Final Design labor
6. 0. 0. 0.Accelerator & HEBT Thermal Control Engineering
1. 0. 0.Final Design labor
2. 0. 0.Fabrication support
7. 0. 0. 0.RF Power System
1. 0. 0.RF control
2. 0. 0.RF Pre-driver (first high gain stage - solid state)
3. 0. 0.RF Final Amplifier (including driver : Approx. 1.3 MW)
4. 0. 0.RF Transport
1. 0.RF station to RFQ
2. 0.RF station to DTL and Momentum Compactor
3. 0.RF station to Energy Dispersion Cavities
4. 0.Circulators (19" Y-junction)
5. 0.Filters (19")
6. 0.Low Power Couplers
7. 0.RF Dummy Loads
8. 0.Air pressurization and distribution
5. 0. 0.Cavity Resonance Control
6. 0. 0.Switchgear
7. 0. 0.Cooling
8. 0. 0.RF station Monitoring and Control
9. 0. 0.Integration Equipment and Services
4. 0. 0. 0. 0.Accelerator #2 (Pollux)
1. 0. 0. 0.Design Updates
1. 0. 0.Injector system
2. 0. 0.RFQ system
3. 0. 0.DTL System
2. 0. 0. 0.Injector System
1. 0. 0.Procurement support/Seller Surveillance
2. 0. 0.Purchased Material
1. 0.Source and RF power supply
2. 0.LEBT
3. 0.Power supplies
4. 0.Operational Controls & Software
5. 0.Vacuum Equipment & Services
6. 0.Thermal Control Equip & Services
7. 0.Structure and Shielding
3. 0. 0.Fabrication Labor
3. 0. 0. 0.Radio Frequency Quadrupole System
1. 0. 0.Procurement support/Seller Surveillance
2. 0. 0.Purchased Material
1. 0.Copper
2. 0.Vacuum System Equipment & Services
3. 0.Drive Loops
4. 0.Electro-forming
5. 0.Miscellaneous Hardware
3. 0. 0.Fabrication Labor
4. 0. 0. 0.Drift Tube Linac System
1. 0. 0.Tank #1
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
2. 0. 0.Tank #2
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
3. 0. 0.Tank #3
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops

9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
4. 0. 0.Tank #4
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
5. 0. 0.Tank #5
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
6. 0. 0.Tank #6
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
7. 0. 0.Tank #7
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
8. 0. 0.Tank #8
1. 0.Procurement support/Seller Surveillance
2. 0.Purchased Material
1.Drift Tubes
2.Drift tube magnets
3.Vacuum system equipment & Services
4.OFHC Copper for tank shell
5.Endwalls with magnets
6.Tank support system
7.Tuners
8.RF drive loops
9.Post couplers
10.Drift tube support girder
11.Focusing quadrupole package
12.Miscellaneous hardware
3. 0.Fabrication Labor
5. 0. 0. 0.HEBT System
1. 0. 0.Procurement support/Seller Surveillance
2. 0. 0.Purchased Material
1. 0.Beam Tube, Flanges, Bellows, etc
2. 0.RF Cavities
3. 0.Support/Alignment Structure
4. 0.Quadrupole magnets: 6" long x 5" dia bore
5. 0.Quadrupole magnets: 16" long x 5" dia bore
6. 0.Quadrupole magnets: 24" long x 5" dia bore
7. 0.Octupole magnets: 16" long x 3.5" dia bore
8. 0.Dipole (45°) magnets: 5" gap
9. 0.Dipole (10°) magnets: 5" gap
10. 0.Energy Spread Monitors
11. 0.Phase Spread Monitors
12. 0.Video Profile Monitor
13. 0.Microstriplines
3. 0. 0.Fabrication Labor
6. 0. 0. 0.RF Power System
1. 0. 0.RF control
2. 0. 0.RF Pre-driver (first high gain stage - solid state)
3. 0. 0.RF Final Amplifier (including driver : Approx. 1.3 MW)
4. 0. 0.RF Transport
1. 0.RF station to RFQ
2. 0.RF station to DTL and Momentum Compactor
3. 0.RF station to Energy Dispersion Cavities
4. 0.Circulators (19" Y-junction)

5. 0.Filters (19")
6. 0.Low Power Couplers
7. 0.RF Dummy Loads
8. 0.Air pressurization and distribution
5. 0. 0.Cavity Resonance Control
6. 0. 0.Switchgear
7. 0. 0.Cooling
8. 0. 0.RF station Monitoring and Control
9. 0. 0.Integration Equipment and Services
5. 0. 0. 0. 0.Beam Calibration Dumps
1. 0. 0. 0.Moveable Beam Dump
1. 0. 0.Final Design
2. 0. 0.Procurement support/Seller Surveillance
3. 0. 0.Purchased Material
4. 0. 0.Fabrication Labor
2. 0. 0. 0.Fixed Beam Dump
1. 0. 0.Final Design
2. 0. 0.Procurement support/Seller Surveillance
3. 0. 0.Purchased Material
4. 0. 0.Fabrication Labor
6. 0. 0. 0. 0.Accelerator System Control
1. 0. 0. 0.Final Design labor
2. 0. 0. 0.Procurement support/Seller Surveillance
3. 0. 0. 0.Purchased Material
1. 0. 0.Central Computers
2. 0. 0.Data Transmission Network
3. 0. 0.Local Control
4. 0. 0.Database Computers
5. 0. 0.Logging and Facility Fault Analysis Computers
7. 0. 0. 0. 0.Accelerator Support Systems

3. 0. 0. 0. 0. 0.Subsystem Install. and Checkout
1. 0. 0. 0. 0.Accelerator #1 (Castor) Install. and Checkout
1. 0. 0. 0.Injector system
2. 0. 0. 0.RFQ system
3. 0. 0. 0.DTL Tank#1 system
4. 0. 0. 0.DTL Tanks #2-#8 system
5. 0. 0. 0.HEBT systems ("Abel", "Baker", and "Charlie")
6. 0. 0. 0.RF power system
7. 0. 0. 0.Beam Dumps
1. 0. 0.Moveable Beam Dump
2. 0. 0.Fixed Beam Dump
8. 0. 0. 0.Full Power Acceptance Test (125 mA)
9. 0. 0. 0.Accelerator Control System
2. 0. 0. 0. 0.Accelerator #2 (Pollux) Install. and Checkout
1. 0. 0. 0.Injector system
2. 0. 0. 0.RFQ system
3. 0. 0. 0.DTL Tank#1 system
4. 0. 0. 0.DTL Tanks #2-#8 system
5. 0. 0. 0.HEBT systems ("Abel", "Baker", and "Charlie")
6. 0. 0. 0.RF power system
7. 0. 0. 0.Full Power Acceptance Testing (250 mA)
8. 0. 0. 0.Accelerator Control System

4. 0. 0. 0. 0. 0.Subsystem Development
1. 0. 0. 0. 0.RF System Development and Test
2. 0. 0. 0. 0.Injector System Development and Test
3. 0. 0. 0. 0.Design Optimization

5. 0. 0. 0. 0. 0. 0. Conventional Facilities

---

1. 0. 0. 0. 0. 0. Conventional Facility Manag.
1. 0. 0. 0. 0. Project Manag. and Administration
1. 0. 0. 0. Administration
2. 0. 0. 0. Cost Control
3. 0. 0. 0. Schedule
4. 0. 0. 0. Doc.
2. 0. 0. 0. 0. Systems Engineering
1. 0. 0. 0. Design Integration
2. 0. 0. 0. Requirements/Specs
3. 0. 0. 0. RAM Analysis
3. 0. 0. 0. 0. Envir., Safety & Health Doc.
4. 0. 0. 0. 0. Quality Assurance

2. 0. 0. 0. 0. 0.Buildings
1. 0. 0. 0. 0.Accelerator Complex
1. 0. 0. 0.Accelerator Hall
2. 0. 0. 0.Beam Turning Building
3. 0. 0. 0.RF Power Bay
4. 0. 0. 0.Accelerator Assembly/Maintenance Bay
2. 0. 0. 0. 0.Target Complex
1. 0. 0. 0.Lithium Processing Cells
2. 0. 0. 0.Processing Cell Liners
3. 0. 0. 0. 0.Test and Examination Complex
1. 0. 0. 0.Test Cells
2. 0. 0. 0.Beam Calibration Cell
3. 0. 0. 0.Test Cell Technology Rooms
4. 0. 0. 0.Access Cell
5. 0. 0. 0.Shielding Doors
6. 0. 0. 0.VTA & Target Service Cell
7. 0. 0. 0.Shielding Doors
8. 0. 0. 0.Module Handling Cell
9. 0. 0. 0.Shielding Door
10. 0. 0. 0.Control Room Data Acquisition Room
11. 0. 0. 0.PIE Laboratory Area
12. 0. 0. 0.Tritium PIE Laboratory Area
13. 0. 0. 0.Hot Cell Utility Cell
14. 0. 0. 0.Corridors
15. 0. 0. 0.Cell Liners
4. 0. 0. 0. 0.Building High Bay
1. 0. 0. 0.High Bay Building
2. 0. 0. 0.Bridge Crane (30 tonne)
3. 0. 0. 0.Hot Shop
4. 0. 0. 0.Uncontaminated Shop
5. 0. 0. 0.Manipulator Repari Room
6. 0. 0. 0.Shipping Bay
7. 0. 0. 0.Rad Waste Processing Bay
8. 0. 0. 0.Rad Waste Shipping Bay
9. 0. 0. 0.Health Physics Station
10. 0. 0. 0.Corridors
5. 0. 0. 0. 0.Support Facility Buildings
1. 0. 0. 0.Plant Service Halls
2. 0. 0. 0.Office Complex

3. 0. 0. 0. 0. 0.Plant Services

1\. 0. 0. 0. 0.Heating Ventilation and Air Conditioning System (HVAC)
1\. 0. 0. 0.Nuclear HVAC
2\. 0. 0. 0.Industrial HVAC
2\. 0. 0. 0. 0.Power System Substation
1\. 0. 0. 0.Main transformer w/breakers & switches
2\. 0. 0. 0.Circuit breakers (20kV), auxiliary power transformer
3\. 0. 0. 0.Generating Set and UPS
3\. 0. 0. 0. 0.Heat Rejection System
4\. 0. 0. 0. 0.Service Water System
5\. 0. 0. 0. 0.Solid and Liquid Rad Waste Processing Facility

4. 0. 0. 0. 0. 0.Site Improvements

1\. 0. 0. 0. 0.Roads and Parking
1\. 0. 0. 0.Roadway
2\. 0. 0. 0.Parking
3\. 0. 0. 0.Lighting
2\. 0. 0. 0. 0.Grading and Landscaping
1\. 0. 0. 0.Clearing and Grading
2\. 0. 0. 0.Landscaping
3\. 0. 0. 0.Fencing
3\. 0. 0. 0. 0.Storm Drainage

6. 0. 0. 0. 0. 0. 0. Common Instrumentation and Central Control Systems

1. 0. 0. 0. 0. 0. System Manag.

1\. 0. 0. 0. 0. Project Manag. and Administration
1\. 0. 0. 0. Administration
2\. 0. 0. 0. Cost Control
3\. 0. 0. 0. Schedule
4\. 0. 0. 0. Doc.
2\. 0. 0. 0. 0. Systems Engineering
1\. 0. 0. 0. Design Integration
2\. 0. 0. 0. Systems Analysis
3\. 0. 0. 0. Requirements/Specs
4\. 0. 0. 0. RAM Analysis
3\. 0. 0. 0. 0. Envir., Safety & Health Doc.
4\. 0. 0. 0. 0. Quality Assurance

2. 0. 0. 0. 0. 0. Common Instrumentation Subsystems

1\. 0. 0. 0. 0. Beam Instrumentation
1\. 0. 0. 0. On-Target Profile Monitor
1\. 0. 0. Optical/IR Viewing
2\. 0. 0. Neutron Imaging
1\. 0. 0.
2\. 0. 0. 0. 0. Radiation Monitoring
1\. 0. 0. 0. Radiation Monitor
1\. 0. 0. Hand & Foot Monitor
2\. 0. 0. GM Survey Meter
3\. 0. 0. Dose Meter (gamma & beta ray)
4\. 0. 0. Neutron REM Counter
5\. 0. 0. Surface Tritium Survey Meter
6\. 0. 0. Portable Tritium Survey Meter
7\. 0. 0. Pocket Dosemeter
8\. 0. 0. Liquid Scintillation Counter
9\. 0. 0. Personnel Glass Dosimeter
10\. 0. 0. Stack Gas Monitor
11\. 0. 0. Stack Dust Monitor
12\. 0. 0. Integral Tritium Monitor
13\. 0. 0. Room Gas Monitor
14\. 0. 0. Neutron Area Monitor
15\. 0. 0. Gamma-ray Area Monitor
16\. 0. 0. Outdoor Monitoring Post
17\. 0. 0. Leak Detector for Organic Loop
18\. 0. 0. Indication Panel
19\. 0. 0. Air Sampling System
20\. 0. 0. Documents
2\. 0. 0. 0. Device Controller
1\. 0. 0. CPU (DVE-AT486, 486, 32MB)
2\. 0. 0. ADC (MVNE-512, 16ch)
3\. 0. 0. Data Input (DVE-528, 49ch)
4\. 0. 0. Data Output (DVE-529, 16ch)
5\. 0. 0. Chassis
6\. 0. 0. Software (Windows-NT)
3\. 0. 0. 0. 0. Video Monitoring
1\. 0. 0. 0. ITV Camera (Low Radiation Area)
1\. 0. 0. CCD Camera
2\. 0. 0. Zoom Lens
3\. 0. 0. Camera Case, Pan Head
4\. 0. 0. Pan Head Controller
5\. 0. 0. Power Supply
6\. 0. 0. Modurator
7\. 0. 0. UPS
2\. 0. 0. 0. ITV Camera (High Radiation Area)
3\. 0. 0. 0. Display
1\. 0. 0. Demodurator
2\. 0. 0. Video-amp
3\. 0. 0. Video Monitor
4\. 0. 0. CPU Unit
5\. 0. 0. Touch Sensor
6\. 0. 0. LAN Box, LAN Translator
7\. 0. 0. Power Supply
4\. 0. 0. 0. Device Controller
1\. 0. 0. Cubicle
2\. 0. 0. Video Switcher
1\. 0. 0. Character/Symbol Generator
2\. 0. 0. Video Controller
2\. 0. 0. Camera Control Terminal
4\. 0. 0. 0. 0. Access Control
1\. 0. 0. 0. Door Limit Switch
1\. 0. 0. Limit Switch
2\. 0. 0. Door Lock
2\. 0. 0. 0. Keybank
1\. 0. 0. Key Switch Panel
2\. 0. 0. Interlock Unit
3\. 0. 0. CPU & Memory
4\. 0. 0. I/O Unit
5\. 0. 0. Programming Tool
6\. 0. 0. Power Source
7\. 0. 0. UPS
8\. 0. 0. Cable, Connector, Terminal Block, MCB
3\. 0. 0. 0. Warning Light
1\. 0. 0. Warning Light
5\. 0. 0. 0. Emergency Stop Switch

1. 0. 0. Switch Box
5. 0. 0. 0. 0. Announciator
1. 0. 0. 0. Speaker
1. 0. 0. Speaker
2. 0. 0. 0. Device Controller
1. 0. 0. Cubicle
2. 0. 0. Amplifier
3. 0. 0. Auto-paging System
3. 0. 0. Control Unit
4. 0. 0. UPS
6. 0. 0. 0. 0. Information Display Stations
1. 0. 0. 0. CATV Network
1. 0. 0. Distributer
2. 0. 0. TV Processor
3. 0. 0. BS Tuner
4. 0. 0. Modulator
5. 0. 0. Mixer
6. 0. 0. Network
2. 0. 0. 0. Controller
1. 0. 0. Amplifier
2. 0. 0. Control System
3. 0. 0. Modulator
3. 0. 0. 0. Display Terminals
1. 0. 0. Demodulator
2. 0. 0. Video Monitor
7. 0. 0. 0. 0. Safety and Emergency Equipments
1. 0. 0. 0. Oxygen Deficit
1. 0. 0. Oxygen Sensor
2. 0. 0. Indicator/Controller
3. 0. 0. Recorder
2. 0. 0. Escape Mask for Oxygen Deficit
3. 0. 0. Oxygen Rescue
2. 0. 0. 0. Fire-proof
1. 0. 0. Fire-proof Protective Clothing
3. 0. 0. 0. Radio Active Gas Leak
1. 0. 0. Self-contained Breathing Apparatus
1. 0. Mask with Bombe
2. 0. Storage Case

3. 0. 0. 0. 0. 0. Central Control Subsystems
1. 0. 0. 0. 0. Central Control
1. 0. 0. 0. Computer System
1. 0. 0. Main Computer (Data Server)
1. 0. Computer (VR410 Basic Set, 128MB)
2. 0. CPU Enhancement (120MHz)
3. 0. 128MB Memory
4. 0. FDDI Adapter
5. 0. Peripheral Equipment
6. 0. Software Manuals
2. 0. 0. Support Computers
1. 0. Computer (VJ110 Basic Set)
2. 0. 128MB Memory
3. 0. CD-ROM Driver
4. 0. Peripheral Equipment
5. 0. Software Manuals
3. 0. 0. Computer Racks, Furniture
1. 0. Cabinet
2. 0. Rack Mount, Filler Panel
3. 0. VR Class Server Mount Kit

2. 0. 0. 0. Data Storage
1. 0. 0. Internal S. E. SCSI DAT 2-16GB
2. 0. 0. Disk Array 16.8GB
3. 0. 0. Magneto-optical Disc 1.3GB
3. 0. 0. 0. Uninterruptable Power Supply
1. 0. 0. 1.8kVA UPS 200V
2. 0. 0. UPS Console
4. 0. 0. 0. Operator Interface
1. 0. 0. X-Window Terminal (21"CRT, 32MB)
2. 0. 0. Console
3. 0. 0. Touch Sensor, Rotary Encoder, Slider
2. 0. 0. 0. 0. LAN
1. 0. 0. 0. Network (Ethernet)
1. 0. 0. HUB for Terminals
2. 0. 0. FDDI Switch
3. 0. 0. PC for Network Observation
4. 0. 0. UPS
2. 0. 0. 0. Substation Interface
1. 0. 0. HUB for Central Control
2. 0. 0. Substation HUB
3. 0. 0. 0. Network Printer
1. 0. 0. Color Printer
2. 0. 0. Monochrome Printer
3. 0. 0. 0. 0. Interlock Logic
1. 0. 0. 0. Hardwired Logic
1. 0. 0. Cubicle
2. 0. 0. Auxiliary Relay Unit
3. 0. 0. Power Source
4. 0. 0. UPS
5. 0. 0. Cables, Connectors, Terminal Blocks, MCB, etc
2. 0. 0. 0. Logic & Status Display
1. 0. 0. Logic Display Panel
2. 0. 0. Auxiliary Relay Unit
3. 0. 0. Power Source
4. 0. 0. Cables, Connectors, Terminal Blocks, MCB, etc
3. 0. 0. 0. Interface for Computer Control
1. 0. 0. CPU & Memory
2. 0. 0. I/O Unit
3. 0. 0. Programming Tool
4. 0. 0. UPS
5. 0. 0. Cables, Connectors, Terminal Blocks, MCB, etc
4. 0. 0. 0. 0. Central Display Panel
1. 0. 0. 0. Subsystem Status (150")
2. 0. 0. 0. Radiation/Access Status (150")
5. 0. 0. 0. 0. Sequence Synchronizer
1. 0. 0. 0. Timing Data Generator
1. 0. 0. CPU & Memory
2. 0. 0. Clock Pulse Generator
3. 0. 0. Timing Generator
4. 0. 0. EO/OE (Electro-Optical Converter)
5. 0. 0. Clock Pulse Distributer
6. 0. 0. VME Chassis
7. 0. 0. Cubicle
7. 0. 0. UPS
8. 0. 0. Cables, Connectors, Terminal Blocks, MCB, etc
9. 0. 0. Software Development Tool, Licence
2. 0. 0. 0. Interface for Computer Control

1. 0. 0. Communication Controller
2. 0. 0. Software Development Tool, Licence
6. 0. 0. 0. 0. Dummy Substation
1. 0. 0. 0. Computer System
1. 0. 0. Work Station
2. 0. 0. Console Desk
2. 0. 0. 0. Operator Interface
1. 0. 0. Display Panel & Switch Board
2. 0. 0. Auxiliary Relay Unit
3. 0. 0. Power Source
4. 0. 0. Cables, Connectors, Terminal Blocks, MCB, etc
3. 0. 0. 0. Interface for Computer Control
1. 0. 0. CPU & Memory
2. 0. 0. I/O Unit
3. 0. 0. Programming Tool
4. 0. 0. Dummy VME System
5. 0. 0. Cubicle
6. 0. 0. Cables, Connectors, Terminal Blocks, MCB, etc
7. 0. 0. 0. 0. Operation and Configuration Control
1. 0. 0. 0. Operation and Configuration Control Softwares

4. 0. 0. 0. 0. 0. System Install. and Checkout
1. 0. 0. 0. 0. Install. and Test
2. 0. 0. 0. 0. System Verification Testing
3. 0. 0. 0. 0. Operational Maintenance
1. 0. 0. 0. Computer System
1. 0. 0. Main Computer
1. 1. Hardware
2. 2. Software
2. 0. 0. Support Computer
1. 1. Hardware
2. 2. Software
2. 0. 0. 0. Central Control Subsystem
3. 0. 0. 0. Data Operations
4. 0. 0. 0. 0. System Update

7. 0. 0. 0. 0. 0. 0. Operational Startup and Commissioning

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1. 0. 0. 0. 0. 0. Personnel & Overhead
1. 0. 0. 0. 0. Regular Staff
2. 0. 0. 0. 0. Startup Staff

2. 0. 0. 0. 0. 0. Electrical Power
1. 0. 0. 0. 0. Accelerator #1
2. 0. 0. 0. 0. Accelerator #2
3. 0. 0. 0. 0. Balance of Plant

3. 0. 0. 0. 0. 0. Utilities
1. 0. 0. 0. 0. Inert Gas
2. 0. 0. 0. 0. Deionized Water
3. 0. 0. 0. 0. Sewer/Water

4. 0. 0. 0. 0. 0. Maintenance

5. 0. 0. 0. 0. 0. Waste Disposal
1. 0. 0. 0. 0. Contaminated
2. 0. 0. 0. 0. Uncontaminated

APPENDIX 5-C

Annual IFMIF Operating Costs

Operations

A. Annual Estimated Cost:

Average: 67,000 kilo ICF/Year

Minimum: 56,000 kilo ICF/Year
Maximum: 78,000 kilo ICF/Year

B. Description:

The cost of operating IFMIF for a normal year has been computed based on the cost of six major elements:

Personnel,
Electric Power,
Utilities (other than power),
Maintenance,
Waste Disposal, and
Miscellaneous.

Personnel and electric power dominate the total cost. Electric power is also a major variable among the parties thus using the differences in this cost a range of total operating costs was developed. The United States would be the least expensive, Japan the most and Europe approximately the average.

C. Detailed WBS Listing:

See Worksheets

D. Costing Rational:

See Worksheets

E. Detailed Costing:

	Estimate		AFI	Total	Maximum	Minimum
1 Personnel	$22,999K	10%	$ 2,300K	$ 25,299K	$ 25,299K	$ 25,299K
2 Electric Power	$31,556K	0%	$ -	$ 31,556K	$ 42,053K	$ 20,299K
3 Utilities	$ 689K	25%	$ 172K	$ 862K	$ 862K	$ 862K
4 Maintenance	$ 8,000K	0%	$ -	$ 8,000K	$ 8,000K	$ 8,000K
5 Waste Disposal	$ 483K	25%	$ 121K	$ 603K	$ 603K	$ 603K
6 Miscellaneous	$ 1,000K	0%	$ -	$ 1,000K	$ 1,000K	$ 1,000K
				$67,320K	**$77,817K**	**$56,063K**

WORKSHEET
Operating Personnel

A. Estimate of Annual Personnel Operating Expense:

25,299 kilo ICF/year

B. Description:

This element includes the technical, managerial and operating staff on-site to operate the IFMIF Facility during during a single full-power year following plant commissioning.

C. Detailed Listing:

See listing in Table 1 below.

D. Costing Rational:

The personnel costs were determined in a two step process; first, the unit cost for each type of personnel (i.e. technicians, managers, engineers and shop labor) including all burdens and overhead in each of the prospective countries was determined. The summary of the rates is included in attached Table OPS.1. The US figures are based on rates at Oak Ridge National Laboratory and those used by Northrop Grumman in similar estimates The EU rates were provided by Frascati and FZK, and the Japanese rate by JAERI. Since the rates for all the countries are comparable within the accuracy of the overall estimate a single average rate was agreed on.

In the second step of the estimating process, the number of personnel required to operate the facilities during startup of both the total IFMIF facility and the individual technical facilities was estimated by the appropriate groups. In addition, the core of the operations staff expected to be hired during the startup and commissioning period was determined. This group will include key supervisory and technical leaders who will ultimately train the operators. An annual summary for the two years (calendar years 2005 and 2006) of the startup is attached as Table 1.

The Allowance For Indeterminates is established at 10% to account for potential staff increases due to unforseen operating difficulties.

A detailed explanation of the subelements in this WBS is as follows:

- Administration: The plant management team will be composed of a small staff since it is assumed that many adminstrative functions will be supported by the parent facility.

- Operations: The operations staff has been determined by each Facility group in accordance with the requirements of similar facilities. The rational for the number of personnel in the accelerator group is provided in attached memo MEM-96-017.

- Maintenance: This staff has been determined by consensous of the IFMIF CDA Team.

- Experimental Operations

This staff will be start being assembled in the final year of the startup phase.

ESTIMATE TYPE: BOTTOMS UP; each element and unit cost was determined individually based on a detailed analysis of the requirements of IFMIF.

E. Detailed Costing:

Table 1. Operating Personnel Costs

	Shift					Rate	Cost
	1	2	3	4	Total	kICF/yr	kICF/yr
Administration	**4**	**1**	**1**	**1**	**7**		**755**
Plant Manager	1	0	0	0	1	195	195
Office Support	2	1	1	1	5	93	467
Visitor Control	1	0	0	0	1	93	93
Plant Operations	**13**	**7**	**7**	**7**	**34**		**4,284**
Shift Superintendent	1	1	1	1	4	161	642
Plant Operators	4	1	1	1	7	106	744
Plant Protection	3	2	2	2	9	106	957
Safety Officer	1	0	0	0	1	153	153
HP Technicians	4	3	3	3	13	137	1,787
Test Operations	**4**	**3**	**3**	**3**	**13**		**1,992**
Experiment Control	2	1	1	1	5	161	803
Operations Labor	2	2	2	2	8	149	1,190
Target Operations	**2**	**1**	**1**	**1**	**5**		**803**
Supervision	2	1	1	1	5	161	803
Accelerator Operations	**26**	**22**	**22**	**22**	**92**		**11,428**
Supervision	5	5	5	5	20	161	3,210
Operations Labor	10	9	9	9	37	106	3,934
Eng & Tech Support	5	4	4	4	17	149	2,528
Accellerator Shop Labor	6	4	4	4	18	98	1,756
Maintenance	**6**	**4**	**4**	**4**	**18**		**1,961**
Maintenance Manager	1	1	1	1	4	149	595
Shop Labor	5	3	3	3	14	98	1,366
Central Control	**5**	**3**	**3**	**3**	**14**		**1,776**
Central Control Operators	3	2	2	2	9	128	1,155
Data Acquisition	2	1	1	1	5	124	621
Operations Staff	**60**	**41**	**41**	**41**	**183**		**22,999**
Contingency						[10%]	2,300
TOTAL							**25,299**

Note: Personnel costs include all overhead and burdens

WORKSHEET
Operations-Electric Power

A. Annual Estimated Cost:

Average: 32,000 kilo ICF/Year
Maximum: 42,000
Minimum: 20,000

B. Description:

Electric power will be the primary source of power for the facility; notably the accelerators.

C. Detailed Listing of Requirements:

See Section E for listing.

D. Costing Rational:

Because the cost of electricity varies substantially between potential site countries both an average cost and site specific costs are computed. The estimated power costs computed for a 40 MW facility are shown in Table 7.2.1:

Table 1. Average power costs for potential site countries

Costs (40 MW cap'ty)	Capacity kICF/yr	Use Rate ICF/kWhr
Italy		0.131
Germany		0.0934
Japan	5,146	0.12
United States		0.066
Average	1,286	0.103

Note that it has been assumed that the power service provider will install the source transformers and power lines with the resulting capacity charge. At some potential sites an existing power system may reduce or eliminate this cost.

The US power rate is based on a national average computed by the "Energy Information Administration"

Table 2 shows the power requirements estimated for IFMIF a standard full-power operating year. The Allowance For Indeterminates is established at 0% since operating problems will result in reduced power usage.

ESTIMATE TYPE: BOTTOMS UP; each element and unit cost was determined individually based on an analysis of the requirements of IFMIF operations.

E. Detailed Costing:

Table 2. Annual Power Costs

Based on 8766 hours/year

	Full Power Usage Mw	Full Power On-time %	Half Power On-time %	Power Off Time %	Annual Power Usage Mwhr	Average		Max Annual Total kICF	Min Annual Total kICF
						Power Rate ICF/kWhr	Annual Total kICF		
Electric Power					**3.08E+08**	**0.103**	**31,556**	**42,053**	**20,299**
1. 0. Accelerator One	19.2	70%	18%	12%	1.33E+08				
2. 0. Accelerator Two	19.2	70%	18%	12%	1.33E+08				
3. 0. Balance of Plant	5.0	90%	10%	0%	4.16E+07				
1. Test Facilities									
2. Target Facilities									
3. Accelerator Facility									
4. Conventional Fac's									
5. Central Control									

WORKSHEET
Operations -Utilities

A. Annual Operating Estimated Cost:

603 kilo ICF/Year

B. Description:

Conventional Utilities will be purchased from commercial vendors and public utilities to support IFMIF operations. These include, sanitary water, sewer, natural gas for heating and inert gases.

The inert gases are assumed to be provided in over-the-road tank trucks or in bottles delivered by a commercial vendor. The gases will be transferred to on-site storage facilities. The quality of the gases required are important in the cost determination; for this estimate the gases are assumed to be pure at the 10^{-4} level.

It is assumed that there will be a water dionization unit on-site at IFMIF, thus all provided water is potable quality. The water and sewer charges vary by a factor of about eight between the three potential sites; however, an average number is applied because the impact on the total cost is relatively small.

C. Detailed WBS Listing:

See detailed listing in Table

D. Costing Rational:

The estimated costs for each utility service in the three potential site countries are shown in Table:

Table 1 shows the utility requirements estimated for IFMIF during the startup and commissioning process. The estimated usages were provided by each Facility group. Note that the sewer charge assumes that all water is cycled to the sewer system.

The Allowance For Indeterminates is established at 25% to account for probable but unpredictable difficulties which will result in extended operating times and increased utility usage.

ESTIMATE TYPE: BOTTOMS UP (Estimate) each utility requirement is estimated; unit costs were determined individually.

E. Detailed Costing:

Table 1 Anuual Waste Disposal Costs

	Annual		
	Usage m^3	Rate ICF/m^3	Total kICF
Waste Disposal			**603**
Contingency		[25%]	121
			483
1. Uncontaminated	1500	75	113
2. Contaminated	50	7400	370

WORKSHEET
Operations -Maintenance

A. Annual Estimated Cost:

8,000 kilo ICF/Year

B. Description:

Maintenance operations include both labor and material. The labor cost is included in the personnel costs, consequently, this section includes only material. Based on historical precedence the total cost of maintenance is approximately 3% of the TEC. Assuming this divides two-thirds as labor and one-third as material the cost will be approximately 1% of the TEC or roughly 8000 K. Note that since this number is based on the TEC and includes AFI additional AFI is not added.

C. Detailed WBS Listing:

Not Applicable

D. Costing Rational:

See Section B. above

E. Detailed Costing:

None

WORKSHEET
Operations-Waste Disposal

A. Annual Operating Estimate:

862 kilo ICF/Yr

B. Description:

Waste Disposal Services will be purchased from commercial vendors or public services to support IFMIF operations. Uncontaminated waste will be handled and removed via conventional transport. Low level contaminated waste will be handled in accordance with local requirements. High level waste is not included in this estimate; the volume will be relatively small and it is considered the responsibility of the Host country.

Note; it is exteremly difficult to estimate both the type and quantity of waste generated by ifmif. It is also difficult to obtain costs for disposal at most facilities. As a result approximate numbers based on engineering judgement are used in this preliminary estimate.

C. Detailed Component Listing:

See Table below.

D. Costing Rational:

The estimated costs for waste disposal costs in the US were estimated from known costs at ORNL. Costs at other sites in Japan and Europe were guessed.

Table 1 shows the disposal requirements estimated for IFMIF during the startup and commissioning process. The estimated rates were estimated by consensus of the IFMIF design integration group based on engineering judgment.

The Allowance For Indeterminates is established at 25% to account for probable but unpredictable difficulties which will result in extended operations and additional waste.

E. Detailed Costing:

Table 1 Annual Estimated Cost of Utilities

	Usage m^3	Cost ICF/m^3	Total kICF
Utilities			**862**
Contingency		[25%]	172
			689
1. 0. 0. Inert Gas (m^3 @ STP)			**53.1**
1. 0. Argon	3,600	14.61	52.6
1. Test Facilities	600		
2. Target Facilities	3,000		
3. Accelerator Facility	0		
4. Conventional Facilities	0		
2. 0. Liquid Nitrogen	40	9.1	0.4
1. Test Facilities	40		
2. Target Facilities	0		
3. Accelerator Facility	0		
4. Conventional Facilities	0		
2. 0. Helium	10	16.91	0.2
1. Test Facilities	10		
2. Target Facilities	0		
3. Accelerator Facility	0		
2. 0. 0. Water	**376,200**	**0.091**	**34.2**
1. 0. Test Facilities	100,000		
2. 0. Target Facilities	100,000		
3. 0. Accelerator Facility	1,000		
4. 0. Conventional Facilities	175,200		
3. 0. 0. Sewer	**376,200**	**1.6**	**602**

APPENDIX 5-D

Preliminary IFMIF
Cost Estimating
Worksheets

Cost Estimating Worksheets

for

WBS 1.0

Project Management

WORKSHEET
WBS 1.0 Project Management

A. Summary Cost Estimate:

On-Site At IFMIF			
Const. Contractor	Instit'al		
Eng/Man	Eng/Man	AFI	Total
0	0	0	54,800 K

Currency Units: kilo ICF

B. Description:

This element includes all project management costs for the management, administration and control of the overall project. The management of the Facility design, testing and installation activities are included in the Facility costs. The management team will begin to form in 1998 and disband following Commissioning. The peak employment years will be between Project Approval at the beginning of the year 2000 and the completion of the major construction elements at the end of the year 2004. The elements included in this section are as follows:

- Project Management and Administration: includes costs for basic management activities such as administration, cost control and scheduling, and documentation. Also included are administrative support, meetings, and publications. The personnel in this category are assumed to be provided by the parent institute

- Systems Engineering: costs for Systems Engineering after the IFMIF is approved as an official project include engineering activities required to ensure the facility functions properly. This will include management of interfaces, coordination of RAM and oversight of Facility engineering. It is assumed that the supporting institues will provide Systems Engineering personnel.

- Environmental, Safety and Health (ES&H): includes cost of personnel responsible for establishing and maintaining procedures in accordance with the regulations of the country responsible for the Facility. It is assumed that the supporting institues will provide ES&H personnel.

- Quality Assurance (QA): includes cost of personnel responsible for establishing and maintaining quality assurance procedures in accordance with the regulations of the country responsible for the Facility. It is assumed that the supporting institues will provide QA personnel.

- Construction Management; coordination of construction activities for all Facilities, development of construction specifications, oversight of contracts. It is assumed that the construction management activities will be performed by a commercial contractor.

Note project management is considered an "on-site" charge since it is assumed that it will be performed in the host country.

The Allowance For Indeterminates (AFI) is established at 0% since the basis of the number are Facilty estimates which already include AFI factors.

C. Detailed WBS Listing:

1\. 0. 0. Project Management

- 1\. 0. Project Management and Administration
  - 1\. Administration
  - 2\. Cost Control
  - 3\. Schedule
  - 4\. Development Oversight
  - 5\. Documentation
- 2\. 0. Systems Engineering
  - 1\. Design Integration
  - 2\. Systems Analysis
  - 3\. Requirements/Specs
  - 4\. RAM Analysis
- 3\. 0. Environmental, Safety & Health Documentation
- 4\. 0. Quality Assurance
- 5\. 0. Construction Management

D. Costing Rationale:

Project management costs for the overall project are provided in Table 1.0.1. Although the table details personnel counts and distributions the total WBS 1.0 cost is based on a percentage of the Total Estimated Cost (TEC) extrapolated from the historical data given in Table 1.0.2.

The history of large projects shows that all Management and Administration costs, including WBS 1.0 and related costs in each Facility WBS X.1.0, should be between 10 and 15% depending on the complexity of the project. For IFMIF the reduced technical complexity is somewhat off-set by the difficulties of coordination of an international facility. Consequently, the total factor is assumed to be approximately 12.0% of the TEC. Thus, the total cost of WBS 1.0 is assumed to be approximately 6.5% of the TEC with the remaining 5.5% accruing in the management of the individual Facilities. The specific management costs for each Facility are detailed in the appropriate worksheets.

Construction Management (WBS 1.5) has historically been in the range of 3-4 % of the TEC. For IFMIF a value of 3.0% is used since the Technical Facilities (i.e. Test, Target, Accelerator and Central I&C) will be installed under the guidance of the Facility groups and the Conventional Facilities are not as complex as the projects used in the historical comparison list.

The personnel estimates are provided in Table 1.0.1 to cross-check the costs as a test of reasonability. The average personnel loading will peak over a five year period at counts approximately 15% higher than the average shown.

E. Detailed Costing:

The average labor cost used in the personnel analysis assumes:

Type	Rate	Team Mix
Engineers	165 kICF/yr	3
Managers	195 kICF/yr	1
Support	50 kICF/yr	1
Average	148 kICF/yr	

Table 1.0.1
WBS 1.0 Project Management

	Total Estimated Cost (TEC)=	$800,000K			
	Avg Team Personnel Cost=	$148K	PPY		
	Project Duration=	6	Yrs		
		% of TEC	**Cost**	**P-Y**	**Avg. Staff**
1. 0. 0.	**0. Project Management**	**6.50%**	**$52,000K**	**193**	**32.2**
1. 0.	0. Project Manag. & Admin.	20%	$10,504K	71	11.8
1.	0. Administration	10%	$5,200K	35	5.9
2.	0. Cost Control	3%	$1,768K	12	2.0
3.	0. Schedule	3%	$1,768K	12	2.0
6.	0. Documentation Control	3%	$1,768K	12	2.0
2. 0.	0. Systems Engineering	15%	$7,696K	52	8.7
1.	0. Design Integration	5%	$2,600K	18	2.9
2.	0. Systems Analysis	3%	$1,768K	12	2.0
3.	0. Requirements/Specs	3%	$1,768K	12	2.0
4.	0. RAM Analysis	3%	$1,560K	11	1.8
3. 0.	0. ES & H Docum.	10%	$5,200K	35	5.9
4. 0.	0. Quality Assurance	10%	$5,200K	35	5.9
5. 0.	0. Development Oversight	5%	$2,600K	18	2.9
6. 0.	0. Construction Management	46%	$23,972K	162	27.0
	CM as % of TEC	3.00%			

Table 1.0.2. Historical Data for Large US Construction Projects

Completed Projects

Laboratory	Brookhaven				Fermi				SLAC				LLNL		PPPL	
Facility	NSLS I		NSLS II		Tevaton II		Tevaton I		PEP		SLC		MFTF-B		TFTR	
Design Start			Oct-83		Feb-82		Oct-80		Oct-75		Oct-79		FY78		FY76	
Construction Start	Jul-78		Nov-83		Aug-82		Jun-82		Apr-76		Oct-83		FY78		FY77	
Construction Complete			Sep-87		Sep-86		Sep-87		Sep-80		Dec-86		FY86		FY83	
	M$	%	M$	%	M$	%	M$	%	M$	%	M$	%	M$	%	M$	%
Total Estimated Cost (TEC)	**24.01**		**19.43**		**49.80**		**84.01**		**80.16**		**112.97**		**241.40**		**314.00**	
EDI & Manage. (Note 1)	4.65	24%	4.44	30%	4.57	10%	10.54	15%	17.95	29%	23.65	26%	34.60	17%	88.00	39%
Eng. Design and Inspection (EDI)	4.36	23%	3.38	23%	3.98	9%	8.96	12%	16.12	26%	21.19	24%	25.60	12%	69.00	31%
Project Management	0.29	1%	1.06	7%	0.59	1%	1.58	2%	1.83	3%	2.46	3%	9.00	4%	19.00	8%
Construction	19.36		14.61		45.19		72.67		62.21		89.32		206.80		226.00	
Conventional Construction	6.69	35%	7.97	53%	23.60	52%	31.29	43%	30.30	49%	26.73	30%	23.00	11%	66.00	29%
Technical Construction	12.67	65%	6.64	44%	21.59	48%	41.38	56%	31.91	51%	62.59	70%	183.80	89%	160.00	71%
Contingency (Note 2)	0.00	0%	0.38	2%	0.04	0%	0.80	1%	0.00	0%	0.00	0%	0.00	0%	0.00	0%

Footnotes regarding percentage information

1. EDI as percentage of Construction (a/b)
2. Contingency as precent of Construction + EDI+Other
3. Other Project Costs as precent of TEC
4. R&D as percent of Tech. Component Construction
5. Startup as percent of TEC
6. Future Annual Req'd Operating Cost as precent of TPC

Table 1.0.2. Historical Data for Large US Construction Projects

Projects Under Construction

DOE Progam	**Basic Energy Scin**				**Fusion**		**Other**		**HEP**				**Nuclear Phy**			
Facility	**ALS**		**APS**		**TPX**		**EMSL**		**B-Fact**		**FMI**		**CEBAF**		**RHIC**	
Data Sheet Version	92 CBR		95 CBR		95 CBR		95 CBR		95 CBR		95 CBR		95 CBR		95 CBR	
Date of Submission or Update	Jan-91		Mar-94		Mar-94		Mar-94		Mar-94		Mar-94		Mar-94		Mar-94	
Construction Complete	Mar-93		Oct-96		Oct-00		Oct-96		Feb-98		Mar-99		Oct-94		Feb-99	
	M$	%	M$	%	M$	%	M$	%	M$	%	M$	%	M$	%	M$	%
Total Project Cost (TPC)	**145.97**		**819.28**		**694.00**		**229.90**		**293.20**		**259.30**		**513.11**		**595.25**	
Total Estimated Cost (TEC)	**99.50**		**474.53**		**597.00**		**207.90**		**177.00**		**229.60**		**313.20**		**475.25**	
EDI & Manage. (#1)	23.30	40%	81.00	23%	162.60	50%	69.28	60%	33.00	30%	26.30	16%	63.70	27%	77.66	30%
Eng. Design and Inspection	15.95	27%	61.74	18%	148.40	46%	44.93	39%	29.10	26%	26.30	16%	50.00	21%	46.59	18%
Construction Management	0.00	0%	11.91	3.4%	14.20	4.4%	4.99	4.3%		0%		0%		0%	31.07	12%
Project Management	7.35	13%	7.35	2%		0%	19.36	17%	3.90	4%		0%	13.70	6%		0%
Construction	58.56		346.20		325.40		115.95		111.00		165.00		234.50		258.86	
Conventional Construction	14.88	20%	136.63	35%	3.30	1%	43.78	32%	4.80	3%	79.20	39%	60.00	24%	9.73	2%
Technical Construction	43.68	57%	209.57	53%	322.10	74%	72.17	52%	106.20	74%	85.80	42%	174.50	70%	249.13	63%
Other (Std Equip. etc)							2.24									
Contingency (#2)	17.64	22%	47.33	11%	109.00	22%	20.43	11%	33.00	23%	38.30	20%	15.00	5%	26.73	8%
Other															112.00	

Cost Estimating Worksheets

for

WBS 2.0

Test Facility

WORKSHEET
WBS 2. 1. 0 Test Facility Management

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
				3000	0	0	0	0	0

Currency Units: kilo ICF

B. Description:

All the management activities required to directly support and complete the Test Facility are included in this element. These include:

- Project Management and Administration: basic management costs such as administration, cost control and scheduling, and documentation. Under each of these categories factors such as administrative support, meetings, and publishing are included.
- Systems Engineering: costs for Systems Engineering after the IFMIF is approved as an official project will be estimated based upon anticipated activities needed to support the procurement of each item in the Test Facility including:
    - Preparation of Specifications
    - Preparation of Preliminary Design
    - Fabrication Oversight
    - Verification Testing Oversight
    - Installation Planning and Coordination
    - Installation Oversight
    - Startup Oversight
- Environmental, Health and Safety Documentation: support for personnel responsible for establishing and maintaining procedures in accordance with the regulations of the country responsible for the Test Facility.
- Quality Assurance: support for personnel responsible for establishing and maintaining quality assurance procedures in accordance with the regulations of the country responsible for the Facility.

C. Detailed WBS Listing:

1. 0. 0. 0. 0. Test Facility Management
1. 0. 0. 0. Project Management and Administration
1. 0. 0. Administration
2. 0. 0. Cost Control
3. 0. 0. Schedule
4. 0. 0. Documentation
2. 0. 0. 0. Systems Engineering
1. 0. 0. Design Integration
2. 0. 0. Systems Analysis
3. 0. 0. Requirements/Specs
4. 0. 0. RAM Analysis
3. 0. 0. 0. Environmental, Safety & Health Documentation
4. 0. 0. 0. Quality Assurance

D. Costing Rationale:

The cost of management is based on a factor of approximately 3% of the Test Facilty TEC.

E. Detailed Costing:

Not Applicable

WORKSHEET
WBS 2.2.1.1 NaK Thermally Controlled High-Flux Vertical Test Assembly
(VTA-1 for Test Cell I)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
248	55	621	185	1109					

Units: U. S. Dollars ($1,000)

B. Description:

VTA-1, which includes the 0.5-L high-flux module, is shown in Fig below. One of the primary design considerations of the VTA-1 is to provide the experimenter with a thermally controlled and well-characterized environment. Because of the thermal considerations in the high flux region, the VTA-1 should be designed with a reliable thermal control system. To accomplish this the high-flux module has been divided into three chambers, each of which is thermally controlled by a liquid metal (NaK) loop. Each chamber is thermally controlled by a separate NaK thermal control system located on top of VTA 1. Each NaK thermal control system consists of a 5-L sump tank, a 2.5-kW cooler a 5-kW heater and a 100-kg/min. induction pump. The thermal control supply and return lines between the thermal control system and module are contained within a through passage that is provided in the Shielding Body. The thermal control line passage is stepped to reduce radiation streaming to the Test Cell Access Room. A vacuum is maintained in this through passage to prevent oxidation of the thermal control lines at elevated temperatures (1000° C and 800° C).

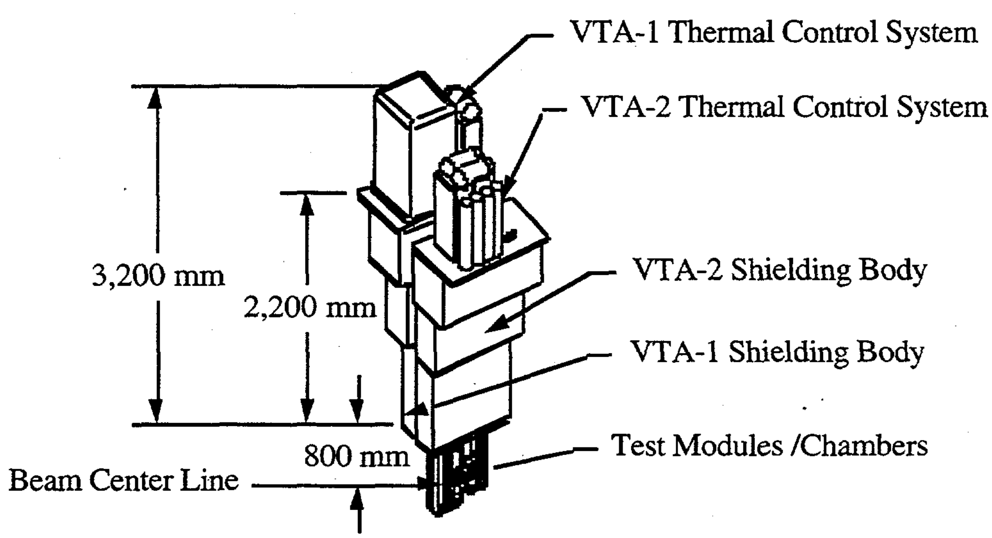


Figure of NaK Thermally Controlled Vertical Test Assemblies VTA-1 and VTA-2

C. Detailed WBS Listing

There are no other WBS Listings in this section of the WBS. The NaK Thermally Controlled High-Flux Vertical Test Assembly (VTA-1), WBS 2.2.1.1, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the VTA-1. The methods, requirements, and procedures for assembly of the VTA-1 were also so evaluated. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the VTA-1 assembly. The fabrication cost is based on a $67.00 hourly rate.

Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the VTA-1 were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 98.50 hourly rate.

E. Detailed Costing:

Engineering estimate for design of VTA-1 Assembly:		
a. two (2) E size drawings	300 hr.	$ 29,550
Labor estimate for assembly of VTA-1 (VTA-1 Body, thermal control Lines, sump pumps, heat exchangers, etc.):	300 hr.	$ 20,100

High Flux VTA-1 Shielding Body TOTAL $136,070

The Shielding Body of the High Flux VTA-1 consists of a stepped, stainless steel liner that is filled with barytes concrete. The liner is equipped with three steps that interface with the TCRC and SP to eliminate irradiation streaming. A through passage is incorporated into each Shielding Body to accommodate the NaK thermal control lines and instrumentation cabling. This through passage is vacuum tight.

Engineering estimate for design of High Flux VTA-1 Body:		
a. six (6) E size drawings	600 hr.	$ 59,100
b. heat transfer calculations	200 hr.	$ 19,700
Labor estimate for fabrication of High Flux VTA-1 Body:		
a. metal prep 34 PC of stainless	240 hr.	$ 16,080
b. welding 35 M X 12.7 mm	210 hr.	$ 14,070
c. machining for O-RING seals @ top and passages, and mounting interfaces	200 hr	$ 13,400
d. Installation of barytes concrete	160 hr.	$ 10,720
Materials estimate for fabrication of High Flux VTA Body (1700 LB stainless @ $1.50/LB. and 4500 LB barytes concrete @ $0.10/LB.)		$ 3,000

High Flux VTA-1 Piping: TOTAL $ 49,935

Six thermal control line assemblies each 25.4 mm Dia., 2.5 M long with eight 90 degree joints, constructed from 1% zirconium and 99% niobium alloy.

Engineering estimate for design of VTA-1 High Flux thermal control lines:.		
a. two (2) E size drawings	200 hr.	$ 9,850
b. heat transfer calculations	200 hr.	$ 4,925
Labor estimate for fabrication of High Flux thermal control lines:		
a. metal prep 18 PC of pipe	100 hr.	$ 5,360
b. welding 48-90 degree joints	400 hr.	$ 26,800
Materials estimate for fabrication of High Flux VTA-1 Piping (15M of 25.4 mm ID. tube and 48-90 degree joints)		$ 3,000
High Flux VTA-1 Thermal Control System	TOTAL	$687,850
Engineering estimate for design of VTA-1 High Flux thermal control system:		
a. three (3) E size drawings	300 hr.	$ 29,550
b. heat transfer/hydraulic calculations	300 hr.	$ 29,550
Engineering estimate for development/design of VTA-1 High Flux thermal control system:		
a. Develop Induction/Conduction pumps	1500 hr.	$146,250
b. Develop NaK Coolers	1500 hr.	$146,250
c. Develop NaK Heaters	1500 hr.	$146,250
Procurement estimate for VTA-1 High Flux thermal control system:		
a. Three 100 Kg/Min. induction pumps		$ 60,000
b. Three 5 kW coolers		$ 60,000
c. Three 2.5 kW Heaters		$ 60,000
d. Three 5L sump Tanks		$ 10,000

WORKSHEET

WBS 2.2.1.2 Helium gas controlled High Flux Vertical Test Assembly for high temperatures (VTA1-Helium for Test Cell I)

A. Summary Cost estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,207	290	60	311	1,868			120	24	144

Units: 1,000 ICF (1 ICF = 1.52 DM)

B. Description:

This high temperature device (VTA1-Helium) includes the 0.5 L high flux test module. One of the primary design considerations of the VTA-1-Helium is to provide a test module for specimen temperatures up to 1000 ∞C. In addition this device offer

- operational flexibility; various different specimen temperatures can be adjusted in one single test module'
- proper specimen temperature control with thermocouples and with integrated ohmic heaters in the specimen encapsulation,
- reduced risk of overall VTA failure
- fast access to VTA and test module (decay heat controlled)
- upgrading capabilities.

Helium gas as coolant has good compatibility with structural materials in particular and for safety considerations with the Li-target. The VTA1-helium is controlled by a helium gas coolant loop. All coolant tubes and electrical connectors are stepped within the shielding body in order to reduce radiation streaming to the Test cell Access Room.

C. Detailed WBS Listing:

2.2.1.2. High flux VTA (VTA-1-Helium):

- 2.2.1.2.1 Rigs for encapsulated specimens
- 2.2.1.2.2 Test Module
- 2.2.1.2.3 VTA shielding body
- 2.2.1.2.4 Helium coolant loop

D. Costing Rationale :

Engineering efforts, fabrication methods, requirements, and procedures were evaluated for the feasibility, fabrication and assembly of each major component of the VTA-1-Helium. From these evaluations, fabrication man-hour estimates were made by the German industry (2.2.1.2.1 - 2.2.1.2.3), and the FZK and Industry (2.2.1.2.4) based on the amount of welding, machining metal preparation and general labor required for fabrication and assembly. Engineering deliverables (such as drawings, FE-calculations, specifications) required for the design were also evaluated. An engineering man-our estimate was made based on these deliverables. The underlying engineering cost is based on DM 120,-or ICF = 75.4 hourly rate.

E. Detailed Costing:

2.2.1.2.1 Rigs for encapsulated specimens:

Construction: (3 sizes A, B, C) incl. drawings and listings of items,

Clarification of Fabrication	110.000,- DM	62,500 ICF
Laboratory costs		
see Attachment (PET comp., p.16)	35.000,- DM	23,000 ICF
TOTAL		85.500 ICF

Fabrication: see Attachment (PET company, p.15)

Specimen encapsulations with integrated Ohmic heaters, Thermoelements, distance holders and rigs (32x)		
	179.200, DM	117,900 ICF
	11.200, DM	7,400 ICF
Rig fabrication (32x)	224.000, DM	50,200 ICF
Assembly incl. welds	64.000, DM	42,100 ICF
Plug system to VTA body: (64x)		
	28.800, -DM	19,000 ICF
Gas and electric power central plug system (metal sealed, 32x)		
	224.000,- DM	147.400 ICF
Fitting material	8.000,- DM	5,300 ICF
TOTAL		389,300 ICF

2.2.1.2.2 Test Module

Construction (see attachment, p.15):	120.000,-DM	79,000 ICF
Static's, FE-calculations	13.000,- DM	8,600 ICF
Development, optimization, sealing tests	55.000,- DM	36,200 ICF
TOTAL		123,800 ICF

Fabrication (see attachment p. 15):		
He-Vessel to grate insets for rigs	120.000,-DM	79,000 ICF
Complete electron beam welding with grates	56.000,- DM	36,800 ICF
Seal plates and flanges	45.000,- DM	29,600 ICF
Upper part above grate insets	182.000,- DM	119,700 ICF
Interface flange	25.000,- DM	16,400 ICF
Metal seals, screws, fittings	8.000,- DM	5,300 ICF
TOTAL	436.000,- DM	286,800 ICF

2.2.1.2.3 VTA shielding body :

Construction (see attachment p. 15,16):		
	90.000,-DM =	59,200 ICF
Fabrication (see attachment):		
Interface to test module	175.000,-DM	115,100 ICF
Steel rips incl. Vessel	370.000,-DM	243,400 ICF
He-coolant ducts, fittings, connectors, etc.	28.000,- DM	18,400 ICF
He-pipes	21.000,- DM	13,800 ICF
Flanges and concrete	18.000,- DM	11,800 ICF
TOTAL	643.000,- DM	423,000 ICF

2.2.1.2.4 Helium gas coolant loop:

According to INTERATOM (SIEMENS Company) design layout for FZK High Energy Dual Beam Facility):

Construction and System specification:		
20% of Fabrication costs	33.000,- DM	21,700 ICF

Fabrication: Root pump incl. motor WKP 8000 (<8000 m^3 from Balzers

30 kW electric power	72.070,- DM	
Rack carrying pump, heat exchanger, valves, instrumentation and fittings (without pump and heat exchanger)		
	25.000,-DM	
Compact heat exchanger	2.500,-	
Complete loop control rack	43.000,-	
Tubes for helium gas inlet and outlet to VTA-1-Helium:		
	21.000,-	
TOTAL	163.570,- DM	107.600 ICF

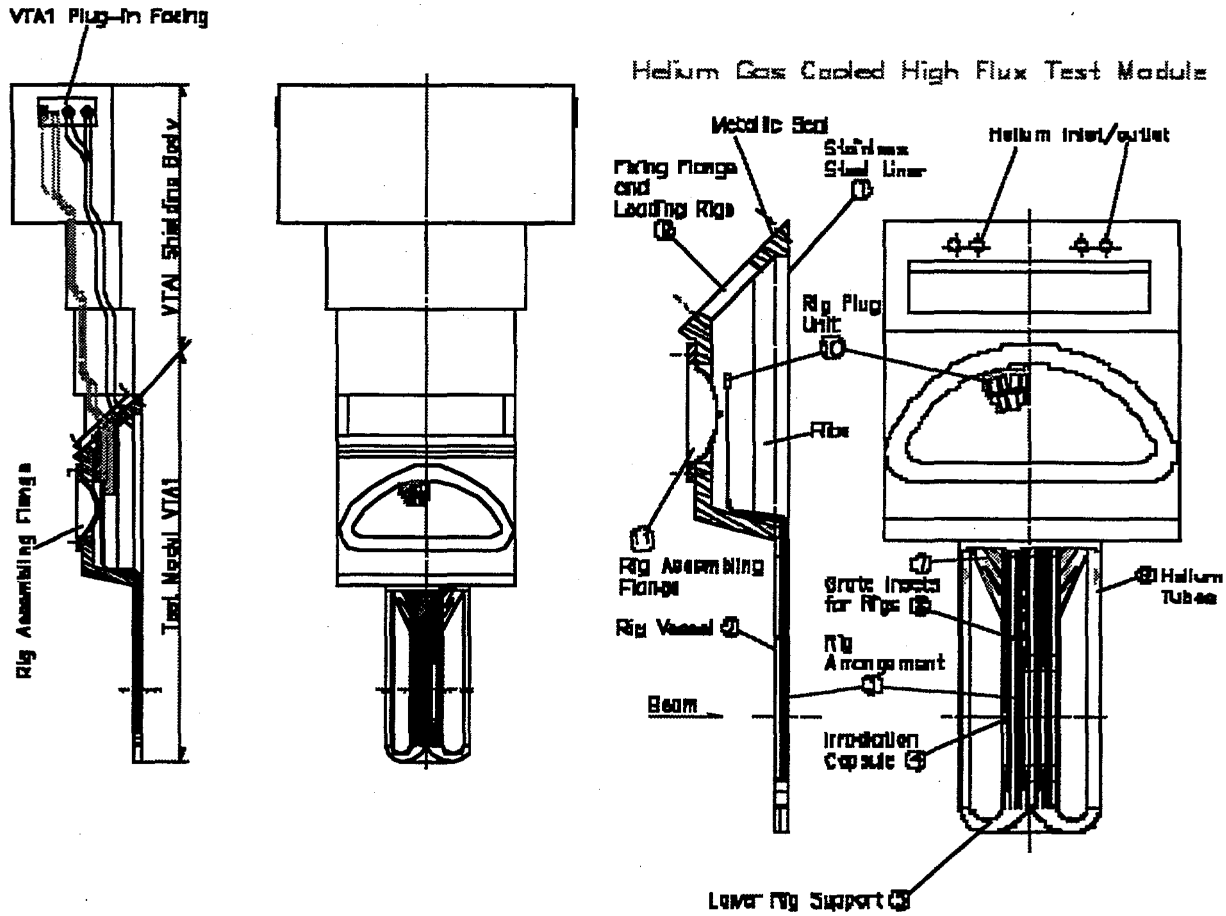


Fig. 2.2.1.2: Elevation and front view of the Helium cooled high flux Test Assembly VTA1-He

WORKSHEET

WBS 2.2.1.3 Helium gas controlled Medium flux Vertical Test Assembly for in situ Creep-Fatigue Tests (VTA 2-He Creep-Fatigue for Test Cell I)

A. Summary Cost estimate

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
695	104	25	165	989			120	24	144

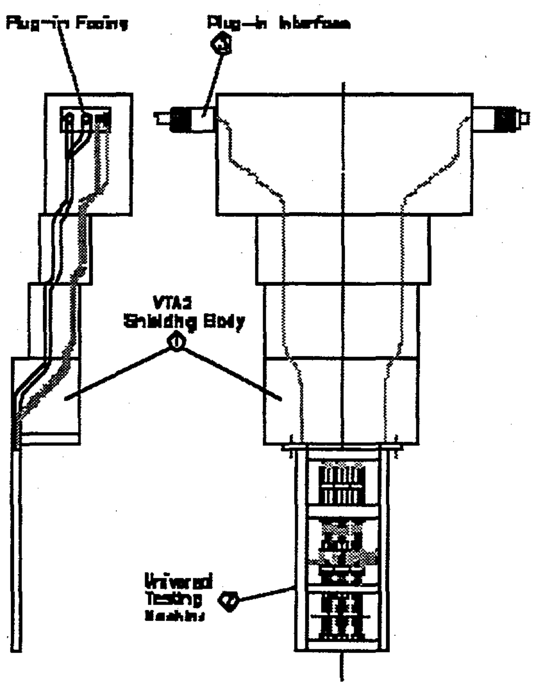
Units: 1,000 ICF (1 ICF = 1.52 DM)

B. Description:

Inert gas cooled (usually helium) medium flux Vertical Test Assembly for instrumented in-situ creep fatigue tests. The complete assembly consists of

- the test module with a miniaturized universal testing machine for individual creep fatigue tests on 3 push-pull fatigue specimens
- the VTA 2 Shielding body with integrated pipes and instrumentation
- the helium gas coolant loop

A suitable specimen design has been already developed which ensures high flexibility with respect to choice of coolant , dynamic temperature variations; mechanical loading conditions and beam-on or beam-off scenarios.



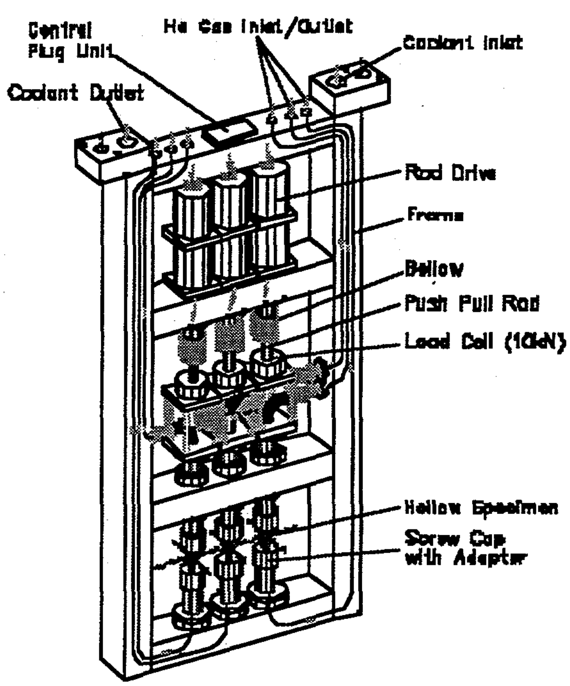


Fig. 2.2.1.3: Elevation view of the VTA 2-He and bird's view of test module for in situ creep-fatigue tests.

C. Detailed WBS Listing:

2.2.1.3. High flux VTA (VTA-1-Helium):

- 2.2.1.3.1 Test module with universal testing device and specimens
- 2.2.1.3.2 VTA shielding body
- 2.2.1.3.3 Helium coolant loop

D. Costing Rationale:

Engineering efforts, fabrication methods, requirements, and procedures were evaluated for the feasibility, fabrication and assembly of each major component of the VTA-2-Helium. From these evaluations, fabrication man-hour estimates were made by the German industry (2.2.1.3.1 & 2.2.1.3.2), and the FZK AND Industry (2.2.1.3.3) based on the amount of welding, machining metal preparation and general labor required for fabrication and assembly.
Engineering deliverables (such as drawings, FE-calculations, specifications) required.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

2.2.1.3.1 Test module with universal testing device:

a) Construction (see attachment):

	100.000,- DM	65,000 ICF

b) Fabrication (see attachment)

Frame with low activation austenitic steel with complete universal testing devices for 3 specimens, He-coolant tubes, bellows, motors, load cell, incl. assembling

	115.000,- DM	
	85.000,- DM	
	42.000,- DM	
	10.000,- DM	
	10.000,- DM	
	14.000,- DM	
	25.000,- DM	
TOTAL	301.000,- DM	198,000 ICF

2.2.1.3.2 VTA 2 shield body:

a) Construction (see attachment):

	60.000,- DM	39,000 ICF

b) Fabrication (see attachment)

	70.000,- DM	
	420.000,- DM	
	21.000,- DM	
	21.000,- DM	
	14.000,- DM	
	14.000,- DM	
	3.000,- DM	
TOTAL	563.000,- DM	370,000 ICF

2.2.1.3.3 Helium gas coolant loop:

Because of compatibility and redundancy the same coolant loop as specified for VTA-1-He is suggested, even if the nuclear heat production in the mid flux region is not as high as in the high flux one. According to INTERATOM (SIEMENS Company) design layout for FZK High Energy Dual Beam Facility):

Construction and System specification:

20% of Fabrication costs	33.000,- DM	25,400 ICF

Fabrication: Root pump incl. motor WKP 8000 (<8000 m^3/h from BALZERS

30 kW electric power	72.070,- DM	
Rack carrying pump, heat exchanger, valves, instrumentation and fittings (without pump and heat exchanger)	25.000,-DM	
Compact heat exchanger	2.500,- DM	
Complete loop control rack	43.000,- DM	
2 Molecular sieves incl. Instr.	30.000,- DM	
Tubes for helium gas inlet and outlet to VTA-1-Helium:	21.000,- DM	
TOTAL	193.570,- DM	127.000 ICF

WORKSHEET

WBS 2.2.1.4 Helium gas controlled Medium flux Vertical Test Assembly for Tritium Release tests on Ceramic Breeders (VTA 2-He Breeders for Test Cell I)

A. Summary Cost estimate

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
640	163	180	197	1,180			150	30	180

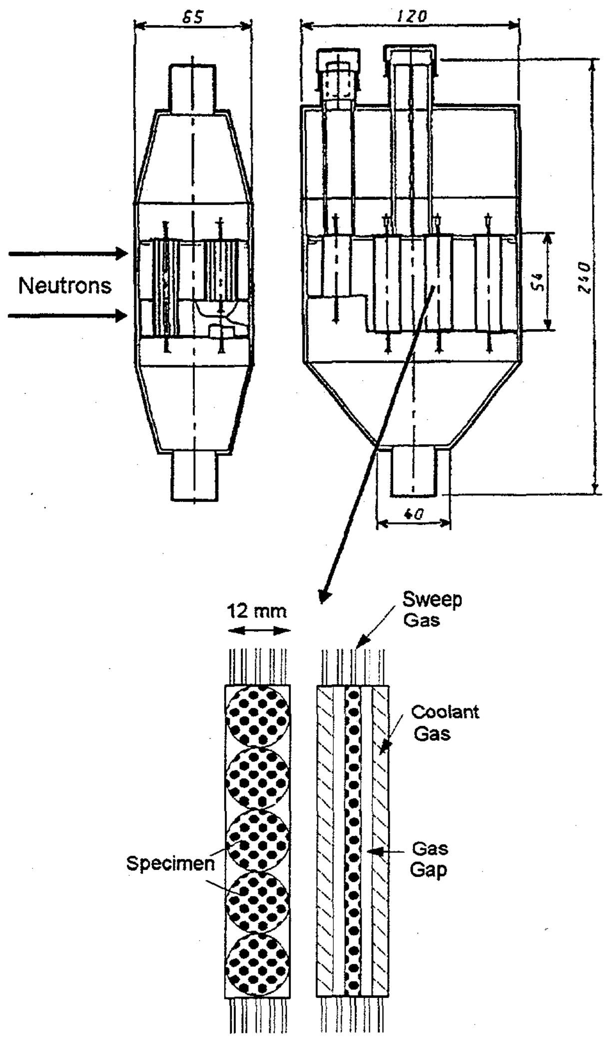
Units: 1,000 ICF (1 ICF = 1.52 DM)

B. Description:

Inert gas cooled (usually helium) medium flux Vertical Test Assembly for instrumented in-situ Tritium release tests on various ceramic breeder materials. The complete assembly consists of

- the test module with at least 4 different subassemblies (chambers)
- the VTA 2 Shielding body with integrated pipes and instrumentation
- the helium gas coolant loop

A suitable specimen design has been already developed which ensures high flexibility with respect to choice of coolant , dynamic temperature variations; mechanical loading conditions and beam-on or beam-off scenarios.



C. Detailed WS Listing:

2.2.1.4. High flux VTA (VTA-1-Helium):

2.2.1.4.1 Subassemblies integrated in one test module
2.2.1.4.2 VTA shielding body
2.2.1.4.3 Helium coolant loop

D. Costing Rationale:

Engineering effort, fabrication methods, requirements, and procedures were evaluated for the feasibility, fabrication and assembly of each major component of the VTA-2-Helium. From these evaluations, fabrication man-hour estimates were made by the JAERI (2.2.1.4.1 & 2.2.1.4.2), and the FZK + Industry (2.2.1.4.3) based on the amount of welding, machining metal preparation and general labor required for fabrication and assembly.
Engineering deliverables (such as drawings, FE-calculations, specifications) required.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

2.2.1.3.1 Test module with integrated subassemblies:

A more global cost estimate of the test module is done by JAERI. However, because the involved specimen volume, the cooling technology and the instrumentation is similar to the Helium cooled High flux test module, the detailed cost estimate of WBS 2.2.1.2.2 is taken:

a) Construction (see 2.2.1.2.2):	TOTAL	123,800 ICF
b) Fabrication (see 2.2.1.2.2)	TOTAL	286,800 ICF

2.2.1.3.2 VTA 2 shield body:

a) Construction (see PET quotation p.19):	60.000,- DM	39,000 ICF
b) Fabrication (see PET quotation p.20):	72.000,- DM	
	370.000,- DM	
	22.000,- DM	
	31.000,- DM	
	21.000,- DM	
	18.000,- DM	
	3.000,- DM	
TOTAL	537.000,- DM	353,000 ICF

2.2.1.3.3 Helium gas coolant loop:

Because of compatibility and redundancy the same coolant loop as specified for VTA-1-He is suggested, even if the nuclear heat production in the mid flux region is not as high as in the high flux one. There is no cost for coolant requirements in this WBS element, because Tritium release tests and creep fatigue tests are not done at the same time. Therefore, the Helium loop specified in WBS 2.2.1.2.3 will be used.

WORKSHEET
WBS 2.2.1.5 Vertical Irradiation Tube (10 VIT's) System for Test Cell I

A. Summary Cost Estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
666	49	1,102	182	1,999	105			21	126

B. Description:

The VIT system consists of an array of tubes, pneumatic pumps, valves and heat exchangers. The VIT system transports pneumatic capsules through an array of tubes from the Loading/Unloading Station to the low and very low irradiation areas in the Test Cell. The pneumatic capsules have OD's of 75 mm and 150 mm. These pneumatic capsules remain in the irradiation region until the specimens are irradiated the desired length of time. The pneumatic capsules are then transported back to the Loading/ Unloading Station where they are removed and placed into a shielded container and transported to the PIE Hot Cells or Lead Boxes.

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The Vertical Tube Irradiation Tube (VIT) system, WBS 2.2.1.5, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the VIT Plug. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the VIT Plug. The fabrication cost is based on a $67.00 hourly rate.

Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the VIT Plug were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 98.50 hourly rate.

The IFMIF VIT Transport/Cooling System is very similar to the ANS pneumatic tube transport system. Therefore the cost estimate of the IFMIF VIT Transport/Cooling System will be based on the cost of the ANS pneumatic tube transport system.

The IFMIF VIT Loading/Unloading Station is very similar to the ANS pneumatic tube Loading Station. Therefore the cost estimate of the IFMIF VIT Loading/Unloading Station will be based on the actual cost of the HFIR pneumatic tube Loading Station.

E. Detailed Costing:

Vertical Irradiation Tube (VIT) Plug TOTAL $220,080

The VIT Plug consist of 10 VITs mounted into a shielding plug arrangement as illustrated below. The 10 VITs are positioned inside a stepped stainless steel liner. Barytes concrete is filled between this liner and the 10 VITs to form the VIT Plug. The barytes concrete provides adequate shielding needed to protect the VTA Access Room from the test cell radiation. The steps in the liner conform to steps in the TCRC and VTA-2 to eliminate radiation streaming. The VITs are mounted in two rows with each row containing 5 VITs. The first row of VITs located closest to the beam source are positioned in the low flux region. The second row of VITs are positioned in the very low flux region.

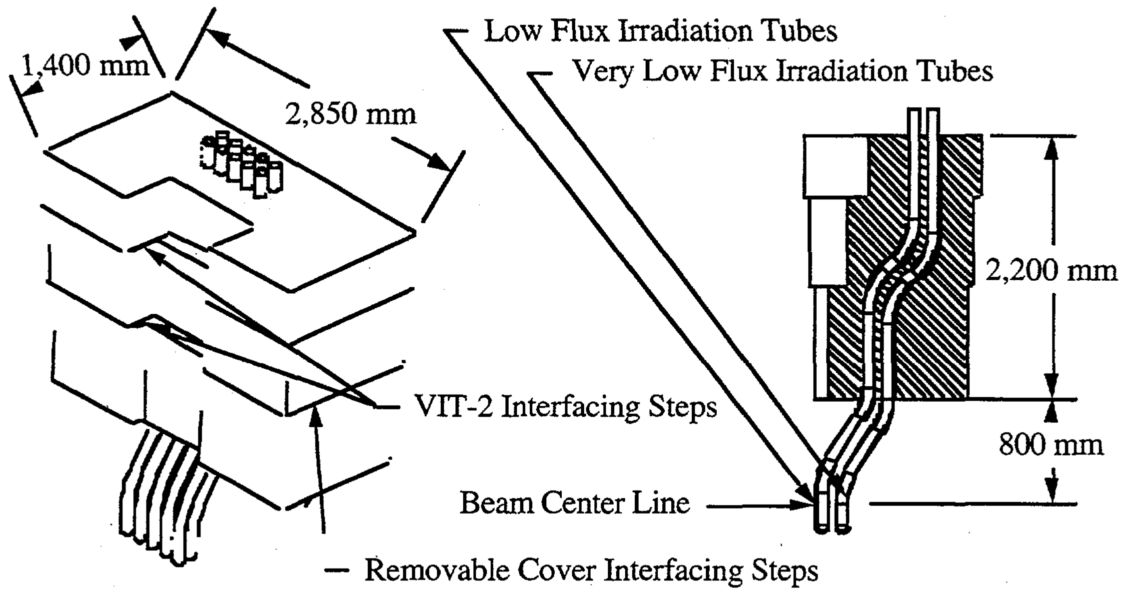


Figure Of The Vertical Irradiation Tube Plug

Engineering estimate for design of VIT plug:		
a. ten (10) E size drawings	1000 hr.	$ 98,500
b. heat transfer/hydraulic calculations	300 hr.	$ 29,550
Labor estimate for fabrication of the VIT Plug:		
a. metal prep 22 PC of stainless plate	100 hr.	$ 6,700
b. metal prep 30 PC (90 M)of double wall stainless pipe each pipe 3.5 M long with 4 bends each	600 hr.	$ 40,200
c. welding 37M X 12.7 mm	250 hr.	$ 16,750
d. machining for Test Cell Seal Plate	40 hr.	$ 2,680
e. Installation of barytes concrete	200 hr.	$ 13,400
Materials estimate for fabrication of VIT Plug: (6000 LB stainless @ $1.50/LB. and 33,000 LB barytes concrete @ $0.10/LB.)		$ 12,300
VIT Transport/Cooling System TOTAL		$557,520

The VIT Transport/Cooling System is located in the Technology Room and consist of coolant flow pumps, valves, and a heat exchanger. The VIT Transport/Cooling System uses circulating gas, probably argon, to transport the pneumatic capsules between the Loading/Unloading Station and the irradiation areas located in the VITs. The VIT Transport/Cooling System is connected to each of the VITs by 80 mm or 160 mm ID tubing running along the wall of the VTA Access Room. The VIT Transport/Cooling System also provides cooling of the pneumatic capsules during irradiation.

The IFMIF VIT Transport/Cooling System is very similar to the ANS pneumatic tube transport system. Therefore the cost estimate of the IFMIF VIT Transport/Cooling System will be based on the cost estimate of the ANS pneumatic tube transport system. The engineering cost for the ANS pneumatic tube transport system was estimated to be $275,000 for 5 pneumatic tubes in 1993. The Engineering effort for the 10 IFMIF pneumatic tubes will be approximately 50 % more involved, which translates to $487,000 in 1996. The Fabrication and Materials cost for the ANS pneumatic tube transport system was estimated to be $14,000 for 5 pneumatic tubes in 1993. This translates to $33,000 for 10 pneumatic tubes in 1996. The installation cost for the ANS pneumatic tube transport system was estimated to be 280 man-hours for 5 pneumatic tubes. This translates to $37,520 for 10 pneumatic tubes at $67.0/hour.

VIT Loading/Unloading Station TOTAL $1,144,400

VIT Loading/Unloading Station is located in the Technology Room and includes its own shielded enclosure. This enclosure contains valves and loading/unloading ports that provide access into the VIT System. The VIT Loading/Unloading Station is used to insert the pneumatic capsules into the VIT System. Here the pneumatic capsules are inserted into the VIT System and then transported to the irradiation area by the VIT Transport/Cooling System. The pneumatic capsules are then transported back to the Loading/Unloading Station where they are removed and placed into a shielded container and transported to the PIE Hot Cells or Lead Boxes.

The IFMIF VIT Loading/Unloading Station is very similar to the ANS pneumatic tube Loading/Unloading Station. Therefore the cost estimate of the IFMIF VIT Loading/Unloading Station will be based on the cost estimate of the ANS pneumatic tube Loading Station. The engineering cost for the ANS pneumatic tube Loading/Unloading Station was estimated to be $275,000 for 5 pneumatic tubes in 1993. The Engineering effort for the 10 IFMIF pneumatic tubes will be approximately 50% more involved, which translates to $487,000 in 1996. The Fabrication and Materials cost for the ANS pneumatic tube Loading/Unloading Station was estimated to be $250,000 for five pneumatic tubes in 1993. This translates to $590,000 for 10 pneumatic tubes in 1996. The installation cost for the ANS pneumatic tube Loading/Unloading Station was estimated to be $200 man-hours for 5 pneumatic tubes in 1993 which translates to $67,400 for 10 pneumatic tubes @ $67.00/hour.

WORKSHEET
WBS 2.2.1.6 Test Cell Shielding Plug for Test Cell I

A. Summary Cost Estimate:
FOR TEST CELL I

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
9		20	6	35					

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell Shielding Plug (SP) interfaces with both VTAs and the Removable Cover. As illustrated below, the Test Cell SP is equipped with steps that conform to the steps in each VTA and the Removable Cover to prevent radiation streaming. The Test Cell Shielding Plug is removed by lifting it straight up. Once the Test Cell SP has been removed ,the VTAs can be lifted out of the Test Cell and into the Test Cell Access Room in any sequence without interfering with the remaining VTA.

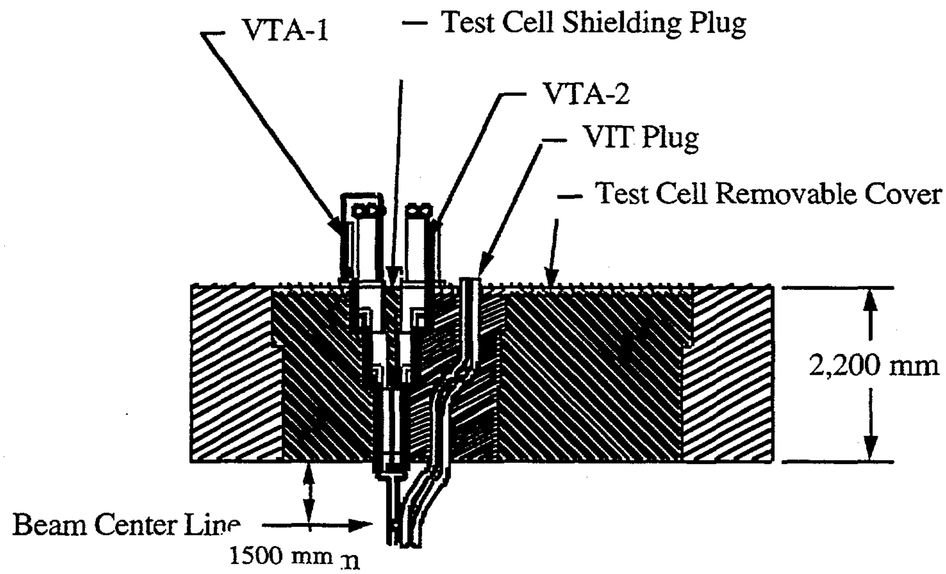


Figure OF Test Cell Shielding Plug Arrangement

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The Test Cell SP WBS 2.2.1.4, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the Test Cell SP. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the Test Cell SP. The fabrication cost is based on a $67.00 hourly rate.

Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the Test Cell SP were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 98.50 hourly rate.

E. Detailed Costing:

Engineering estimate for design of Test Cell SP:		
a. two (2) E size drawings	200 hr.	$ 19,700
Labor estimate for fabrication of Test Cell SP		
a. metal prep 10 PC of stainless	40 hr.	$ 2,680
b. welding 5M X 12.7 mm	35 hr.	$ 2,345
c. machining for VTA/Removable Cover Interface	30 hr.	$ 2,010
d. Installation of barytes concrete	20 hr.	$ 1,340
Materials estimate for fabrication of SP: 250 LB stainless for casing @ $1.50/LB., 500 LB barytes concrete @ $0.10/LB. and $325 misc.)		$ 750

WORKSHEET
WBS 2.2.2.1 Test Cell Removable Cover for Test Cell I

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site				On-Site At IFMIF			
Industry		Instit'al		Const. Contractor		Instit'al	
Mat'l/Lab	Engin'g	Engin'g	AFI Total	Mat'l/Lab	Engin'g	Engin'g	AFI Total
1,045		184	246 1,475				

Units: 1,000 ICF (1 ICF =1.52 DM)

B. Description:

The Test Cell Removable Cover (TCRC) is positioned along top of the Test Cell to provide adequate shielding needed to protect the VTA access area from the test cell radiation as shown below. The TCRC thickness of 2.2 M is adequate to protect the equipment in the Test Cell Access Room (i.e., the dose to the equipment is expected to be small enough to allow the use of organic seal, lubricating, and insulating materials). The TCRC interfaces with the Test Cell Liner to provide a vacuum enclosure within the Test Cell. The TCRC also interfaces with gas cooling ducts that cool the Upper Test Cell Heat Shield (UTCHS). The UTCHS is mounted in the lower portion of the TCRC.. A low-activation stainless steel is used to construct the UTCHS. The UTCHS is approximately 300 mm thick and is cooled on both sides. The UTCHS is positioned 25 mm below the shielding concrete of the TCRC and 25 mm above the bottom exterior lining of the TCRC.

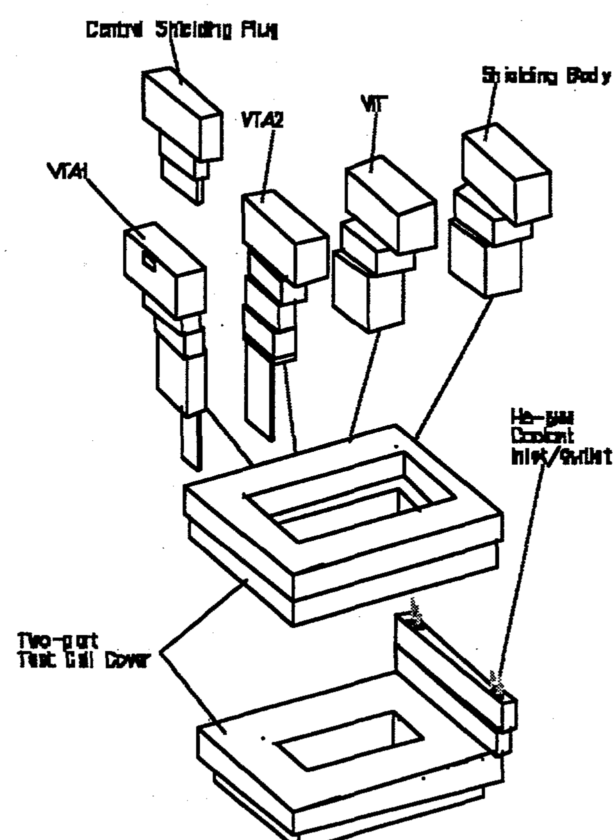


Fig. 2.2.2.1: Two-part Test Cell removable Cover

The TCRC is removable to gain access to the interior of the Test Cell. Vacuum compatible sealing surfaces are placed along the top of the TCRC adjacent to the VTA's and VIT Plug. These sealing surfaces interface with the Test Cell Seal Plate to provide a vacuum tight seal between the VTA's and VIT Plug. In order to reduce the weight for the lifting system the TCRC is sectioned into two parts,

- the upper TCRC with a weight of approximately 66,68 to, and a volume of 16m^3, and
- the lower TCRC with a weight of approximately 57,6 to, and volume of 12 m^3. Integrated rips and coolant pipes are foreseen to guarantee stiffness and ambient temperatures during irradiation.

C. Detailed WBS Listing:

2.2.2.1 Test Cell Removable Cover (TCRC)
- 2.2.2.1.1 Upper Test Cell Removable Cover
- 2.2.2.1.2 Lower Test Cell Removable Cover

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the TCRC. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the TCRC.
Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the TCRC were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a ICU 78.90 hourly rate.

E. Detailed Costing:

2.2.2.1.1 Upper Test Cell Removable Cover:		
Engineering estimate for design :		
a. Construction and FE-calculations	100.000,- DM	65,800 ICF
b. Static,	20.000,- DM	13,200 ICF
Labor estimate for fabrication of TCRC:		
a. metal prep.	325.000,- DM	213.800 ICF
b. welding	185.000,- DM	121,700 ICF
c. ducts and pipes incl. Welding	20.000,- DM	13,200 ICF
d. Fabrication and polishing of seal surfaces, bolts and VTA Interface	170.000,- DM	111,800 ICF
e. Leak tests	15.000,- DM	9,900 ICF
f. Installation of special concrete	95.000,- DM	62,500 ICF
TOTAL	810.000,- DM	533,000 ICF
2.2.2.1.2 Lower Test Cell Removable Cover:		
Engineering estimate for design :		
a. Construction and FE-calculations	140.000,- DM	92,100 ICF
b. Static,	20.000,- DM	13,200 ICF
Labor estimate for fabrication of TCRC:		
a. metal prep.	280.000,- DM	184,200 ICF
b. welding	195.000,- DM	128,300 ICF
c. ducts and pipes incl. Welding	80.000,- DM	52,600 ICF
d. Fabrication and polishing of surfaces, bolts and VTA Interface	125.000,- DM	82,200 ICF
e. Leak tests	15.000,- DM	9,900 ICF
f. Installation of special concrete	95.000,- DM	62,500 ICF
TOTAL	790.000,- DM	512,000 ICF

WORKSHEET
WBS 2.2.2.2 Test Cell Liner for Test Cell I

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
891		155	209	1,255	59			12	71

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell Liner serves as the interior surface of the Test Cell as illustrated in figure shown below. The Test Cell Liner provides the Test Cell with a vacuum enclosure when sealed by the TCRC. The Test Cell Liner is constructed from 20 mm thick low-activation stainless steel to sustain the 1 bar external pressure. Active cooling in the form of circulating gas, probably argon, is provided along the external surface of the Test Cell Liner. This will maintain the interior surface of the Test Cell Liner within a safe temperature.

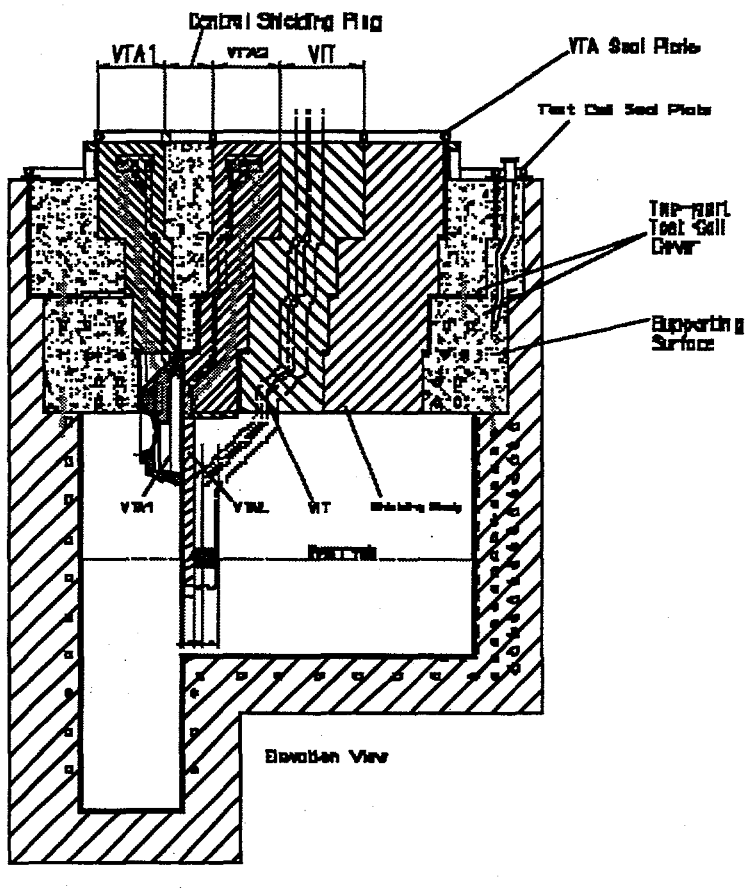


Fig. 2.2.2.2: Figure of Test Cell with Test Cell liner

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The Test Cell Liner, WBS 2.2.2.2, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the Test Cell Liner. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the Test Cell Liner
Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the Test Cell Liner were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 78,90 hourly rate.

E. Detailed Costing:

The offer of the PET Company has been used. A second, much cheaper estimate of ORNL is also available.

Engineering estimate for design of the Test Cell Liner:		
a. Construction, hear transfer calculations, drawings	195.000,-DM	128,300 ICF
b. Static	40.000,- DM	26,300 ICF
Labor estimate for fabrication of the Test Cell Liner (according to PER offer p. 9):		
a. metal prep	910.000,- DM	598,700 ICF
b. coolant ducts, pipes, rips	310.000,-DM	210,500 ICF
c. special fittings for sealing plate, 24 fitting plates	35.000,- DM	23,000 ICF
d leak tests of chamber, all flanges and instruments	90.000,- DM	59,200 ICF
TOTAL	1.355.000,- DM ,	891,000 ICF

ORNL Engineering estimate for installation of the Test Cell Liner:		
a. five (5) E size drawings	500 hr.	$ 48,750
b. calculations	100 hr.	$ 9,750
Labor estimate for installation of the Test Cell Liner:		
a. position and mounting liner in place	500 hr.	$ 33,500
b. welding vacuum lines	300 hr.	$ 20,100
Materials estimate for installation of Test Cell Liner (misc.)		$ 5,000

WORKSHEET
WBS 2.2.2.3 Test Cell Heat Shield for Test Cell I

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
599		255	171	1025	79			16	95

Units: U. S. Dollars ($1,000)

B. Description:

The TCHS is placed between the exterior surfaces of the Test Cell Liner and the interior surfaces of the Shielding Concrete surrounding the Test Cell as shown in figure below. This arrangement reduces the neutronic heat loads in the Test Cell Liner and the Shielding Concrete surrounding the Test Cell. A 25 mm gap is provided between the TCHS and the Shielding Concrete and Test Cell Liner. With the use of the TCHS, the shielding concrete and the Test Cell Liner can be simply cooled from the edges adjacent to the TCHS using the Test Cell Cooling System. This eliminates the need to use cooling passages embedded in the shielding concrete. A low-activation stainless steel is used to construct this shielding with a thickness of 500 mm needed along the surface facing the lithium target and 300 mm along the other Test Cell walls. The shielding is cooled along its interior edges with circulating gas. With this arrangement, the stainless steel heat shield temperature can be maintained to be less than [TBD]°C higher than the gas coolant at all locations. The peak temperature of the shielding concrete surrounding the Test Cell is expected to be only [TBD]°C higher than the Test Cell gas coolant.

An alternative coolant system has been proposed by FZK and PET Company based on coolant ducts integrated in concrete. However, for the cost estimate the ORNL proposal is used.

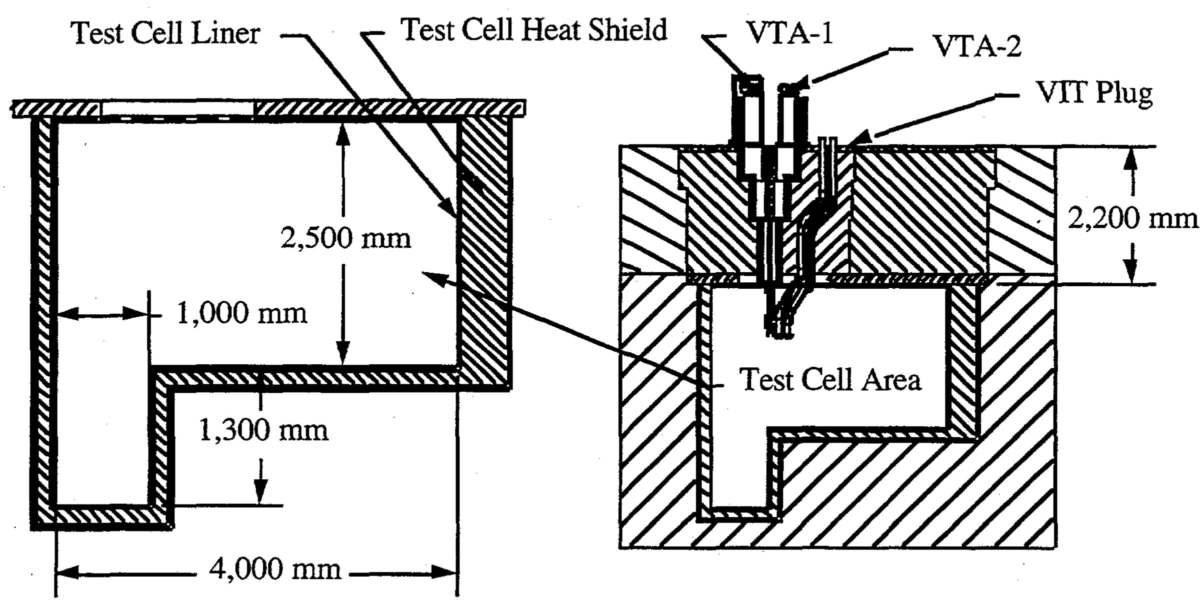


Figure Of Test Cell Liner And Heat Shield

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The TCHS WBS 2.2.2.3, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the TCHS. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the TCHS. The fabrication cost is based on a $67.00 hourly rate.

Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the TCHS were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 98.50 hourly rate.

E. Detailed Costing:

Engineering estimate for design of Test Cell Heat Shield:		
a. ten (10) E size drawings	1000 hr.	$ 98,500
b. heat transfer calculations	600 hr.	$ 58,500
Labor estimate for fabrication of Test Cell Heat Shield :		
a. metal prep 16 PC of stainless steel	1000 hr.	$ 67,000
b. welding 25 M X 12.7 mm	300 hr.	$ 20,100
c. fabrication of Heat Shield supports	200 hr.	$ 13,400
Materials estimate for fabrication of Test Cell Heat Shield		
a. Heat Shield opposite beam: 3000 mm X 2500 mm X 500 mm - 65,000 LB. stainless shielding @ $1.75/LB.		$113,750
b. Heat Shield right of beam: 2500 mm X 4000 mm X 300 mm +1200 mm X 1000 mm X 300 mm - 60,000 LB. stainless shielding @ $1.75/LB.)		$105,000
c. Heat Shield left of beam: 2500 mm X 4000 mm X 300 mm +1200 mm X 1000 mm X 300 mm - 60,000 LB. stainless shielding @ $1.75/LB.)		$105,000
d. Heat Shield in floor: 3000 mm X 6400 mm X 300 mm - 100,000 LB. stainless shielding @ $1.75/LB.		$175,000
Engineering estimate for installation of Test Cell Heat Shield:		
a. eight (8) E size drawings	800 hr.	$ 78,000
b. calculations	200 hr.	$ 19,500
Labor estimate for installation of Test Cell Heat Shield :		
a. position/mounting Heat Shield in place	600 hr.	$ 40,200
b. welding cooling lines	500 hr.	$ 33,500
Materials estimate for fabrication of Test Cell Heat Shield (misc.)		$ 5,000

WORKSHEET
WBS 2.2.2.4 Test Cell Seal Plate

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
309		26	67	402					

Units: U. S. Dollars ($1,000)

B. Description:

Two seal systems are presently considered to be necessary:
- The first sealing system is necessary to seal the removable Test cell Cover and consists of a frame with a thickness of 20 to 25 mm, a O-ring system (diameter 15 mm), size 5.500 x 4.500 mm with bellows to adjust different levels and an inner plate
- The second sealing system is necessary for the VTAs and the VIT system. This Test Cell Seal Plate (TCSP) is located on top of the TCRC and interfaces with each VTA and the VIT Plug. The TCSP provides a vacuum seal for the Test Cell by sealing each VTA and the VIT Plug to the Removable Cover. The vacuum sealing surfaces for each VTA and the VIT Plug is located along its top seal plate. The TCSP mates with these seal plates and another seal plate mounted in the Removable Cover. Fig. 2.2.2.2 shows the seal ing systems.

C. Detailed WBS Listing:

2.2.2.4 Test Cell Seal Plates:
- 2.2.2.4.5 Seal frame for the removable Test cell cover
- 2.2.2.4.6 Seal Plate for the VTAs and the VIT

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the TCSP. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the TCSP.

Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the TCSP were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 78.90 hourly rate.

Two estimates have been made, one by the ORNL and the second by the German industry (PET): For the cost estimate the offer of PET has been used.

E. Detailed Costing:

Engineering estimate for design:

2.2.2.4.1 Construction and calculations	13.000,-DM	6,600 ICF
2.2.2.4.2 Construction and calculations	30.000,-DM	19,700 ICF

Labor estimate for fabrication of seal plates:

2.2.2.4.1 Seal frame with bellows, O-rings and cover interface	130.000,-DM	85.500 ICF
Stabilization frame for lifting and adjusting	50.000,-DM	32,900 ICF
Leak and manipulation tests	20.000,-DM	13,200 ICF
TOTAL	200.000,-DM	132,000 ICF
2.2.2.4.1 Seal frame with bellows. O-rings and cover interface	130.000,-DM	85.500 ICF

Stabilization frame for lifting and adjusting	50.000,-DM	32,900 ICF
Leak and manipulation tests	20.000,-DM	13,200 ICF
TOTAL	200.000,-DM	132,000 ICF

WORKSHEET
WBS 2.2.2.5 Test Cell Camera System for Test Cell I

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
162		236	80	478	84			17	101

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell Camera System (TCCS) provides viewing of the Test Cell interior to aid in the removal and installation of the VTA's and VIT. Viewing takes place only when the beam is not operating and the Test Cell is vented. The TCCS consists of two cameras, two pitch/yaw mechanisms, two camera booms, two shield plugs, two monitors, and two control panels that control the zoom and position of each camera. Each camera is supported by a pitch/yaw mechanism and is equipped with a zoom lens to provide a wide range of viewing. The pitch/yaw mechanism and camera assembly is mounted on the end of the camera boom. The camera boom is equipped with a 2 M telescoping section to control the angle of viewing . The cameras are positioned in the Test Cell by inserting the booms through vertical ports that are located in opposite corners of the TCRC. Each TCRC port is plugged by the Camera Shield Plug (CSP) during beam operation. These camera shield plugs are equipped with elastomer O-Ring seals that interface with the top of the TCRC to provide a vacuum tight enclosure. Each CSP consists of a stepped, stainless steel liner that is filled with barytes concrete. Each CSP has a cylindrical cross section and is equipped with three steps that conform to steps in the TCRC ports to prevent radiation streaming. The CSP are removed and replaced by the camera booms when viewing is required.

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The TCCS WBS 2.2.2.6, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the TCSP. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the TCSP. The fabrication cost is based on a $67.00 hourly rate.

Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the TCSP were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 98.50 hourly rate.

E. Detailed Costing:

I. Engineering estimate for design of two CSP:		
a. six (6) E size drawings	600 hr.	$ 59,100
b. stress calculations	100 hr.	$ 9,850
I. Labor estimate for fabrication of two CSP:		
a. metal prep 14 PC of stainless	140 hr.	$ 9,380
b. welding 8 M X 12.7 mm	20 hr.	$ 1,340
c. machining for O-Ring seal surfaces and mounting interfaces	200 hr.	$ 13.400
d. Installation of barytes concrete	100 hr.	$ 6,700
Materials estimate for fabrication of two CSP: (1,500 LB stainless @ $1.50/LB. and 3,000 LB barytes concrete @ $0.10/LB.)		$ 2,550
II. Engineering estimate for design of two camera booms		
a. ten (10) E size drawings	1000 hr.	$ 98,500
b. stress calculations	100 hr.	$ 9,850
II. Labor estimate for fabrication of two camera booms:		
a. metal prep 16 PC of stainless	400 hr.	$ 26,800
b. welding 40 M X 12.7 mm	250 hr.	$ 16,750
c. machining for telescoping surfaces and mounting interfaces	600 hr.	$ 40,200
Materials estimate for fabrication of two camera booms: (1,500 LB stainless @ $1.50/LB., screw jacks, and, servo motors)		$ 10,000
III. Engineering estimate for design of two camera control panels		
a. six (6) E size drawings	600 hr.	$ 59,100
III. Labor estimate for fabrication of the two camera control panels:		$ 20,000
Materials estimate for Procurement of:		
a. two cameras:		$ 4,000
b. two monitors:		$ 1,000
c. two pitch/yaw mechanisms:		$ 10,000
IV. Labor estimate for installation of Test Cell Camera System		
a. cabling	1000 hr.	$ 67,000
b. control panels	250 hr.	$ 16,750

WORKSHEET
WBS 2.2.2.6 Neutron and Gamma Source diagnostics for Test Cell I

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
99		20 118,7			

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

During the set-up phase of IFMIF neutron and gamma flux contours downstream the Li-Target have to be monitored carefully and compared with the results of the transport codes in order to assess the sensitivity of the codes. This is especially important because the neuron source term in thick Li-targets is still a matter with various uncertainties (e.g. production yield of sequential (p, Li) reaction induced additional neutrons. In addition, the heat deposition rate distribution at least in the High Flux VTA has to be determined as a function of different deuteron beam currents both for continuous beam on-target and various beam-on-beam-off scenarios.

The above procedures includes the availability of suitable neutron and gamma dosimetry as well as the use of a High Flux VTA with a special test module. While the VTA body and the coolant system can be identical with those specified for normal operations (see 2.2.1), the test module with already integrated specimens and specimen capsules has to be instrumented with various thermocouples and suitable dosimetry foils.

With respect to uncollided neutrons it is assumed that suitable high flux neutron and gamma monitors for the analysis e.g. of beam foot print and beam density profiles immediately behind the Li-target are not part of the Test Facility (Is that true ?). Nevertheless, a beam density profile monitor is suggested, based on the experience of already existing facilities. However, because of the high IFMIF beam density the applicability of conventional monitors is questionable.

C. Detailed WBS Listing:

There is no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The estimate is base on fully equipped commercial camera systems.

E. Detailed Costing:

2-D-camera systems for X-rays and infrared light (offer from German Industry 1995)
150.000,-DM 98.700 ICF

WBS 2.2.2.7 Test Cell Diagnostics for Test Cell I

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
53	nc	11 64			

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

At present beam diagnostics has not been specified in detail and also the responsibility (Test Cell, Li-Target or Accelerator Group?) is still not clarified. Nevertheless, a rough description will be given here.

Beam stability, beam profile, beam density and beam time structure are of outstanding importance both for the quality of the irradiation and for safety reasons. While for the irradiation of specimens a fast response is not really needed - to confirm the beam parameters from time to time should be sufficient for the bulk of irradiation experiments - the emergency shutdown system has to be very quick (see WBS 2.2.2.8).

Data collection, conversion and processing are considered to be in the Test Cell Technology Room. Consequently only the sensors has to considered here.

a) Beam diagnostics: various fast response gamma radiation sensors

b) Test cell diagnostics: ~24 thermocouples Type K (radiation resistant) homogeneously distributed over the inner Test Cell surface,
some liquid metal sensors (e.g. sensors sensitive to short circuit current to monitor liquid metal spill)
some low and high vacuum sensors

C. Detailed WBS Listing:

There are no other elements listed in this section. 2.2.2.7 is the lowest WBS level listed.

D. Costing Rationale:

Engineering deliverable (such as drawings, FE-calculations, specifications) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing (roughly estimated):

a) 4 Gamma radiation sensors: 40.000,- DM 26,000 ICF
24 thermocouples a 200,- DM including installation and testing
24.000,- DM 16,000 ICF
4 liquid metal sensors including installation and testing
16.000,- DM 11,000 ICF

WORKSHEET
WBS 2.2.2.8 Emergency shutdown system for Test Cell I

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
40	72	22	134		72	14	86

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

At present emergency shutdown systems has not been specified in detail and also the responsibility (Test Cell, Li-Target or Accelerator Group?) is still not clarified. Nevertheless, a rough description will be given here.

Beam stability, beam profile, beam density and beam time structure are of outstanding importance both for the quality of the irradiation and for safety reasons. While for the irradiation of specimens a fast response is not really needed - to confirm the beam parameters from time to time should be sufficient for the bulk of irradiation experiments - the emergency shutdown system has to be very quick. The system include

a) Data collection from beam and Test Cell diagnostics
b) Real time data conversion and processing
c) Hard wired line to central control system.

C. Detailed WBS Listing:

There are no other elements listed in this section. 2.2.2.7 is the lowest WBS level listed.

D. Costing Rationale:

Engineering deliverable (such as drawings, FE-calculations, specifications) required.
The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

a) Data collection:
Beam diagnostics data (e.g. various gamma irradiation monitors) and Test Cell diagnostics data (~24 thermocouples at different positions on the Test Cell and Li-Target surfaces, a few liquid metal detectors, a few vacuum sensors) has to be recorded with high frequency of typically 5 Hz.
b) Real time data conversion:
Conversion to industrial standard signals

The requirements very roughly specified in a) and b) can easily be fulfilled with e.g. Hewlett Packard VXI-system.

60.000,- DM 39,500 ICF

Engineering costs: Detailed system specification, programming and testing.

110.000,- DM 72,400 ICF

WORKSHEET

WBS 2.2.3.1 Assembly and Testing with Test Cell Technology Room I

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry		Instit'al		Industry		Instit'al	
Mat'l/Lab	Engin'g	Engin'g	AFI Total	Mat'l/Lab	Engin'g	Engin'g	AFI Total
nc		nc	nc	nc		77,9	16 93,9

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

All costs for the assembly and testing of subsystems are already included in the related WBS of the individual systems. However the experience with large accelerator facilities has shown that it is not sufficient to test all subsystems individually. It is necessary to show, that all individual systems can work at the same time and communicate, if necessary, with each other. Realistic testing includes also, that for the licensing authorities detailed listings has to be established which includes for any normal and of-normal condition a save and proper response of the control system.
The licensing authority release commissioning only when all system functions works perfectly.

C. Detailed WBS Listing:

2.2.3.1: Assembly and testing of Test Cell and VTAs
- 2.2.3.1.1: Assembly
- 2.2.3.1.2: Testing

D. Costing Rationale:

Engineering deliverable (such as specifications, listings, system programming and testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

2.2.3.1.1 Assembly:
All costs are considered to be included in the individual WBS elements

2.2.3.1.2 Testing:
On-site Engineering estimate
1500 hr. 118.400,- DM 77,900 ICF

WORKSHEET
WBS 2.2.3.2 Cooling System for Test Cell I

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site				On-Site At IFMIF				
Industry		Instit'al		Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
154		99	253	107		79	35	221

Units: U. S. Dollars ($1,000), 1,000 $ = 1,000 ICF

B. Description:

The Test Cell Cooling System is located in the Technology Room and consists of coolant flow pumps, valves, and a heat exchanger. The Test Cell Cooling System uses a circulating gas coolant to cool the Test Cell Heat Shield and Liner. The Test Cell Liner is cooled along its interior edges and the Test Cell Heat shield is cooled along both of its edges with this circulating gas coolant. The gas coolant will be maintained at a low pressure and is transported from the Technology Room to the Test Cell in ducts. Heat exchangers are used to remove heat from the gas coolant. Low pressure pumps are used to circulate the gas coolant.

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The Test Cell Cooling System WBS 2.2.3.2, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and installation of each major component of the Test Cell Cooling System. From these evaluations, fabrication and installation man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and installation of these major components. The fabrication cost is based on a $67 hourly rate.
Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the Test Cell Cooling System were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 98.50 hourly rate.

E. Detailed Costing:

Engineering estimate for design of Test Cell Cooling System:

a. Four (4) E size drawings	400 hr.	$ 39,400
b. Stress calculations	100 hr.	$ 9,850
c. Five Specifications	500 hr.	$ 49,250

Engineering estimate for installation of Test Cell Cooling System:

a. Ten (10) E size drawings	500 hr.	$ 49,250
b. Stress calculations	100 hr.	$ 9,850
c. Two Specifications	200 hr.	$ 19,700

Labor estimate for fabrication of Test Cell Cooling System:

a. metal prep for coolant ducts	800 hr.	$ 53,600
b. welding 40M X 12.7 mm	300 hr.	$ 20,100

Labor estimate for Installation of Test Cell Cooling System:

a. Installation for coolant ducts	800 hr.	$ 53,600
b. Installation for coolant flow pumps (2)	200 hr.	$ 13,400
c. Installation for coolant heat exchangers (2)	200 hr.	$ 13,400
d. Installation for coolant valves	200 hr.	$ 13,400
e. Installation for Shielding material	200 hr.	$ 13,400

Materials estimate for fabrication of Test Cell Cooling System:

a. Coolant ducts	$ 10,000
b. Coolant Control Valve (8)	$ 15,000
c. Coolant Heat Exchangers (3)	$ 20,000
d. Coolant Flow Pumps (3)	$ 25,000
e. Shielding material	$ 10,000

WORKSHEET

WBS 2.2.3.3 Vacuum Pumping System for Test Cell I

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
89,3	8,2	20	117,5	18,2	6,2	5	29,4

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

In order to meet several safety and reliability requirements, the Test Cell will be evacuated before and during irradiation to a nominal pressure or 10^{-1} Pa. For maximum redundancy three vacuum pumps are foreseen (see attachment page 1-3)

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Test cell vacuum pumping system WBS 2.2.3.3 is the lowest WBS listed.

D. Costing Rationale:

Engineering efforts, fabrication methods, requirements, and procedures were evaluated for the feasibility, fabrication and assembly of each major component of the Test cell vacuum pumping System. From these evaluations, fabrication man-hour estimates were made. Engineering deliverable (such as drawings and system design) required for the design of these components, the assembly and testing are also evaluated.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Engineering estimate:

a) design calculations based on detailed outgassing rates, layout of ducts:
80 hr 6.300,- DM 4,100 ICF

b) System specification
80 hr 6.300,- DM 4,100 ICF

a) On-site system testing and commissioning
120 hr 9.500,- DM 6,200 ICF

Labor estimate for fabrication and on-site assembly

a) 3 pumps (see attachment): 36,700 $ 36,700 ICF

b) Material for tubes, ducts, fittings, gas exhaust, shielding of pumps (low level tritium).
80.000,- DM 52,600 ICF

c) On site installation/assembly
350 hr 27.600 DM 18,200 ICF

WORKSHEET

WBS 2.2.3.4 Argon Backfill System for Test Cell I

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
36	19	11	66	13	6	4	23

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

After an irradiation campaign, for maintenance requirements, for the exchange of Test Assemblies, for inspections, and for off-normal conditions it is necessary to flood the evacuated Test Cell with inert gas. Due to safety arguments it is foreseen to use Argon gas. The density of Argon is above that of normal air or nitrogen and therefore it does hardly escape into the Access Cell. Also in case of Lithium spill Argon prevents the floor of the Test Cell from Oxygen or other gaseous molecules. Another advantage of Argon is that due to missing H_2O molecules final vacuum pressure can be achieved in the shortest possible time. The Ar backfill system is located in the Technology room. From a technical standpoint of view it is very easy to flood the Test Cell within a few seconds with Argon. Therefore e.g. pressurized Argon bottles (50 Liter, 200 atm nominal pressure) might be used. The Test Cell can be flooded several times with one singe bottle.
However, to maintain a continuous flow of Argon to the Test Cell in case of accident or in case of a removed Test Cell cover, a bundle of about 6 bottles should be installed in the test Cell control room.

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Test Argon backfill system WBS 2.2.3.4 is the lowest WBS listed.

D. Costing Rationale:
The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Engineering estimate:
a) Design calculations to estimate the Argon gas escape into the Access Cell in case of removed Test Cell cover, Argon release tests after installation for various conditions
240 hr 19.000,- DM 12,500 ICF
b) Design of remote handling and control, test after installation
120 hr 9.500,-,- DM 6,300 ICF
a) On-site system testing and commissioning
120 hr 9.500,- DM 6,200 ICF

Labor estimate for fabrication and on-site assembly
a) 6 Argon bottles, 6 remote controlled mixing valves, 12 remote controlled pressure gauges
54.000.- DM 35,500 ICF
b) Material for tubes, fittings, bottle holders 20.000,- DM 13,200 ICF

WORKSHEET

WBS 2.2.3.5 Diagnostic and Control for Test Cell I

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
63		13 75	31	62	19 112

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Before, during and after irradiation relevant parameters from the Test Cell and its supporting devices have to be monitored and controlled.
Therefore three 19" Rack Cabinets (60 cm width 200 cm high) housing all instrumentation and control units are foreseen in the Test Cell Technology Room.

Rack 1: - 2 control units for each of the three vacuum pumps, incl. power supply (6 units)

Rack 2: - 3 control units for the Test Cell cooling system, incl. power supply
- 1 instrumentation unit for the Test cell cooling system
- 1 control unit for the Argon backfill system

Rack 3: Hardware units: Data collection from beam and Test Cell diagnostics (the sensors are in the Test Cell and therefore part of WBS 2.2.2.8)
The rack includes controllers for all thermocouples, liquid metal leak detectors, vacuum sensors and gamma irradiation monitors (5 slots, width 19").
Firm and Software unit: This is the interface between the hardware/electronics and the central control computer and is able to manage the complete data acquisition and process control of the Test Cell. Is is suggested to use an industrial standardized VXI-system. Such a system includes ease of use and programming, configuration flexibility and not very high costs. (2 slots, width 19").

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Test Argon backfill system WBS 2.2.3.5 is the lowest WBS listed.

D. Costing Rationale:
The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:
Engineering estimate:
System design, development and testing:
1200 hr. 94.700,- DM 62,300 ICF
Labor estimate for installation and wiring:
600 hr. 47,300.- DM 31,100 ICF

VXI hardware and software, e.g. Hewlett Packard VXI Mainframe E1491 A C-size, incl. all controllers and interfaces, HP VEE software
95.000,- DM 62.500 ICF

WORKSHEET

WBS 2.2.3.6 Subsystem Power for Test Cell I

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	1	1	4	nc	1 5

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Electric Power has to installed which is suitable to feed all devices in the Test Cell Technology Room.
Estimated Power:

a) Test Cell cooling system (inert gas pump)	35 KW
b) Vacuum pumping system (3 turbomolecular pumps a 1.2 KW	4 KW
c) Argon backfill system	0 KW
d) VIT system	5 KW
d) Rack 1:	3 KW
e) Rack 2:	3 KW
f) Rack 3:	1 KW

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Test Argon backfill system WBS 2.2.3.6 is the lowest WBS listed.

D. Costing Rationale:

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Engineering estimate:

Layout of electric power installation		
10 hr.	800,- DM	500 ICF
Labor estimate for plug installation and wiring:		
40 hr.	3,200.- DM	2,100 ICF
Material (e.g. plugs, cables):,		
	2.000,- DM	1,400 ICF

WORKSHEET
WBS 2.2.4.1 NaK Thermally Controlled High-Flux Vertical Test Assembly (VTA-1 for Test Cell II)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF			
Industry		Instit'al			Const. Contractor		Instit'al	
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI Total
248	55	62	63	1104				

Units: U. S. Dollars ($1,000)

B. Description:

VTA-1-NaK for Test Cell II is identical to the VTA-1-NaK for Test Cell I (WBS 2.2.1.1).

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The NaK Thermally Controlled High-Flux Vertical Test Assembly (VTA-1), WBS 2.2.4.1, is the lowest WBS level listed.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the VTA-1 for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.1.1

WORKSHEET

WBS 2.2.4.2 Helium gas controlled High Flux Vertical Test Assembly for high temperatures (VTA1-Helium for Test Cell II)

A. Summary Cost estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,207	29	6	248	1,490			12	2	14

Units: 1,000 ICF (1 ICF = 1.52 DM)

B. Description:

VTA-1-He for Test Cell II is identical to the VTA-1-He for Test Cell I (WBS 2.2.1.2).

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The He Thermally Controlled High-Flux Vertical Test Assembly (VTA-1), WBS 2.2.4.2, is the lowest WBS level listed.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the VTA-1He for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.1.2

WORKSHEET

WBS 2.2.4.3 Helium gas controlled Medium flux Vertical Test Assembly for in situ Creep-Fatigue Tests (VTA 2-He Creep-Fatigue for Test Cell II)

A. Summary Cost estimate

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
695	10	3	142	849			12	2	14

Units: 1,000 ICF (1 ICF = 1.52 DM)

B. Description:

The inert gas cooled (usually helium) medium flux Vertical Test Assembly for instrumented in-situ creep fatigue ; VTA 2 is identical to the the aseembly proposed for Test Cell I (WBS 2.2.1.3)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the VTA-2 for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.1.3

WORKSHEET

WBS 2.2.4.4 Helium gas controlled Medium flux Vertical Test Assembly for Tritium Release tests on Ceramic Breeders (VTA 2-He Breeders for Test Cell II)

A. Summary Cost estimate

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
640	16	18	135	809			15	3	18

Units: 1,000 ICF (1 ICF = 1.52 DM)

B. Description:

The inert gas cooled (usually helium) medium flux Vertical Test Assembly for instrumented in-situ Tritium release tests on various ceramic breeder materials. (VTA 2) is identical to the the assembly proposed for Test Cell I (WBS 2.2.1.4)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the VTA-2 for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.1.4

WORKSHEET
WBS 2.2.4.5 Vertical Irradiation Tube (10 VIT's) System for Test Cell II

A. Summary Cost Estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
666	5	110	78	859	105			21	126

B. Description:

The VIT system proposed for Test Cell II is identical to the the aseembly proposed for Test Cell I (WBS 2.2.1.5)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the VTI system for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.1.5

WORKSHEET
WBS 2.2.4.6 Test Cell Shielding Plug for Test Cell II

A. Summary Cost Estimate:
FOR TEST CELL II

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
9		2	2	13					

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell Shielding Plug (SP) is identical to the the assembly proposed for Test Cell I (WBS 2.2.1.6)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the VTA-2 for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.1.6

WORKSHEET
WBS 2.2.6.7 Infrastructure

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc		nc	658	99	151	908

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Main infrastructure installations include

- Electric power which is suitable to feed all devices in the Access Cell
- compressed air, inert gases, cables
- Lightning
- Support structures for Universal Robot System, Cell Maintenance, Hydraulic Systems
- Storage for 5 VTAs

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Infrastructure Installation WBS 2.2.9.7 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Attention: the costs in this section are only roughly estimated

Engineering (global estimate 15 % of Mat, fabr., install, and testing):

150.000,- DM 98,700 ICF

Material, fabrication, installation and testing (PET):

1.000.000,- DM 658,000 ICF

WORKSHEET
WBS 2.2.7.1 Assembly and Testing of Test Facility Control Room

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	nc	nc	nc	62,3	12 75

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

All costs for the assembly and testing of subsystems are already included in the related WBS of the individual systems. However, it is necessary to show, that all individual systems can work at the same time and communicate, if necessary, with each other. Realistic testing includes also, that the supervising computer can handle all individual experiments as well as the status information from Accelerators, Li-Target and Test Cell. The supervising computer in the Test Cell Control Room can also be used as server for the front end computers of the individual experiments and should therefore be equipped with printers and data storage units.

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Assembly and testing WBS 2.2.7.1 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as system programming and test) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Labor estimate for on-site engineering:

1200 hr.	94,700,- DM	62,300 ICF

WORKSHEET

WBS 2.2.7.2 Data Acquisition and Process Control for VTA-1-NaK

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
43	nc	9	52	nc	36	7	44

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The NaK thermally controlled VTA-1-NaK is described in WBS 2.2.1.2.
For a proper control of the VTA-1-NaK with it's 3 individual test modules one 19" Cabinet 60 cm width x 200 cm high) in the Test Facility Control Room is sufficient. It includes 7 units (width 20 cm)

a) NaK loop for chamber 1 (Temp. T1):
- Power control unit for heater and cooler incl. flow controller
- Instrumentation unit (display for 6 thermocouples, 2 pressure sensors, 1 flowmeter)

b) NaK loop for chamber 2 (Temp. T2):
- Power control unit for heater and cooler incl. flow controller
- Instrumentation unit (display for 6 thermocouples, 2 pressure sensors, 1 flowmeter)

b) NaK loop for chamber 3 (Temp. T3):
- Power control unit for heater and cooler incl flow controller
- Instrumentation unit (display for 6 thermocouples, 2 pressure sensors, 1 flowmeter)

c) Data acquisition and process control unit (rack integrated PC)

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Assembly and testing WBS 2.2.4.2 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as system definition, PC programming and test) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Engineering estimate for system design, wiring scheme, installation, programming and test

700 hr.	55.200,- DM	36,300 ICF

Labor estimate for fabrication, racking, cabling:

- 3 Power control units	12.000,-	7,900 ICF
- 3 Instrumentation units	36.000,-	23,700 ICF
- PC based data acquisition and control unit	18.000,-	11,800 ICF

WORKSHEET

WBS 2.2.7.3 Data Acquisition and Process Control for VTA-1-Helium

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
105,3	nc	21	126	nc	36,3	7	44

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Helium gas cooled VTA-1-helium is described in WBS 2.2.1.2 and WBS 2.2.4.2. For a proper control of the VTA-1-Helium two 19" Cabinet 60 cm width x 200 cm high) in the Test Facility Control Room are sufficient.

19" Rack Cabinet 1
- -Power control unit for helium gas loop
- PID governors to control helium gas flow
- Instrumentation unit (display for 6 thermocouples, 2 pressure sensors, 1 flowmeters)

19" Rack cabinet 2:
- Display unit for all rig-temperatures (32 thermocouples)
- Display and control unit for 32 Ohmic heaters of the specimen capsules
- Data acquisition and process control unit (rack integrated PC)

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Assembly and testing WBS 2.2.7.3 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as system definition, PC programming and test) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Engineering estimate for system design, wiring scheme, installation, programming and test
700 hr. 55.200,- DM 36,300 ICF

Labor estimate for fabrication, racking, cabling:

19" Rack 1 (identical with rack 3 in WBS 2.2.7.4) 105.00,- DM 69,100 ICF

19" Rack 2 (estimated according to experience from FZK Dual Beam Facility)
55.000,- 36,200 ICF

WORKSHEET

WBS 2.2.7.4 Data Acquisition and Process Control for In-situ Creep-Fatigue Tests in the Medium Flux Region

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
262.9	31,2	59	353	nc	62,3	12	75

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Helium gas cooled VTA-2-Helium for in-situ creep fatigue tests is described in WBS 2.2.1.3. It is foreseen to test 3 push-pull fatigue specimens simultaneously, each independent from the other.

For a proper control of the 3 individual creep-fatigue specimens three 19" Cabinets (60 cm width x 200 cm high) in the Test Facility Control Room will be sufficient.

The Helium-gas coolant loop is considered to be located in the Access Cell side by side with that one used for the High flux VTA-1-Helium. That is, one fraction of the signals from the Test Cell Control room goes to that Helium gas loop while the others will go directly to the VTA-2-Helium.

19" Rack Cabinet 1:

- 3 power packages, 3 driving units, 3 high level universal testing control units
- 3 on-board PC processors for closed loop experiments

19" Rack cabinet 2:

- 3 extensiometer control units
- Data acquisition from 3 extensiometers, 3 load cells and 18 thermocouples: 64 channel Scanning A/D, one thermocouple measuring transducer, one $6^{1/2}$ Digital Multimeter
- one Process Computer (PC) with suitable I/O slots and software to control the complete VTA-2-Helium.

19" Rack cabinet 3:

- Power control unit for Helium gas loop
- 4 PID governors to control helium gas flow inside the hollow specimens
- Instrumentation unit (display for 6 gas temperatures, 6 pressure sensors, 3 flowmeters)

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Assembly and testing WBS 2.2.7.4 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as system definition, PC programming and test) required. The in-situ creep fatigue experiments in the IFMIF medium flux position are with respect to the concept very similar to those ones of the FZK High Energy Dual Beam Facility. Therefore the cost estimate of the IFMIF VTA-2-Helium will be based on the actual cost of the FZK High Energy Dual Beam Facility.

E. <u>Detailed Costing:</u>

Engineering estimate for system design, programming and extended tests		
800 hr.	94.700,- DM	62,300 ICF
Engineering estimate for drawings, wiring scheme and installation		
400 hr.	47.400,- DM	31,200 ICF

19" Rack Cabinet 1:

TOTAL: 122.700,- DM 80,700 ICF

Because the IFMIF system is very similar to that one of the FZK Dual Facility, the IFMIF cost estimate will be based on the FZK system.

The complete power, driving and control units for one universal testing device was 38.930,- DM (Feb. 1995) which translates to 40.870,- DM.(May 1996). Consequently three units will cost 122.700,- DM.

The vendor was ZWICK GmbH & Co, D-89079 Ulm, Germany

19" Rack Cabinet 2:

TOTAL: 171.000,- DM 113,100 ICF

Because the IFMIF system is very similar to that one of the FZK Dual Facility, the IFMIF cost estimate will be based on the FZK system.

The complete data acquisition and control units incl. all software for one universal testing machine was 29.819,- DM (Feb. 1995) which translates to 31.300,- DM.(May 1996). Consequently three units will cost 93.900,- DM. 61,800 ICF

One suitable Process Computer incl. software (estimated) 60.000,- DM 39,500 ICF

3 extensiometer control units (e.g. Company HOTTINGER) including special cables, all instruments certified 18.000,- DM 11,800 ICF

19" Rack Cabinet 3:

TOTAL: 105.000,- DM 69,100 ICF

Because the IFMIF system is very similar to that one of the FZK Dual Facility, the IFMIF cost estimate will be based on the FZK system.

The complete power control unit 70.000,- DM (1985) which translates approximately to 105.000,- DM (1996).

WORKSHEET

WBS 2.2.7.5 Data Acquisition and Process Control for Tritium Release In-situ Tests in the Medium Flux Region

A. Summary Cost estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
270		30	60	360	?		?	?	

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The system still needs to be described with respect to cost estimate (JAERI)

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Assembly and testing WBS 2.2.7.5 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as system definition, PC programming and test) required.

E. Detailed Costing:

Due to the quite complex experimental set-up it is considered, that 2-3 19:" Rack Cabinets are necessary for the experimental control and data acquisition. Therefore, the overall costs are considered to be similar to that ones of the In-situ creep-fatigue tests.

Rough estimate 300,000 ICF

This number has to be verified by JAERI

WORKSHEET
WBS 2.2.5.1 Test Cell Removable Cover for Test Cell II

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,045		18	213	1,276					

Units: 1,000 ICF (1 ICF =1.52 DM)

B. Description:

The Test Cell Removable Cover (TCRC) is identical to the the assembly proposed for Test Cell I (WBS 2.2.2.1)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the TCRC for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.1

WORKSHEET
WBS 2.2.5.2 Test Cell Liner for Test Cell II

A. Summary Cost Estimate:
FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
891		16	181	1,088	59			12	71

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell Liner is identical to the the assembly proposed for Test Cell I (WBS 2.2.2.2)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the Test Cell Liner for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.2

WORKSHEET
WBS 2.2.5.3 Test Cell Heat Shield for Test Cell II

A. Summary Cost Estimate:

FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
599		26	125	749	79			16	95

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell Heat Shield (TCHS) is identical to the the assembly proposed for Test Cell I (WBS 2.2.2.3)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the TCHS for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.3

WORKSHEET
WBS 2.2.5.4 Seal Plate for Test Cell II

A. Summary Cost Estimate:

FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
309		3	62	374					

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell seal systems are identical to those proposed for Test Cell I (WBS 2.2.2.4)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the Test Cell Seal Systems for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.4

WORKSHEET
WBS 2.2.5.5 Camera System for Test Cell II

A. Summary Cost Estimate:

FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
162		24	37	223	84			17	101

Units: U. S. Dollars ($1,000)

B. Description:

The Test Cell Camera System (TCCS) is identical to that proposed for Test Cell I (WBS 2.2.2.5)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the TCCS for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.5

WORKSHEET
WBS 2.2.5.6 Neutron and Gamma Source Diagnostics for Test Cell II

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
99		20 118,7			

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Neutron and Gamma Source Diagnostics for Test Cell II are identical to those proposed for Test Cell I (WBS 2.2.2.6)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the Diagnostics for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.6

WBS 2.2.5.7 Test Cell Diagnostics for Test Cell II

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
53	nc	11	64				

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:
The Test Cell Diagnostics for Test Cell II are identical to those proposed for Test Cell I (WBS 2.2.2.7)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the Diagnostics for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.7

WORKSHEET

WBS 2.2.5.8 Emergency shutdown system for Test Cell II

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
40	7	9	57		7	2	9

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:
The emergency shutdown system for Test Cell II is identical to that proposed for Test Cell I (WBS 2.2.2.8)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the emergency shutdown system for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.2.8

WORKSHEET

WBS 2.2.6.1 Assembly and Testing with Test Cell Technology Room II

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF			
Industry	Instit'al		Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	39	8	47

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

All costs for the assembly and testing of subsystems are already included in the related WBS of the individual systems. However the experience with large accelerator facilities has shown that it is not sufficient to test all subsystems individually. It is necessary to show, that all individual systems can work at the same time and communicate, if necessary, with each other. Realistic testing includes also, that for the licensing authorities detailed listings has to be established which includes for any normal and of-normal condition a save and proper response of the control system.
The licensing authority release commissioning only when all system functions works perfectly.

C. Detailed WBS Listing:

2.2.6.1: Assembly and testing of Test Cell and VTAs
- 2.2.6.1.1: Assembly
- 2.2.6.1.2: Testing

D. Costing Rationalee:

Engineering deliverable (such as specifications, listings, system programming and testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate. It is assumed that approximately half the Tech. Cell #1 engineering effort will be required to accomplish the assembly and testing of Tech. Cell #2.

E. Detailed Costing:

2.2.6.1.1 Assembly:
All costs are considered to be included in the individual WBS elements

2.2.6.1.2 Testing:
On-site Engineering estimate

750 hr.	59200,- DM	38,950 ICF

WORKSHEET
WBS 2.2.6.2 Cooling System for Test Cell II

A. Summary Cost Estimate:

FOR ONE TEST CELL

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
154		10	33	197	107		8	23	138

Units: U. S. Dollars ($1,000), 1,000 $ = 1,000 ICF

B. Description:

The Test Cell Cooling System is identical to that proposed for Test Cell I (WBS 2.2.3.2)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationalee:

The cost of fabrication is assumed to be the same as for the emergency shutdown system for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.3.2

WORKSHEET

WBS 2.2.6.3 Vacuum Pumping System for Test Cell II

A. Summary Cost estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
89,3		1	18	108		2	1	0	3

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Vacuum Pumping System for Test Cell II is identical to that proposed for Test Cell I (WBS 2.2.3.3)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the emergency shutdown system for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.3.3

WORKSHEET

WBS 2.2.6.4 Argon Backfill System for Test Cell II

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
36	2	8	45	13	1	3	16

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:
The Argon Backfill System for Test Cell II is identical to that proposed for Test Cell I (WBS 2.2.3.4)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the emergency shutdown system for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.3.4

WORKSHEET

WBS 2.2.6.5 Diagnostic and Control System for Test Cell II

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
63		13	75	31	6	7	45

Units: 1,000 ICF (1,000 ICF = 1.520,-DM)

B. Description:

The Diagnostic and Control System for Test Cell II is identical to that proposed for Test Cell I (WBS 2.2.3.5)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication is assumed to be the same as for the emergency shutdown system for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.3.5

WORKSHEET

WBS 2.2.6.6 Subsystem Power for Test Cell II

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	0	0	4	nc	1 5

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The electric power distribution system for Test Cell II is identical to that proposed for Test Cell I (WBS 2.2.3.6)

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS.

D. Costing Rationale:

The cost of fabrication and installation is assumed to be the same as for for Test Cell I. Engineering is estimated to be 10% as required to follow the fabrication process.

E. Detailed Costing:

See Worksheet for WBS 2.2.3.6

WORKSHEET

WBS 2.2.7.6 Data Acquisition and Process Control for VIT system

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
145	41	37	223	nc	31,2	6	37

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The VIT control system includes
- Temperature control and control of the instrumented specimen capsules
- The control units for the coolant flow pump (helium gas is recommended). This coolant flow pump is located together with a heat exchanger in the Access Cell (not in the Test Cell Technology Room) side by side with the coolant pumps for the high and medium flux VTAs.
- Control units for the loading/unloading station.

Two 19' Rack cabinets are considered to be sufficient for the complete VIT control

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Assembly and testing WBS 2.2.7.6 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as system definition, PC programming and test) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Engineering rough estimate for system design, programming and tests
400 hr. 47.400,- DM 31,200 ICF

Engineering rough estimate for drawings, wiring scheme and installation
400 hr. 47.400,- DM 31,200 ICF

a) 19" Rack Cabinet 1:
Data acquisition and irradiation experiment control:
No detailed definition of the exact type of experiments will be given during the CDA-Phase. The VIT system has a high flexibility for a broad parameter range. Therefore, the actual instrumentation can only be roughly estimated. According to the experience with existing facilities the costs for a typical Rack is estimated to 120,000,-DM 78,900 ICF

b)19" Rack Cabinet 2:

- Power control unit for Helium gas loop,
- PID governors to control inert gas coolant loop and the fraction of coolant for each row of specimens (low and very low flux regions)
- Instrumentation unit (display for gas temperatures, pressure sensors and flowmeters)
- control units for the loading/unloading station.

No detailed definition of the exact type of experiments will be given during the CDA-Phase. According to the experience with inert gas coolant loops and loading/unloading stations in already existing facilities, the costs for a typical Rack is estimated to

	100,000,-DM	65,800 ICF

Labor estimate for fabrication, racking, cabling:		
- 3 Power control units	12.000,- DM	7,900 ICF
- 3 Instrumentation units	36.000,- DM	23,700 ICF
- PC based data acquisition and control unit	18.000,- DM	11,800 ICF

WORKSHEET

WBS 2.2.7.7 Supervising Computer for Test Cell Control Room

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
46	nc	9	55	nc	62,3	12	75

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

A supervising computer is required to coordinate, if necessary, all individual experiments as well as the status information from Accelerators, Li-Target and Test Cell. The supervising computer in the Test Cell Control Room can also be used as server for the front end computers of the individual experiments and should therefore be equipped with printers and data storage units.

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Assembly and testing WBS 2.2.7.7 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as system programming and test) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Estimate for on-site engineering (system integration, programming):

1200 hr.	94,700,- DM	62,300 ICF

Suitable Real Time Multi User Computer (e.g. Workstation with UNIX-System) incl. Terminals, Software, storage and printer units.

Rough Estimate:	70.000,- DM	46,000 ICF

WORKSHEET
WBS 2.2.7.8 Subsystem Power

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	1	1	4	nc	1 5

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. <u>Description:</u>

Electric Power has to be installed which is suitable to feed all devices in the Test Cell Control Room. Estimated Power:

a) WBS 2.2.4.2	1 19" Cabinet	3 KW
b) WBS 2.2.4.3	2 19" Cabinets	5 KW
c) WBS 2.2.4.4	3 19" Cabinets	7 KW
d) WBS 2.2.4.5	3 19" Cabinets	7 KW
e) WBS 2.2.4.6	2 19" Cabinets	5 KW
f) WBS 2.2.4.7	1 Computer incl. units	1 KW

C. <u>Detailed WBS Listing:</u>

There is no other listings in this section of the WBS. The Test Argon backfill system WBS 2.2.4.8 is the lowest WBS listed.

D. <u>Costing Rationale:</u>

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. <u>Detailed Costing:</u>

Engineering estimate:
Layout of electric power installation

10 hr.	800,- DM	500 ICF

Labor estimate for plug installation and wiring:

40 hr.	3,200.- DM	2,100 ICF

Material (e.g. plugs, cables):,

	2.000,- DM	1,400 ICF

WORKSHEET

WBS 2.2.8.1 Assembly and Testing of Access Cell

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry		Instit'al		Industry		Instit'al	
Mat'l/Lab	Engin'g	Engin'g	AFI Total	Mat'l/Lab	Engin'g	Engin'g	AFI Total
nc		nc	nc	nc		125	25 150

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. <u>Description:</u>

The Access Cell is located directly above the Test Cells and has in the present design an inner length of 21,00 m and a width of 8,00 m. All costs for the assembly and testing of subsystems are already included in the related WBS of the individual systems. However the experience with large accelerator facilities has shown that it is not sufficient to test all subsystems individually. It is necessary to show, that all individual systems can work at the same time and communicate, if necessary, with each other. Realistic testing includes also, that the licensing authorities inspects on the basis of detailed listings all relevant maintenance operations necessary for normal and off-normal operations.

While the all devices inside to Access Cell and also the Through Wall Windows are part of the Access Cell WBS, the conventional construction including shielding doors and the removable ceiling are considered to be part of the Conventional Facility.
It is thought, that the Access Cell does not need a Cell Liner.

C. <u>Detailed WBS Listing:</u>

2.2.8.1 Assembly and testing of Access Cell
- 2.2.8.1.1 Assembly
- 2.2.8.1.2 Testing

D. Costing Rationale:

Engineering deliverable (such as listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. <u>Detailed Costing:</u>

2.2.8.1.1 Assembly:
All costs (incl. engineering ones) are considered to be included in the individual WBS elements.

2.2.8.1.2 Testing:
Engineering estimate for IFMIF On-site costs:
- Detailed definition of manipulation sequences for all remote handling operations
- Test on real devices under normal and simulated off-normal conditions

2400 hr. 189.400,- DM 124,600 ICF

WORKSHEET

WBS 2.2.8.2 Access Cell Structure

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc			nc	164	13	35	212

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Access Cell is located directly above the Test Cell. It houses all remote handling equipment necessary to handle the Vertical Test Assemblies, shield plugs, Test Cell removable cover. All manipulator systems necessary for any maintenance in the Test Cell (including the Li-Target) under normal and off-normal conditions are part of the Access Cell.

In contrast to e.g. the Test Module Handling Cell and the Service cell no steel liner should be necessary in the Access Cell. The conventional construction including shielding doors and removable ceiling are part of the Conventional Facility.

C. Detailed WBS Listing:

2.2.8.2. Access Cell Structure:
- 2.2.8.2.1 Cell liner
- 2.2.8.2.3 Through wall windows

D. Costing Rationale:

Engineering efforts, fabrication methods, requirements, and procedures were evaluated for the feasibility, fabrication and assembly of each major component of the Access Cell. From these evaluations, fabrication man-hour estimates were made by based on the amount of welding, machining metal preparation and general labor required for fabrication and assembly.
Engineering deliverable (such as drawings, FE-calculations, specifications) required.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

The cost estimate is done according to the experience from the FZK Hot Cells (see note from M. Nägele, Head of FZK Hot Cells).

E. Detailed Costing:

2.2.8.2.1 Cell liner:

In contrast to e.g. the Test Module Handling Cell and the Service Cell no steel liner is considered in the Access Cell. **Is that true?**

Therefore, this element of the WBS has no costs.

If a steel liner is considered to be necessary, the costs would be considerable due to the large size of the Access Cell (20m x 8 m). In this case the costs are estimated assuming a liner thickness of 10 mm, an inner surface of 650 $m^{2:}$

- Materials estimate for On-site fabrication:	(650.000,- DM)	
- 1300 m^2 proved welds	(220.000,- DM)	
-TOTAL	(870.000,- DM)	(572,000 ICF)

2.2.8.2.2 Through Wall Windows:

Such windows are necessary for the Telescopic manipulator systems. They also allow a much better visualization of the Access Cell interior as any remote controlled camera system. The global estimate is based on existing lead windows in the FZK Cyclotron Facility.
Window thickness equivalent to 20 cm lead.
Window size 100 cm x 100 cm

Material, fabrication and assembling:		
5 Through wall windows	250.000,-	164,000 ICF
Engineering (layout and drawings):		
250 hr	19.500,-	12,800 ICF

WORKSHEET

WBS 2.2.8.3 Universal Robot System

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
3,434	nc	687	4121	nc	395	79	474

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Universal Robot System is the main device in the Access Cell for

- routine Vertical Test Assembly removal and reloading operations both in the Access Cell itself and in the Test Cell,
- removal and exact insertion of shield plugs and Removable test Cell Cover
- any power maintenance operation in the Access Cell and the Test Cells including Maintenance on the Li-target during normal and off-normal operations.

This Universal Robot System should be able

- to handle very heavy loads as lifting device (up to 50 tons if the Test Cell Cover has to be removed by this system),
- for precise positioning (1 mm) of Test Assemblies, Shield plugs and Removable Cover
- to carry various multiple-purpose modular articulated robot systems for any remote handling manipulations. E.g. Modular Robot Systems like "TELEBOT-Wälischmiller" allow unlimited rotation of all shafts up to 240 Kg,
- to allow remote vision manipulations.

Important features of the Universal Robot System include also positioning of loads in all three dimensions and the ability for virtual reality simulation (e.g. system KISMET-Wälischmiller).

Two Universal Robot System are presently under discussion:

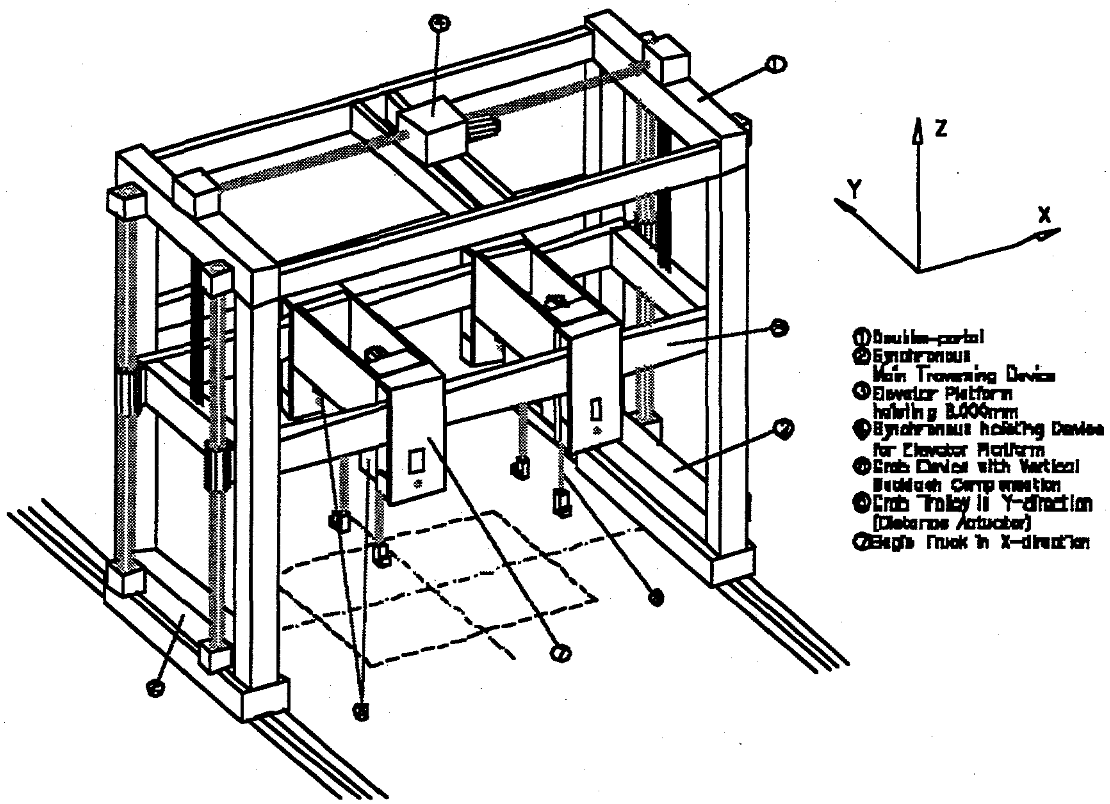
- The General handling Robot ROBERTINO (see attached figures)
- A Robot and Lifting Device from PET.

C. Detailed WBS Listing:

There is no other listings in this Section of the WBS. The Universal Robot System WBS 2.2.8.3. is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design improvement, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.



E. Detailed Costing:

Because costs of the ROBERTIO type System are pending (ENEA), the cost estimate of the quotation page 23 from PET (Darmstadt, Germany) is used.

Engineering (global estimate from PET):		
	600.000,- DM	395,000 ICF
Material, fabrication, installation and testing (PET):		
a) Mainframe complete, wingspread <10 m, lifting 6 m		
	1.080.000,- DM	711,000 ICF
b) Synchro drive for Mainframe (Y-direction):		
	360.000,- DM	237,000 ICF
c)Lifting platform , 4-fold precision guide bearings in Z-direction:		
	540.000,- DM	355,000 ICF
d) Synchrodrive at two sides for lifting platform:		
	780.000,- DM	513,000 ICF
e) 4 columnar liftings (Z-direction):		
	110.000,- DM	72,000 ICF
f) 2 drive units for 2 columnar liftings each		
	530.000,- DM	349,000 ICF
g) 2 drive units for loads in X-direction		
	950.000,- DM	625,000,- ICF
h) 50 m rails (2 sides) for Universal Robot System		
	360.000,- DM	237,000 ICF
i) Electronics, control units, positioning,		
	500.000,- DM	329,000 ICF
TOTAL	5.220.000,- DM	3,434,000 ICF

WORKSHEET

WBS 2.2.8.4 Manipulator Systems

A. Summary Cost estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
2,140		nc	428	2,568	nc		165	33	198

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Manipulator Systems are regarded to be necessary for all handling and maintenance purposes which cannot be done by the Universal Robot System. They also assist the Universal Robot System during removal and reloading operations in the Access Cell. The Manipulators should be also able to do maintenance in the Test Cell itself. In the present design

- 5 Power Master/Slave Manipulators are foreseen, integrated in the Access Cell Wall in connection with Through Wall windows. Telescopic Manipulator based systems with electric indexing for handling loads up to 20 Kg and reach up to 5 m are necessary
- 2 Mobile Service Robots for special purpose Activities. They are necessary because due to the inner with of the Access Cell (8 m) not all work can be done by the Master/Slave manipulators.

C. Detailed WBS Listing:

2.2.8.4 Manipulator Systems

2.2.8.4.1 Telescopic Master/Slave Manipulators

2.2.8.4.2 Service Robots

D. Costing Rationale:

Engineering deliverable (such as design improvement, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (global estimate from PET):

2.2.8.4.1	150.000,- DM	99,000 ICF
2.2.8.4.2	100.000,- DM	66.000 ICF

Material, fabrication, installation and testing (PET):

2.2.8.4.1 5 Complete Telescopic Master/Slave Manipulator Systems

2.250.000,- DM 1,480,000 ICF

2.2.8.4.2 2 Mobile Service Robots

1.000.000,- DM 660,000 ICF

WORKSHEET
WBS 2.2.8.5 Maintenance and Support Equipment

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
136		375	102	613			132	26	158

Units: U. S. Dollars ($1,000)

B. Description:

Test Cell Handling Fixtures are used in the removal and installation operations of VTA-1, VTA-2, and the VIT Plug. Handling fixtures are also used in transporting the VTA's and the VIT Plug to the Service Cell. In addition, fixtures are also used in the Test Module removable and installation operations. These fixtures work in conjunction with the remote handling equipment and are designed to perform a particular function. A list of these Fixtures, located in the Access Cell, is given below.

Fixture Name	Function
VTA-1 Lifting Fixture	Used in lifting VTA-1
VTA-2 Lifting Fixture	Used in lifting VTA-2
VIT Plug Lifting Fixture	Used in lifting VIT Plug
VTA-1 Inverting Fixture	Used in inverting VTA-1
VTA-2 Inverting Fixture	Used in inverting VTA-1
VTA-1 Transporting Fixture	Used in transporting VTA-1 to Service Cell
VTA-2 Transporting Fixture	Used in transporting VTA-1 to Service Cell
VIT Plug Transporting Fixture	Used in transporting VIT to Service Cell
VTA-1 Module Cover Fixture	Used to protect VTA-1 Module during transport
VTA-2 Module Cover Fixture	Used to protect VTA-2 Module during transport
VTA-1 Module Removal Fixture	Used in removing VTA-1 Test Module
VTA-2 Module Removal Fixture	Used in removing VTA-2 Test Module
VTA-1 Module Installation Fixture	Used in installing VTA-1 Test Module
VTA-2 Module Installation Fixture	Used in installing VTA-2 Test Module

C. Detailed WBS Listing:

There are no other WBS Listings in this section of the WBS. The Test Cell SP WBS 2.2.8.5, is the lowest WBS level listed.

D. Costing Rationale:

Fabrication methods, requirements, and procedures were evaluated for the fabrication and assembly of each major component of the Test Cell SP. From these evaluations, fabrication man-hour estimates were made based on the amount of welding, machining, metal preparation, and general labor required for fabrication and assembly of these major components and the Test Cell SP. The fabrication cost is based on a $67.00 hourly rate.
Engineering deliverables (such as drawings, specifications, and calculations) required for the design of these components and the assembly of the Test Cell SP were also evaluated. An engineering man-hour estimate was made based on these deliverables. The estimated engineering cost is based on a $ 98.50 hourly rate.

E. Detailed Costing:

1. Engineering estimate for design of VTA-1 Lifting Fixture:		
a. three (3) E size drawings	300 hr.	$ 29,550
1. Labor estimate for fabrication of VTA-1 Lifting Fixture:		
a. metal prep 20 PC of carbon steel	80 hr.	$ 5,360
b. welding 10M X 12.7 mm	70 hr.	$ 4,690
c. machining for VTA-1 interface	50 hr.	$ 3,350
1. Materials estimate for fabrication of VTA-1 Lifting Fixture:		
250 LB carbon steel @ 0.60/lb. $500 misc.)		$ 650
	Total	$ 43,600

2. The cost of the following fixtures will be assumed to be the same as VTA-1 Lifting Fixture.

VTA-2 Lifting Fixture
VIT Plug Lifting Fixture
VTA-1 Inverting Fixture
VTA-2 Inverting Fixture
VTA-1 Transporting Fixture
VTA-2 Transporting Fixture
VIT Plug Transporting Fixture

3. Engineering estimate for design of VTA-1 Module Cover Fixture:		
a. two (2) E size drawings	200 hr.	$ 19,700
3. Labor estimate for fabrication of VTA-1 Module Cover Fixture:		
a. metal prep 10 PC of carbon steel	40 hr.	$ 2,680
b. welding 5M X 12.7 mm	35 hr.	$ 2,345
c. machining for VTA-1 interface	30 hr.	$ 2,010
3. Materials estimate for fabrication of VTA-1 Module Cover Fixture:		
250 LB carbon steel @ 0.60/lb. $500 misc.)		$ 650

4. The cost of the following fixtures will be assumed to be the same as the VTA-1 Module Cover Fixture:

VTA-2 Module Cover Fixture
VTA-1 Module Removal Fixture
VTA-2 Module Removal Fixture
VTA-1 Module Installation Fixture
VTA-2 Module Installation Fixture

WORKSHEET
WBS 2.2.8.6 Infrastructure

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc		nc	526	79	121	726

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Main infrastructure installations include
- Electric power which is suitable to feed all devices in the Access Cell
- compressed air, inert gases, cables
- Lightning
- Support structures for Universal Robot System, Cell Maintenance, Hydraulic Systems,

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Infrastructure Installation WBS 2.2.8.6 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design improvement, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (global estimate from PET):	120.000,- DM	79,000 ICF
Material, fabrication, installation and testing (PET):	800.000,- DM	526,000 ICF

WORKSHEET
WBS 2.2.9.1 Assembly and Testing of Service Cell

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	nc	nc	nc	125	25 150

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The large Service Cell will be immediately connected to a Access Cell . All costs for the assembly and testing of subsystems are already included in the related WBS of the individual systems. However the experience with large accelerator facilities has shown that it is not sufficient to test all subsystems individually. It is necessary to show, that all individual systems can work at the same time and communicate, if necessary, with each other. Realistic testing includes also, that the licensing authorities inspects on the basis of detailed listings all relevant maintenance operations necessary for normal and off-normal operations.

While all devices inside to Access Cell and also the Through Wall Windows are part of the Service Cell WBS, the conventional construction including shielding doors and the removable ceiling are considered to be part of the Conventional Facility. The Service Cell will have a steel liner.

C. Detailed WBS Listing:

2.2.9.1 Assembly and testing of Access Cell
- 2.2.9.1.1 Assembly
- 2.2.9.1.2 Testing

D. Costing Rationale:

Engineering deliverable (such as listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

2.2.9.1.1 Assembly:

All costs (incl. engineering ones) are considered to be included in the individual WBS elements.

2.2.9.1.2 Testing:

Engineering estimate for IFMIF On-site costs (similar to the Access Cell):
- Detailed definition of manipulation sequences for all remote handling operations
- Test on real devices under normal and simulated off-normal conditions

2400 hr. 189.400,- DM 124,600 ICF

WORKSHEET

WBS 2.2.9.2 Service Cell Structure

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc		nc	573	13	117	703

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Service Cell is located directly near the Access Cell. It houses all remote handling equipment necessary to handle the Vertical Test Assemblies, Test Modules, Specimen Rigs and Li-Target components. All manipulator systems necessary for any maintenance in the Service Cell (including the Li-Target) under normal and off-normal conditions are part of the Service Cell.

In contrast to the Access Cell, the remote handling devices inside the Service Cell must be capable to completely strip down and reassemble all devices to be irradiated in the Test Cell. Also unexpected maintenance operations (e.g. welding, cutting) should be possible.

The Service Cell will have a steel liner. The conventional construction including shielding doors and removable ceiling are part of the Conventional Facility.

C. Detailed WBS Listing:

2.2.9.2. Service Cell Structure:
- 2.2.9.2.1 Cell liner
- 2.2.9.2.3 Through wall windows

D. Costing Rationale:

Engineering efforts, fabrication methods, requirements, and procedures were evaluated for the feasibility, fabrication and assembly of each major component of the Access Cell. From these evaluations, fabrication man-hour estimates were made by based on the amount of welding, machining metal preparation and general labor required for fabrication and assembly.
Engineering deliverable (such as drawings, FE-calculations, specifications) required.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

The cost estimate is done according to the experience from the FZK Hot Cells (see note from M. Nägele, Head of FZK Hot Cells).

E. Detailed Costing:

2.2.9.2.1 Cell liner:

The costs are considerable due to the large size of the Service Cell (13.8m x 5.5 m). The costs are estimated assuming a liner thickness of 10 mm, an inner surface of 500 $m^{2:}$

- Materials estimate for On-site fabrication:	500.000,- DM	329,000 ICF
- 1000 m^2 proved welds	170.000,- DM	112,000 ICF
-TOTAL	670.000,- DM	441,000 ICF

2.2.9.2.2 Through Wall Windows:

Such windows are necessary for the Telescopic manipulator systems. They also allow a much better visualization of the Access Cell interior as any remote controlled camera system. The global estimate is based on existing lead windows in the FZK Cyclotron Facility.
Window thickness equivalent to 20 cm lead.
Window size 100 cm x 100 cm

Material, fabrication and assembling:		
4 Through wall windows	200.000,-	132,000 ICF
Engineering (layout and drawings):		
250 hr	19.500,-	12,800 ICF

WORKSHEET
WBS 2.2.9.3 Component Transfer Systems

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF			
Industry	Instit'al		Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc	nc	198	26	45	269

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

In order to transport huge devices from the Access Cell to the Service Cell, a suitable transport system is necessary. This system is capable to carry heavy (several tons) and long (4.5 meter) devices like complete VTAs. Before VTAs are transported, they have to be turned from a vertical position to a horizontal one. In order to guarantee a safe and quick transport, a rail (8 m) based chart is suggested. For the transport of the much smaller test modules (length <1.5 m) a transfer chart between the Service Cell and the Test Module Handling Cell is considered to be sufficient.

C. Detailed WBS Listing:

2.2.9.3 Component Transfer Systems
- 2.2.9.3.1 Transfer Rail System
- 2.2.9.3.2 Transfer Chart

D. Costing Rationale:

Engineering deliverable (such as design, drawings, listings, testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Attention: the costs in this section are only roughly estimated

2.2.9.3.1 Transfer Rail System:

Engineering: draft estimate for rails, chart system and remote drive
300 Hr. 23.700 DM 15,600 ICF

Material, fabrication and installation: draft estimate:
200.000,- 132,000 ICF

2.2.9.3.2 Transfer Chart:

Engineering: draft estimate for rails, chart system and remote drive
200 Hr. 15.800 DM 10,400 ICF

Material, fabrication and installation: draft estimate:
100.000,- 66,000 ICF

WORKSHEET
WBS 2.2.9.4 Manipulator Systems

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
1546	nc	309	1855	nc	224	45	269

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Manipulator Systems are regarded to be necessary for all handling and maintenance purposes. All manipulator systems necessary for any maintenance in the Service Cell (including the Li-Target) under normal and off-normal conditions are part of the Service Cell. In contrast to the Access Cell, the remote handling devices inside the Service Cell must be capable to completely strip down and reassemble all devices to be irradiated in the Test Cell. Also unexpected maintenance operations (e.g. welding, cutting) should be possible. The manipulators are fitted also with cutting and welding tools. In the present design

- 3 Power Master/Slave Manipulators are foreseen, integrated in the Access Cell Wall in connection with Through Wall windows. Telescopic Manipulator based systems with electric indexing for handling loads (?) 20 Kg) and long reach (?) 5 m) are necessary.
- 1 Mobile Service Robots for special purpose Activities. It is also necessary because due to the inner with of the Service Cell not all work can be done by the Master/Slave manipulators.
- 1 Special purpose Manipulator to turn upside town the NaK cooled VTA-1 in order to drain the liquid metal into sump tanks.

C. Detailed WBS Listing:

2.2.9.4 Manipulator Systems
- 2.2.9.4.1 Telescopic Master/Slave Manipulators
- 2.2.9.4.2 Service Robot
- 2.2.9.4.3 Special Purpose Manipulator

D. Costing Rationale:

Engineering deliverable (such as design, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (global estimates from PET and FZP Hot Cells):

2.2.9.4.1	120.000,- DM	79,000 ICF
2.2.9.4.2	100.000,- DM	66,000 ICF
2.2.9.4.3	120.000,- DM	79,000 ICF

Material, fabrication, installation and testing (PET):

2.2.9.4.1	3 Complete Telescopic Master/Slave Manipulator Systems	1.350.000,- DM	888,000 ICF
2.2.9.4.2	1 Mobile Service Robots	500.000,- DM	329,000 ICF
2.2.9.4.3	1 Special Purpose Robot	500.000,- DM	329,000 ICF

WORKSHEET

WBS 2.2.9.5 Bridge Crane

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc		nc	460	6,2	93	559

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Bridge Crane in the Service Cell is necessary to lift

- VTAs and in exceptional cases Li-Target components from and onto the transfer rail system between the Service Cell and the Access Cell,
- test modules from and onto the transfer chart between Service cell and Access Cell

Because some VTAs have a weight of up to ~11 tons, the bearing capacity should be sufficiently high. For the specified purposes its not necessary to have a high precision positioning bridge crane.

C. Detailed WBS Listing:

There is no other listings in this section of WBS. The Bridge Crane WBS 2.2.9.5 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design, drawings, and testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (estimates from FZK Hot Cells):

120 hr.	9.500,- DM	6,200 ICF

Material, fabrication and installation (estimate from existing Bridge Cranes in FZK Hot Cell)

Complete 15 tons Bridge Crane:	700.000,- DM	460,000 ICF

WORKSHEET
WBS 2.2.9.6 Maintenance and Support Devices

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc		nc	660	132	158	950

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. <u>Description:</u>

Various Maintenance and Support systems are necessary like card receivers, tables, special purpose tools for check-out and repair operations as well as diagnostic tools (vacuum leakage detectors, electric signal detectors, positioners).

C. <u>Detailed WBS Listing:</u>

There is no other listing s in this section of the WBS. The Maintenance and Support Devices WBS 2.2.9.6 is the lowest WBS listed.

D. <u>Costing Rationale:</u>

Engineering deliverable (such as design improvement, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. <u>Detailed Costing:</u>

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (global estimate: 20% of the material, fabrication and installation costs):
200.000,- DM 132,000 ICF

Material, fabrication and installation (FZK Hot Cell estimate):
1.000.000,- DM 660,000 ICF

WORKSHEET

WBS 2.2.10.1 Assembly and Testing of Test Module Handling Cell

A. Summary Cost estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc		nc	nc		nc		78	16	94

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Test Module Handling Cell will be immediately connected to a Service Cell . All costs for the assembly and testing of subsystems are already included in the related WBS of the individual systems. However the experience with large accelerator facilities has shown that it is not sufficient to test all subsystems individually. It is necessary to show, that all individual systems can work at the same time and communicate, if necessary, with each other. Realistic testing includes also, that the licensing authorities inspects on the basis of detailed listings all relevant maintenance operations necessary for normal and off-normal operations.

While all devices inside to Test Module Handling Cell and also the Through Wall Windows are part of the Service Cell WBS, the conventional construction including shielding doors and the removable ceiling are considered to be part of the Conventional Facility. The Service Cell will have a steel liner.

C. Detailed WBS Listing:

2.2.10.1 Assembly and testing of Test Module Handling Cell
- 2.2.10.1.1 Assembly
- 2.2.10.1.2 Testing

D. Costing Rationale:

Engineering deliverable (such as listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

2.2.10.1.1 Assembly:

All costs (incl. engineering ones) are considered to be included in the individual WBS elements.

2.2.10.1.2 Testing:

Engineering estimate for IFMIF On-site costs (similar to the Access Cell):
- Detailed definition of manipulation sequences for all remote handling operations
- Test on real devices under normal and simulated off-normal conditions

1500 hr. 118.000,- DM 77,900 ICF

WORKSHEET

WBS 2.2.10.2 Test Module Handling Cell Structure

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
43	nc	9	52	280	12,8	59	352

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Test Module Handling Cell is located directly near the Service Cell. The disassembly and reassembly of the test modules will be conducted in this cell. The packages containing the individual specimens will be removed from the test modules, and the packets will be cut open to retrieve the irradiated specimens in this Hot Cell. This cell will also be used for final assembly of the specimen packets and rigs into the test module prior to irradiation. This Test Module Handling Cell houses all remote handling equipment necessary to handle the test modules, the rigs (in case of helium cooled test modules), the specimen capsules and its instrumentation.

Tritium-containing specimens:
a) 1st option: Tritium Laboratory available: For tritium containing or tritium-contaminated materials, only disassembly of the test module will be carried out in this Hot Cell and retrieval of the specimens by cutting the capsule will be done in the Tritium Laboratory.
b) 2nd option: No Tritium Laboratory on IFMIF site: Retrieval of the specimens by cutting the capsule will be done in this Test Module Handling Cell. If the specimens can be kept during this procedure at ambient temperatures or slightly above, practically all tritium remains trapped inside the specimens ("frozen"), that is, uncontrolled escape of tritium into the environment can be practically excluded. Whether option 1 or 2 has to be used depends on the Tritium release rates allowed on IFMIF site.

This cell is equipped beside other devices with various welding and cutting tools. The Test Module Handling Cell will have a steel liner. The conventional construction including shielding doors and removable ceiling are part of the Conventional Facility.

C. Detailed WBS Listing:

2.2.10.2. Service Cell Structure:
- 2.2.10.2.1 Cell liner
- 2.2.10.2.2 Through wall windows
- 2.2.10.2.3 Tube Mailing system to PIE Hot Cells and Tritium Laboratory

D. Costing Rationale:

Engineering efforts, fabrication methods, requirements, and procedures were evaluated for the feasibility, fabrication and assembly of each major component of the Test Module Handling Cell. From these evaluations, fabrication man-hour estimates were made by based on the amount of welding, machining metal preparation and general labor required for fabrication and assembly.
Engineering deliverable (such as drawings, specifications, testing) required.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

The cost estimate is done according to the experience from the FZK Hot Cells (see note from M. Nägele, Head of FZK Hot Cells).

E. Detailed Costing:

2.2.10.2.1 Cell liner:

The size of the Test Module handling Cell is assumed to be (5.5 m x 5.5 m). The costs are estimated assuming a liner thickness of 10 mm, an inner surface of 260 m^2

- Materials estimate for On-site fabrication:	260.000,- DM	135,000 ICF
- 520 m^2 proved welds	88.000,- DM	46,000 ICF
-TOTAL	348.000,- DM	181,000 ICF

2.2.10.2.2 Through Wall Windows:

Such windows are necessary for the Telescopic manipulator systems. They also allow a much better visualization of the test Module Handling Cell interior as any remote controlled camera system. The global estimate is based on existing lead windows in the FZK Cyclotron Facility. Window thickness equivalent to 20 cm lead.
Window size 100 cm x 100 cm

Material, fabrication and assembling:		
3 Through Wall Windows	150.000,-	99,000 ICF
Engineering (layout and drawings):		
250 hr	19.500,-	12,800 ICF

2.2.10.2.3 Tube mailing system:

Presently a tube mailing system to the PIE Hot Cells is not considered to be of primary importance because of the relatively low specimen yield. Therefore, no costs are given for this section of the WBS. Nevertheless a rough estimate will be given:

Engineering (layout and drawings)		
150 hr.	(11.800,- DM)	(7,800 ICF)
Material, fabrication and assembling (rough estimate)		
	(150.000,- DM)	(99,000 ICF)

WORKSHEET
WBS 2.2.10.3 Manipulator Systems

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
1,414	nc	283	1,697	nc	145	29	174

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Manipulator Systems are regarded to be necessary for all handling and maintenance purposes. A more general short description of this Cell is given in WBS 2.2.7.2. Also unexpected maintenance operations should be possible. The manipulators are fitted among others with cutting and welding tools. In the present design

- 3 Telescopic Master/Slave Manipulators are foreseen, integrated in the Access Cell Wall in connection with Through Wall windows. Telescopic Manipulator based systems with electric indexing for handling loads (<20 Kg) and long reach (<5 m) are necessary.
- 4 Modular Robot Systems for disassembly and assembly and check the rigs, specimen packages and test modules. It is foreseen to use multiple purpose modular acticulated robot systems with handling loads of <240 Kg (E.g. TELBOT-Systems from Wälischmiller, Germany).

C. Detailed WBS Listing:

2.2.10.3 Manipulator Systems
- 2.2.10.3.1 Telescopic Master/Slave Manipulators
- 2.2.10.3.1 Modular Robot Systems

D. Costing Rationale:

Engineering deliverable (such as design, drawings, listings, system programming and extended testing) required.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (global estimates from FZK Hot Cells):

2.2.10.3.1	120.000,- DM	79,000 ICF
2.2.10.3.2	100.000,- DM	66,000 ICF

Material, fabrication, installation and testing (global estimate from FZK Hot Cell):

2.2.10.3.1 3 Complete Telescopic Master/Slave Manipulator Systems

1.350.000,- DM 888,000 ICF

2.2.10.3.2 4 Modular Robot Systems

800.000,- DM 526,000 ICF

WORKSHEET
WBS 2.2.10.4 Bridge Crane

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc	nc		197	6,2	41	244

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Bridge Crane in the Test Module Handling Cell is necessary to lift test modules, rigs and other disassembled irradiation devices during maintenance and handling operations. It will be also used to bring complete test modules from and onto the transfer chart between Test Module Handling Cell and Service Cell.

C. Detailed WBS Listing:

There is no other listings in this section of WBS. The Bridge Crane WBS 2.2.10.4 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design, drawings, and testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (estimates from FZK Hot Cells):

120 hr.	9.500,- DM	6,200 ICF

Material, fabrication and installation (estimate from existing Bridge Cranes in FZK Hot Cell)

Complete 5 tons Bridge Crane:	300.000,- DM	197,000 ICF

WORKSHEET
WBS 2.2.10.5 Maintenance and Support Devices

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	nc	nc	197	79	55 331

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Various Maintenance and Support systems are necessary like card receivers, tables, special purpose tools for check-out and repair operations as well as diagnostic tools (vacuum leakage detectors, electric signal detectors, positioners).

C. Detailed WBS Listing:

There is no other listing s in this section of the WBS. The Maintenance and Support Devices WBS 2.2.10.5 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design improvement, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (global estimate: 20% of the material, fabrication and installation costs):
120.000,- DM 79,000 ICF

Material, fabrication and installation (FZK Hot Cell estimate):
300.000,- DM 197,000 ICF

WORKSHEET
WBS 2.2.10.6 Infrastructure

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF			
Industry	Instit'al		Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc	nc	164,5	24,7	38	226

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Main infrastructure installations include

- Electric power which is suitable to feed all devices in the Access Cell
- compressed air, inert gases, cables
- Lightning
- Support structures for Robot Systems, Cell Maintenance, Hydraulic Systems

C. Detailed WBS Listing:

There is no other listings in this section of the WBS. The Infrastructure Installation WBS 2.2.10.6 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design, drawings, listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Attention: the costs in this section are only roughly estimated

Engineering (global estimate 15% of Mat'l, fabr., install., and testing):

. 37.500,- DM 24,700 ICF

Material, fabrication, installation and testing:

250.000,- DM 164,500 ICF

WORKSHEET

WBS 2.2.11.1 Assembly and Testing of PIE Hot Cell

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	nc	nc	nc	103	21 124

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

In contrast to a former concept discussed in the first half of the CDA-Phase, a Hot Cell Design is now favored which has only one large Hot Cell instead of various independent small ones . That is, all mechanical test devices are within one common Cell. One of the main arguments for one single Hot Cell is a significant cost reduction with respect to installation and ventilation.
The present design is modular with respect to the size of all remote handling stations and with respect to maintenance procedures.
Because Conventional Hot Cells are operated in a variety of associations all with long term experience, the bulk of all IFMIF Hot Cell assembly and testing procedures is already well known.

C. Detailed WBS Listing:

2.2.11.1 Assembly and testing of Test Module Handling Cell
- 2.2.11.1.1 Assembly
- 2.2.11.1.2 Testing

D. Costing Rationale:

Engineering deliverable (such as listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

No relevant cost uncertainties are expected. Nevertheless, the global cost estimate given below has to evaluated in more detail.

2.2.11.1.1 Assembly:

All costs (incl. engineering ones) are considered to be included in the individual WBS elements.

2.2.11.1.2 Testing (including support for commissioning):

Engineering estimate for IFMIF On-site costs:

2000 hr.	157.800,- DM	103,000 ICF

WORKSHEET
WBS 2.2.11.2 PIE Hot Cell Structure

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF			
Industry	Instit'al		Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc	nc	1,868	164	406	2,438

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Test Module Handling Cell is an individual, stand alone Hot Cell mainly dedicated to mechanical testing of postirradiated specimens. It consists of the main Hot Cell structure which houses all mechanical testing devices including instrumentation, and an affiliated access cell. If any maintenance or change of a specific test device is necessary, it will be lifted in the PIE Hot Cell onto a transfer rail system and brought into the Access Cell. In the PIE access cell personal may enter to accomplish maintenance or fitting activities.

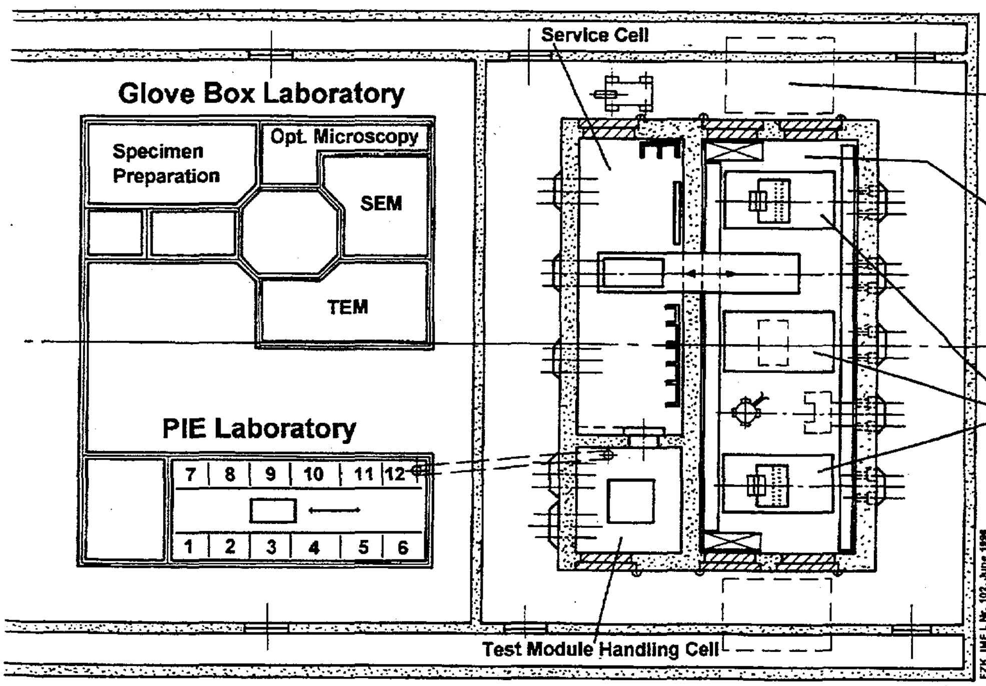


Fig. 2.2.11.2: Plan view of the Test facilities with PIE Laboratory.

C. Detailed WBS Listing:

2.2.11.2. Service Cell Structure:
- 2.2.11.2.1 Cell liner
- 2.2.11.2.2 Lead shielding
- 2.2.11.2.3 Removable cell ceiling

D. <u>Costing Rationale:</u>

Engineering efforts, fabrication methods, requirements, and procedures were evaluated for therefore the feasibility, fabrication and assembly of each major component of the Test Module Handling Cell. From these evaluations, fabrication man-hour estimates were made by based on the amount of welding, machining metal preparation and general labor required for fabrication and assembly.
Engineering deliverable (such as drawings, specifications, testing) required.

The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

The cost estimate is done according to the experience from the FZK Hot Cells (see note from M. Nägele, Head of FZK Hot Cells).

E. <u>Detailed Costing:</u>

<u>2.2.11.2.1 Cell liner:</u>

The sizes of the main PIE Hot Cell and the PIE access cell are assumed to be ~13m x ~5.5m, and 4m x 5.5m, respectively. The costs are estimated assuming a liner thickness of 10 mm, and an inner surface of 250 m^2

- Materials estimate for On-site fabrication:	250.000,- DM	164,000 ICF
- 500 m^2 proved welds	84.000,- DM	55,000 ICF
-TOTAL	334.000,- DM	219,000 ICF

<u>2.2.11.2.2 Lead shielding:</u>

This lead shielding is integrated in the steel structure and has in the present design a thickness of 20 cm. *Whether it is possible to reduce significantly the wall thickness has to be evaluated on the basis of relevant activation analyses.* From the experience with miniaturized specimens it is not unrealistic to assume that a PIE Hot Cell wall thickness of 10 cm might be sufficient. The wall thickness reduction would have a big impact on cost reduction.

Material (20 cm), fabrication and assembling:
2.250.000,- DM 1.320,000 ICF

Engineering (global estimate 10% of material, fabrication and installation:
225.000,-DM 148,000 ICF

<u>2.2.11.2.3 Removable cell ceiling:</u>

30 cm steel construction is assumed. A ceiling area of 100 m^2 implies 30 m^3 volume and 250 tons steel à 2000/t DM (completely assembled).

Engineering (global estimate 5% of material, fabrication and installation):
25.000,- DM 16,400 ICF

Material, fabrication and assembling (rough estimate)
500.000,- DM 329,000 ICF

WORKSHEET

WBS 2.2.8.3 Manipulator Systems

A. Summary Cost estimate:

Off-IFMIF Site					On-site at IFMIF				
Industry		Instit'al			Industry		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
2214		nc	443	2657	nc		112	22	134

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Manipulator Systems are necessary for all handling and maintenance purposes. A more general short description of this Cell is given in WBS 2.2.7.2. In the present design

- 15 Working stations (incl. through wall windows) are foreseen which are integrated in the PIE Hot Cell wall.
- 2 Power Master/Slave Manipulator Systems with various tools are also necessary for general Maintenance and fitting purposes.

C. Detailed WBS Listing:

2.2.11.3 Manipulator Systems
- 2.2.11.3.1 Working stations
- 2.2.11.3.2 Power Manipulator Systems

D. Costing Rationale:

Engineering deliverable (such as design, drawings, listings, and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (global estimates from FZK Hot Cells):

2.2.11.3.1	120.000,- DM	79,000 ICF
2.2.11.3.2	50.000,- DM	33,000 ICF

Material, fabrication, installation and testing (global estimate from FZK Hot Cell):

2.2.11.3.1 15 Complete Working stations including through wall windows, each 500.000,- DM 7.500.000,- DM 888,000 ICF

2.2.11.3.2 2 Power Manipulator systems, each 1.000.000,-DM 2.000.000,- DM 1,326,000 ICF

WORKSHEET
WBS 2.2.11.4 Bridge Crane

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc	nc		197	6,2	41	244

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The Bridge Crane in the PIE Hot Cell is necessary to lift mechanical testing devices during maintenance and handling operations. It will be also used to move complete test modules from and onto the transfer chart between the main PIE Hot Cell and the PIE access cell.

C. Detailed WBS Listing:

There is no other listings in this section of WBS. The Bridge Crane WBS 2.2.11.4 is the lowest WBS listed.

D. Costing Rationale:

Engineering deliverable (such as design, drawings, and testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

Because a more detailed cost estimate is pending (ENEA), the global cost estimate from the FZK Hot Cell will be used as input.

Engineering (estimates from FZK Hot Cells):
120 hr. 9.500,- DM 6,200 ICF

Material, fabrication and installation (estimate from existing Bridge Cranes in FZK Hot Cell)
Complete 5 tons Bridge Crane: 300.000,- DM 197,000 ICF

WORKSHEET
WBS 2.2.11.5 Infrastructure

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
nc	nc		nc	1317	132	290	1,739

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Main infrastructure installations include

2.2.11.5.1 - Electric power which is suitable to feed all devices in the PIE Hot Cell
- compressed air, inert gases, cables
- Lightning

2.2.11.5.2 - Support structures for Robot Systems, Cell Maintenance, Hydraulic Systems, locks
- Waste storage containers
- Transfer rail system with cross table

C. Detailed WBS Listing:

2.2.11.5 Infrastructure Installation
- 2.2.11.5.1 Electric power and gases
- 2.2.11.5.2 Mechanical Infrastructure

D. Costing Rationale:

Engineering deliverable (such as design, drawings, listings and testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. Detailed Costing:

The global cost estimate from the FZK Hot Cell will be used as input.

2.2.11.5.1: Material, fabrication, installation and testing:

	500.000,- DM	330,000 ICF
Engineering (10%):	50.000,- DM	33,000 ICF

2.2.11.5.2: Material, fabrication, installation and testing:

	1.500.000,- DM	987,000 ICF
Engineering (10%):	150.000,- DM	98,700 ICF

WORKSHEET

WBS 2.2.11.6 Examination Equipment for PIE Hot Cells

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
1,074	nc	215	1,289	nc	42	8	50

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

The testing equipment inside the conventional PIE Hot Cell is necessary to do all mechanical investigations on all kinds of irradiated specimens. Also investigations on unirradiated control specimens will be done there. The equipment is defined by the actual requirements to produce relevant data for DEMO oriented materials data bases. Presently the instrumentation includes all mechanical tests foreseen for seven different types of miniaturized specimens mainly irradiated in the high flux region.

C. Detailed WBS Listing:

2.2.11.6 Examination equipment inside the conventional PIE Hot Cells:
- 2.2.11.6.1 Universal testing machines
- 2.2.11.6.2 Furnaces
- 2.2.11.6.3 Thermal fatigue test devices
- 2.2.11.6.4 Corrosion test devices
- 2.2.11.6.5 Fracture toughness test devices
- 2.2.11.6.6 Fatigue crack growth test device
- 2.2.11.6.7 Pressurized tube test devices
- 2.2.11.6.8 Optical microscope
- 2.2.11.6.9 Specimen preparation tools

D. Costing Rationale:

The cost estimate is done according to the experience from the FZK Hot Cells (see note from R. Lindau, FZK).The costs are based on already existing devices and were updated according to inflation, if necessary. Because essentially all equipment can be purchased by the industry, the engineering efforts are considered to be negligible compared to the total costs.

At IFMIF on site 4 MJ will be necessary for tests and putting all apparatus into operation
4 x 2000h x 78.90 DM = 63.120 DM/h 41,500 ICF.

E. Detailed Costing:

2.2.11.6.1-9 (see attachment with detailed listings):
TOTAL 1.633.000,- DM 1,074,000 ICF

Post irradiation examination test equipment for IFMIF

Number	Testing device	Load range	Temperature range	Environment	Manufacturer testing machines	Estimated costs per unit	Total costs	Total
				Tensile tests				
2	UTM	10 kN			Zwick	100.000 DM	200.000 DM	
2	vacuum furnace		20-1000 °C	vacuum	PET	100.000 DM	200.000 DM	
								400.000 DM
				Push-pull fatigue tests				
2	FTM	10 kN			Zwick	100.000 DM	200.000 DM	
2	vacuum furnace		20-600 °C	vacuum	PET	100.000 DM	200.000 DM	
				inert gas		TBD		
1	corrosion test rig			aqueous		TBD		
1	corrosion test rig			liquid metal		TBD		
								400.000 DM
				Corrosion fatigue tests				
1	UTM	10 kN			Zwick	100.000 DM	100.000 DM	
1	corrosion test rig			aqueous		TBD		
1	corrosion test rig			liquid metal		TBD		
								100.000 DM
				Fracture toughness tests				
2	UTM			vacuum	Zwick	100.000 DM	200.000 DM	
								200.000 DM
				Fatigue crack growth rates				
1	FTM			vacuum	Zwick	100.000 DM	100.000 DM	
								100.000 DM
				Pressurized creep tube tests (laser profilometry)				
1	leakage test device				Balzers	40.000 DM	40.000 DM	
1	laser profilometry				MAVIS	50.000 DM	50.000 DM	
								90.000 DM
				Optical microscopy/specimen preparation				
1	Opt. microscope incl. microhardness tester				Leitz	250.000 DM	250.000 DM	
1	diamond saw *				Buehler	10.000 DM	10.000 DM	
1	grinder *				Buehler	6.000 DM	6.000 DM	
1	mech. polisher *				Buehler	6.000 DM	6.000 DM	
								272.000 DM
				Longterm annealing of specimens				
3	Furnaces		1500 °C	Vac./inert gas	Heraeus	20.000 DM	60.000 DM	
								60.000 DM
								1.622.000 DM

* conventional type
costs for hot-cell adaption not considered

WORKSHEET

WBS 2.2.12.1 Assembly and Testing of Shielded Glove Box Laboratory

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	nc	nc	nc	103	21 124

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. <u>Description:</u>

Similar to the arguments for one large PIE Hot Cell also here one common laboratory (only one ventilation system) with separated areas is favored.
Because shielded glove boxes are operated in a variety of associations all with long term experience, the bulk of all necessary assembly and testing procedures is already well known.

C. <u>Detailed WBS Listing:</u>

2.2.12.1 Assembly and testing of Shielded Glove Box Laboratory
- 2.2.12.1.1 Assembly
- 2.2.12.1.2 Testing

D. <u>Costing Rationale:</u>

Engineering deliverable (such as listings, system programming and extended testing) required. The estimated engineering cost is based on a 120,- DM or 78.90 ICF hourly rate.

E. <u>Detailed Costing:</u>

No relevant cost uncertainties are expected. Nevertheless, the global cost estimate given below has to evaluated in more detail.

2.2.12.1.1 Assembly:
All costs (incl. engineering ones) are considered to be included in the individual WBS elements.

2.2.12.1.2 Testing (including support for commissioning):
Engineering estimate for IFMIF On-site costs:

2000 hr.	157.800,- DM	103,000 ICF

WORKSHEET

WBS 2.2.12.2 Structure and Support Systems for Shielded Glove Box Laboratory

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
7896	0	1579	9475	0	nc	0	0

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Shielded glove boxes are useful for PIE of very small or low-dose specimens of all kinds of materials, since specimen handling is easy and effective compared with hot cells.

C. Detailed WBS Listing:

2.2.12.2. Structure and Support Systems:
- 2.2.12.2.1 Lead shielded glove box structure
- 2.2.12.2.2 Support systems

D. Costing Rationale:

The cost estimate is done according to the experience from the FZK Hot Cells (see note from M. Nägele, Head of FZK Hot Cells). *More detailed specifications are pending*

E. Detailed Costing:

2.2.12.2.1 Lead shielded glove box:

The overall costs for the steel structure, the lead shields (10 cm), the glove box devices incl. through wall windows, doors and ceiling is roughly estimated to

10.000.000,- DM 6,580,000 ICF

2.2.12.2.2 Support systems:

They include the complete infrastructure installation like electric power, compressed air, inert gases, lighting, waste disposal, small manipulator systems and universal remote tongs.

2.000.000,- DM 1,316,000 ICF

WORKSHEET

WBS 2.2.12.3 Examination Equipment for Shielded Glove Box Laboratory

A. Summary Cost estimate:

Off-IFMIF Site				On-site at IFMIF			
Industry	Instit'al			Industry	Instit'al		
Mat'l/Lab Engin'g	Engin'g	AFI	Total	Mat'l/Lab Engin'g	Engin'g	AFI	Total
1,074	nc	215	1,289	nc	208	42	250

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Microstructural analyses will be indispensable to describe and understand the irradiation induced defects and their impact on materials properties. Because only very small specimens sizes are necessary for these analyses, shielded glove boxes are sufficient. According to the international standards, this Laboratory will be equipped with 10 bench-top glove boxes, modern scanning and transmission electron microscopes (SEM and TEM), TEM specimen preparation tools, an optical microscope, a microhardness tester, a temporary vacuum storage grid for TEM specimens, and an activation analysis system. The latter is important to confirm experimentally on low and reduced activation materials the predictions from activation inventory codes.

C. Detailed WBS Listing:

2.2.12.3. Examination equipment:

- 2.2.12.3.1 SEM
- 2.2.12.3.2 TEM
- 2.2.12.3.3 TEM preparation
- 2.2.12.3.4 Specimen storage
- 2.2.12.3.5 Optical microscope
- 2.2.12.3.6 Microhardness tester
- 2.2.12.3.7 Activation analysis system

D. Costing Rationale:

The cost estimate is done according to the experience from the FZK Hot Cells (see note from R. Lindau, FZK).The costs are based on already existing devices and were updated according to inflation, if necessary. Because essentially all equipment can be purchased by the industry, the engineering efforts are considered to be negligible compared to the total costs.

E. Detailed Costing:

2.2.9.3.1-7 (see attachment with detailed listings):

TOTAL	2.956.500,- DM	1,945,000 ICF

Additional on-site manpower (2 MJ)will be available for test and putting apparatus into operation:

2 x 2000h x 78.90 DM/h =	316.000,-DM	208,000 ICF

Post irradiation examination test equipment for IFMIF

Number	Testing device	Manufacturer testing machines	Estimated costs per unit	Total costs	Total	
Electron Microscopy / Preparation						
SEM						
1	SEM	CamScan	400.000 DM	400.000 DM		
1	WDX	Microspec	220.000 DM	220.000 DM		
1	EDX	Noran	120.000 DM	120.000 DM		
1	Shielding		100.000 DM	100.000 DM		
1	Sputter-Unit	Balzers	30.000 DM	30.000 DM		
					870.000 DM	
TEM						
1	TEM (200 kV) incl.:	Philips	1.500.000 DM	1.500.000 DM		
	EDX	Noran			1.500.000 DM	
TEM-Preparation						
1	Electrolyt. Polisher *	Struers	15.000 DM	15.000 DM		
1	Ion-Mill *	GATAN	120.000 DM	120.000 DM		
1	Dimple Grinder *	GATAN	25.000 DM	25.000 DM		
1	US Disc Cutter *	GATAN	16.000 DM	16.000 DM		
1	Lapping Kit *	GATAN	1.500 DM	1.500 DM		
1	Hot Plate *	GATAN	1.000 DM	1.000 DM		
1	Grinder *	Buehler	5.000 DM	5.000 DM		
1	Spec.Prep.Kit *	Strecker	3.000 DM	3.000 DM		
1	Diamond Wire saw *	Well	15.000 DM	15.000 DM		
1	Accessories *	Well	3.000 DM	3.000 DM		
					204.500 DM	
TEM-Specimen Storage						
1	Vacuum Storage Grid	Heraeus	30.000 DM	30.000 DM		
					30.000 DM	
Optical microscopy/specimen preparation						
1	Opt. microscope incl. microhardness tester *	Leitz	150.000 DM	150.000 DM		
1	diamond saw *	Buehler	10.000 DM	10.000 DM		
1	grinder *	Buehler	6.000 DM	6.000 DM		
1	mech. polisher *	Buehler	6.000 DM	6.000 DM		
					172.000 DM	
Microhardness Tester						
1	Microhardness tester	Leitz	30.000 DM	30.000 DM		
					30.000 DM	
Activation analysis System						
1	Ge, Si-Li gamma ray spectrometer		150.000 DM	150.000 DM		
					150.000 DM	
					2.956.500 DM	

* conventional type
costs for hot-cell adaption not considered

WORKSHEET
WBS 2.2.14 Maintenance Systems

A. Summary Cost estimate:

Off-IFMIF Site			On-site at IFMIF		
Industry	Instit'al		Industry	Instit'al	
Mat'l/Lab Engin'g	Engin'g	AFI Total	Mat'l/Lab Engin'g	Engin'g	AFI Total
nc	nc	nc	1,970	591	512 3,073

Units: 1,000 ICF (1,000 ICF = 1.520,- DM)

B. Description:

Beside the maintenance devices already described in the specific WBS elements of the individual cells and rooms, some additional devices are considered to be necessary for unusual events. E.g. for the Access Cell, the Service Cell and the Test Module Handling Cell a supervision robot and special purpose tooling should be available, and for the shipping of huge irradiated or activated devices suitable shielding containers are necessary.

C. Detailed WBS Listing:

2.2.14. Maintenance Systems
- 2.2.14.1 Maintenance Procedure Development
- 2.2.142 Special Purpose Tooling
- 2.2.14.3 Remote Handling Equipment
- 2.2.14.4 Mock-up Facilities and Testing

D. Costing Rationale:

The cost estimate is done according to the long term experience from the FZK Hot Cells and the FZK Cyclotron Facility.

Only a global estimate can be given at present.

E. Global Costing:

TOTAL	3.000.000,- DM	1,970,000 ICF

WORKSHEET
WBS 2.2.13.1 Tritium Laboratory Assembly and Testing

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
	906	286	239	1431	0	906	286	1193	2385

Currency Units: kilo ICF

B. Description:

This element is the cost for installation and initial testing of the tritium laboratory, that is a part of the Post Irradiation Test facility of the test cell subsystem.

The testing equipment inside the tritium laboratory is necessary for all kinds of mechanical and microstructural investigations on tritium contaminated or tritium-containing specimens that generate as the results of the irradiation test. The capsules irradiated in the medium flux region will contain highly activated ceramic breeders like Li_4SiO_4, Li_2TiO_3 or other innovative lithium based ceramics. Retrieval of tritium containing specimens from capsules and investigation of mockups with breeder materials requires suitable hot cells. To minimize any cross contamination and to assure effective tritium retention, hot cells for tritium contaminated and containing materials are separated from that of other materials. The fig. shows a bird's eye view of the main subsystems of the Tritium Facility: (i) The airtight tritium handling hot cells for disassembling, preparation and investigation of high gamma-ray activated specimens, (ii) the airtight tritium glove boxes to analyze small pieces or low activated ceramic breeders, (iii) the temporary storage for tritiated specimens and devices. Detailed layouts have been developed for tritium processing systems with effective detriation and effluent tritium removal subsystems.

These equipment also serves as a tritiated solid waste handling system housing for the radio-active and contaminated wastes generated in the entire IFMIF facility.

C. Detailed WBS Listing

2.2.13 TRITIUM LABORATORY

D. Costing Rationale:

Due to the nature of this subsystem, most of the cost estimated are obtained by scaling and factoring from the experience of the existing facilities.

Instruments and equipment to be installed in the hot cells and gloveboxes are assumed to be purchased from the industry including design, assembly and testing. Industry and institutional engineering costs are estimated for each subsystems. AFIs are estimated to be small, because although some equipment require R&D before purchase, major part of the system can be assembled with existing technology.

Personnel costs are estimated as follows;
Industry: 10 % manager, 50% experts and 40% labor, averaged to be 19Myen/year.
Institutional : 15M yen/year, engineers only.

Worksheet
WBS 2.2.13.2 Tritium Hot Cell

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
5267	5439	286	1502	12494	143	1812	1143	509	3607

Currency Units: kilo ICF

B. Description:

This element covers the fabrication and initial testing of the hot cell of the tritium laboratory, that is part of the post irradiation test facility.
The major function of the element is to process specimens obtained from the medium flux region of the test cell, and to perform various analyses and measurements. Research programs of the IFMIF will include the irradiation of breeding blanket materials and other materials that possibly generate tritium by nuclear reactions. Such samples are handled in the special facility that have a specific leak tightness and capability to handle tritium. This equipment is designed to handle relatively high gamma radiation that should be shielded by hot cells.

Another major function of this system is decontamination and processing of tritium contaminated solid wastes that will generate in the entire IFMIF facility. Because of the capability of this tritium hot cell to handle highly activated and tritium contaminated materials and mechanically cut and process solid pieces, this equipment can be used for housing solid waste treatment system.

C. WBS Listing:

2.2.13.2 Tritium Hot Cell

D. Costing Rationale:

Because there is no similar facilities that handles gamma activity and tritium contamination, the cost is estimated from the scaling from existing plutonium or uranium hot cells. Personnel costs are estimated in the method same as in the other tritium systems..

Worksheet
WBS 2.2.13.3 Tritium Gloveboxes

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
5600	3625	143	1730	11098	95	1812	131	1526	3564

Currency Units: kilo ICF

B. Description:

This element covers the fabrication, installation and initial testing of the gloveboxes of the tritium laboratory, that is a part of the Post Irradiation Test facility of the test cell subsystem. A closed loop atmosphere detritiation that controls these gloveboxes, as well as the tritium hot cell, is included.

The major function of the element is to perform various analysis and measurement of the irradiated breeding materials, that has less gamma activity and requires more delicate handling than that in the hot cells. Such samples are handled in the special confinement that have a specific leak tightness and capability to handle tritium through gloves. This equipment is designed to handle relatively low gamma radiation, but some local shielding may be considered. Further material testing that require more delicate hands-on operation will be possible with small test specimens prepared in these gloveboxes.

The glovebox atmosphere detritiation system recalculates the inert gas in the gloveboxes and hot cells and remove tritiated species. Oxygen in the atmosphere and bound in the form of moisture is removed by ceramic electrolyte cell. Tritium is removed by gettering with hidriding metal beds. Negative pressure and oxygen concentration is also monitored and controlled. Leak tightness of the glovebox and hot cell confinement can be continuously monitored by these pressure and oxygen concentration. Excess gas resulted from the maintaining negative pressure is sent to the exhaust detritiation of the conventional facility.

C. WBS Listing:

2.2.13.3 Tritium glovebox

D. Costing Rationale:

There are similar tritium facilities where large amount of tritium is handled in Japan, Germany, US and some other countries, and cost data base is available from recently commissioned facilities such as TLK in FzK and TPL in JAERI. Personnel costs are estimated on the basis of WBS 2.2.13.1.

Cost Estimating Worksheets

for

WBS 3.0

Target Facility

WORKSHEET
WBS 3.1.0 Target Facility Management
WBS 3.1.1 Project Management and Administration

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
286,000	1,715,000	40,020	102,051	2,143,071	0	0	0	0	0

Currency Units: ICF

B. Description:

In the construction of IFMIF target system, a full time project management is necessary until its completion. Following are included in the management:

a) Time schedule management, b) Process management, c) Cost control, d) Regulation with the Accelerator and Test Cell Facilities.

Among the items of Administration, the costs of the admission of design and construction and that of safety licenses are not included. They are included in Design Integration (WBS 3.1.2.1) and Licenses (WBS 3.1.3.2), respectively.

C. Detailed WBS Listing:

1. 0. 0. 0. Project Management and Administration
   1. 0. 0. Administration
   2. 0. 0. Cost Control
   3. 0. 0. Schedule
   4. 0. 0. Documentation

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material / Labor :
Drawings and Instruction manual are included
Type of Estimate : Scaling from the cases of BWR, FBR, etc.

(2) Cost of Industry Engineering :
Management Engineering : 9m-year
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	286,000 ICF
(2)	Industry Engineering	:	1,715,000 ICF
(3)	Institutional Engineering: 2% of ((1)+(2))	:	40,020 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	102,051 ICF
	Subtotal	:	2,143,071 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.1.2 System Engineering

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
953,000	1,220,0 00	43,460	110,823	2,327,283	0	0	0	0	0

Currency Units: ICF

B. Description:

The costs of the Engineering and the computer analysis for the following works are estimated in this category.
a) Settlement of the specifications, b) System design, c) Basic design for the components, d) Structural analysis, e) Thermal-Fluid analysis, f) Works of design integration.
The cost of Requirement / Specifications is included in the items of Design Integration.
The cost of RAM Analysis is excluded from the present cost estimations.

C. Detailed WBS Listing:

2. 0. 0. 0. Lithium Target System
   1. 0. 0. Design Integration
   2. 0. 0. System Analysis
   3. 0. 0. Requirement / Specifications
   4. 0. 0. RAM Analysis

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material / Labor :
Running cost of a high performance compute
Type of Estimate : Scaling from the existing plants

(2) Cost of Industry Engineering :
Manpower provided Design Engineering : 80m-month
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	953,000 ICF
(2)	Industry Engineering	:	1,220,000 ICF
(3)	Institutional Engineering: 2% of ((1)+(2))	:	43,460 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	110,823 ICF
	Subtotal	:	2,327,283 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.1.3 Environmental, Safety & Health Doc.

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	381,000	0	19,050	400,050	0	0	0	0	0

Currency Units: ICF

B. Description:

The Engineering cost is the cost of a full-time superintendent for the safety management during 2 years installation.

The cost of licenses which include the items of the admission of design and construction, safety licenses, admission of transportation of heavy components, etc. are excluded from the present cost estimations.

C. Detailed WBS Listing:

3. 0. 0. 0. Environmental, Safety & Health Doc.
1. 0. 0. Environmental, Safety & Health Doc.
2. 0. 0. Licenses

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Engineering :
The full-time superintendent of the Installation works : 2m-year
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	0 ICF
(2)	Industry Engineering	:	381,000 ICF
(3)	Institutional Engineering	:	0 ICF
(4)	AFI : 5% of ((1)+(2)+(3))	:	19,050 ICF
	Subtotal	:	400,050 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.1.4 Quality, Assurance

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	1,743,0 00	0	87,150	1,830,150	0	0	0	0	0

Currency Units: ICF

B. Description:

The item includes the a) Quality assurance (QA), b) Quality control (QC), c) Production control and d) Purchase arrangement

C. Detailed WBS Listing:

4. 0. 0. 0. Quality, Assurance

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Engineering :
Manpower provided Engineering for QA, QC, and so on : 10m-year
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	0 ICF
(2)	Industry Engineering	:	1,743,000 ICF
(3)	Institutional Engineering	:	0 ICF
(4)	AFI : 5% of ((1)+(2)+(3))	:	87,150 ICF
	Subtotal	:	1,830,150 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.1.5 Other Costs

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	629,000	12,580	32,079	673,659	0	0	0	0	0

Currency Units: ICF

B. Description:

The travel allowance of business trip and the other miscellaneous expenses are included in this item.

C. Detailed WBS Listing:

5. 0. 0. 0. Other Costs

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Engineering :

a. The travel allowance of the business trip for

(a) the previous arrangement in the period of design / production, and

(b) the regulations and test operations of the components and the system.

Type of Estimate : Bottoms-Up

b. The other miscellaneous expenses

Type of Estimate: Scaling from the existence plants

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	0 ICF
(2)	Industry Engineering	:	629,000 ICF
	--- Contents of Industry Engineering		
	a. The travel allowance of the business trip		(391,000 ICF)
	b. The other miscellaneous expenses		(238,000 ICF)
(3)	Institutional Engineering : 2% of (2)	:	12,580 ICF
(4)	AFI : 5% of ((1)+(2)+(3))	:	32,079 ICF
	Subtotal	:	673,659 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.2.0 Subsystem
WBS 3.2.1 Lithium Target System

A. Summary Cost Estimate:

	Off-IFMIF Site					On-Site at IFMIF				
	Industry		Instit'			Const. Contractor		Instit'		
WBS	Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
3.2.1.	**3,608,000**	**603,000**	**679,740**	**2,445,3 70**	**7,336,110**	**574,000**	**0**	**0**	**28,700**	**602,700**
-.1.0.0	0	0	0	0	0	0	0	0	0	0
-.2.1.0	953,000	115,000	410,000	739,000	2,217,000	58,000	0	0	2,900	60,900
-.2.2.0	2,216,000	422,000	269,740	1,453,8 70	4,361,610	516,000	0	0	25,800	541,800
-.2.3.0	439,000	66,000	0	252,500	757,500	0	0	0	0	0

Currency Units: ICF

B. Description:

Lithium Target System consists of two sets of target assemblies, interfaces with deuteron accelerator beamline and with test cell. The costs of Assembly and Testing listed in the WBS(3.2.1.1) are not included in this items but are included in the cost of Installation (WBS (3.3.1)).

In the cost of Target Assembly, following components (WBS level-6) are included : 1)Lithium inlet piping, 2)Flow straightener, 3)Nozzle, 4)Replaceable backwall, 5)Downstream and 6)Mechanical connectors. The cost of two kind of the downstream structure (diffuser type and baffles type) is included.

In the Beam-Target Interface, the deferential pumping systems are set up for each beam line in the interface region. The total eight turbo molecular pumps (four are the spares for the redundancy) are installed in this system.

In the Target-Test Cell Interface, the bellows seal structure are set up for following three components --- deuteron beam transport lines, and lithium inlet and outlet which penetrate the Test Cell vacuum boundary.

The nuclear grade design and materials are applied on this system.

C. Detailed WBS Listing:

1. 0. 0. 0. Lithium Target System
    1. 0. 0. Assembly and Testing
        1. 0. Assembly
        2. 0. Testing
    2. 0. 0. Components
        1. 0. Target Assembly
        2. 0. Beam-Target Interface
        3. 0. Target-Test Cell Interface

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material / Labor :

a. Target Assembly (WBS 3.2.1.2.1.0)

(a) two set of target assembly systems which include 1)Lithium inlet piping, 2)Flow straightener, 3)Nozzle, 4)Downstream diffuser, 5)Downstream baffles and 6)Mechanical connectors, respectively., and

(b) two replaceable backwalls

Type of Estimate : Bottoms-Up

b. Beam-Target Interface (WBS 3.2.1.2.2.0)

(a) two deuteron beam transport lines and four gate valves

(b) four set of the turbo molecular pump systems which respectively include one spare for the redundancy (total eight turbo molecular pumps).

Type of Estimate : Bottoms-Up

c. Target-Test Cell Interface (WBS 3.2.1.2.3.0)

(a) four bellows seal structures for the deuteron beam transport lines, and lithium inlet and outlet which penetrate the Test Cell vacuum boundary.

(b) two argon hoods provided target assembly exchanging

Type of Estimate : Bottoms-Up

(2) Cost of Industry Engineering :

The cost of vendor provided design and inspection engineering for the target assembly system is included.

a. Target Assembly

Type of Estimate : Bottoms-Up

b. Beam-Target Interface

Type of Estimate : Bottoms-Up

c. Target-Test Cell Interface

Type of Estimate : Bottoms-Up

(3) Cost of Institutional Engineering :

The cost of manpower (engineering, labor and technician) provided by the responsible institute is included.

a. Target Assembly

Type of Estimate : Bottoms-Up

b. Beam-Target Interface

Type of Estimate : Bottoms-Up

c. Target-Test Cell Interface

The cost of Off-IFMIF site Institutional Engineering is not included in this item but is included in the cost of the Beam-Target Interface and the lithium Cooling System (WBS (3.2.2)).

On-Site at IFMIF :

(1) Cost of Construction Contractor Material / Labor :

The cost of construction contractor provided installation labor and supervision, and the cost of verification testing labor and support are included.

a. Target Assembly

Type of Estimate : Bottoms-Up

b. Beam-Target Interface

Type of Estimate : Bottoms-Up

c. Target-Test Cell Interface

The cost of Construction Contractor Material and Labor is not included in this item but is included in the cost of the Beam-Target Interface and the lithium Cooling System.

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	3,608,000 ICF
	--- Contents of Industry Material / Labor		
	a. Target Assembly		(953,000 ICF)
	b. Beam-Target Interface		(2,216,000 ICF)
	c. Target-Test Cell Interface		(439,000 ICF)
(2)	Industry Engineering	:	603,000 ICF
	--- Contents of Industry Engineering		
	a. Target Assembly		(115,000 ICF)
	b. Beam-Target Interface		(422,000 ICF)
	c. Target-Test Cell Interface		(66,000 ICF)
(3)	Institutional Engineering	:	679,740 ICF
	--- Contents of Institutional Engineering		
	a. Target Assembly		(410,000 ICF)
	b. Beam-Target Interface		(269,740 ICF)
	c. Target-Test Cell Interface		(0 ICF)
(4)	AFI : 50% of ((1)+(2)+(3))	:	2,445,370 ICF
	Subtotal	:	7,336,110 ICF

On-Site at IFMIF :

(1)	Construction Contractor Material / Labor	:	574,000 ICF
	--- Contents of Const. Contractor Matl/Lab		
	a. Target Assembly		(58,000 ICF)
	b. Beam-Target Interface		(516,000 ICF)
	c. Target-Test Cell Interface		(0 ICF)
(2)	AFI : 5% of (1)	:	28,700 ICF
	Subtotal	:	602,700 ICF

Total :

Total Estimated Capital Cost (TEC)	:	7,938,810 ICF
--- Contents of TEC		
a. Target Assembly		(2,277,900 ICF)
b. Beam-Target Interface		(4,903,410 ICF)
c. Target-Test Cell Interface		(757,500 ICF)

WORKSHEET
WBS 3.2.2 Lithium Cooling System

A. Summary Cost Estimate:

	Off-IFMIF Site					On-Site at IFMIF				
	Industry		Instit'			Const. Contractor		Instit'		
WBS	Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
3.2.2.	**16,113,000**	**3,462,000**	**929,000**	**3,956,400**	**24,460,400**	**2,296,000**	**0**	**0**	**114,800**	**2,410,800**
-.1.0.0	0	0	0	0	0	0	0	0	0	0
-.2.1.0	9,627,000	2,193,000	546,000	2,959,400	15,325,400	1,204,000	0	0	60,200	1,264,200
-.2.2.0	4,570,000	800,000	249,000	745,100	6,364,100	594,000	0	0	29,700	623,700
-.2.3.0	1,916,000	469,000	134,000	251,900	2,770,900	498,000	0	0	24,900	522,900

Currency Units: ICF

B. Description:

Lithium Cooling System consists of a main lithium loop, primary, secondary and tertiary heat removal system.

The Main lithium Loop which circulates the lithium to and from the target assembly, removes the 10MW heat deposited by the deuteron beam. A single lithium loop provides flow to either of the target assemblies in the two test cells. A maximum 10% flow is provided to the inoperative target for decay heat removal. In the cost of main lithium loop, following components (WBS level-6) are included : 1)EM pump, 2)Valves, 3)Flow meters, 4)Piping, 5)Quench tank, 6)Dump tank, 7)Surge tank, 8)Trace heater, 9)Insulation, 10)Argon/vacuum system, 11)Instrumentation and 12)lithium metal.

The Primary Heat Removal System is the organic oil loop, and transfers the heat from main lithium loop to water loop (secondary heat removal system). In the cost of this system, 1)Primary heat exchanger(lithium to Oil), 2)Piping 3)Pump, 4)Valves, 5)Flow meters, 6)Organic dump tank, 7)Instrumentation, 8)Organic oil and 9)Organic heater are included.

The Secondary Heat Removal System is the water loop, and transfers the heat to the open-air through the cooling tower (tertiary heat removal system). In the cost of this system, 1)Secondary heat exchanger(Oil to Water), 2)Piping 3)Pump, 4)Valves, 5)Flow meters and 6)Instrumentation are included.

The cost of the Tertiary Heat Removal System is to be estimated in conventional facility and is excluded from this sheet.

The nuclear grade design and materials are applied on the Main lithium Loop system and the Primary Heat Removal System.

C. Detailed WBS Listing:

2. 0. 0. 0. Lithium Cooling System
  1. 0. 0. Assembly and Testing
    1. 0. Assembly
    2. 0. Testing

  2. 0. 0. Components
    1. 0. Main lithium loop
    2. 0. Primary Heat Removal System
    3. 0. Secondary Heat Removal System
    4. 0. Tertiary Heat Removal System (Water Cooling System)

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material / Labor :

a. Main lithium loop (WBS 3.2.2.2.1.0)

Following components (WBS level-6) are included :
1)EM pump, 2)Valves, 3)Flow meters, 4)Piping, 5)Quench tank, 6)Dump tank, 7)Surge tank, 8)Trace heater, 9)Insulation, 10)Argon/vacuum system, 11)Instrumentation and 12)lithium metal

Type of Estimate : Bottoms-Up

b. Primary Heat Removal System(WBS 3.2.2.2.2.0)

Following components (WBS level-6) are included :
1)Primary heat exchanger, 2)Piping, 3)Pump, 4)Valves, 5)Flow meters, 6)Organic dump tank, 7)Instrumentation, 8)Organic oil and 12)Organic heater

Type of Estimate : Bottoms-Up

c. Secondary Heat Removal System(WBS 3.2.2.2.3.0)

Following components (WBS level-6) are included :
1)Secondary heat exchanger, 2)Piping, 3)Pump, 4)Valves, 5)Flow meters and 6)Instrumentation

Type of Estimate : Bottoms-Up

(2) Cost of Industry Engineering :

The cost of vendor provided design and inspection engineering for each component is included.

a. Main lithium loop

Type of Estimate : Bottoms-Up

b. Primary Heat Removal System

Type of Estimate : Bottoms-Up

c. Secondary Heat Removal System

Type of Estimate : Bottoms-Up

(3) Cost of Institutional Engineering :

The cost of manpower (engineering, labor and technician) provided by the responsible institute for important components is included.

a. Main lithium loop

Type of Estimate : Bottoms-Up

b. Primary Heat Removal System

Type of Estimate : Bottoms-Up

c. Secondary Heat Removal System

Type of Estimate : Bottoms-Up

On-Site at IFMIF :

(1) Cost of Construction Contractor Material / Labor :

The cost of construction contractor provided installation labor and supervision, and the cost of verification testing labor and support are included.

a. Main lithium loop

Type of Estimate : Bottoms-Up

b. Primary Heat Removal System

Type of Estimate : Bottoms-Up

c. Secondary Heat Removal System

Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	16,113,000 ICF
	--- Contents of Industry Material / Labor		
	a. Main lithium loop		(9,627,000 ICF)
	b. Primary Heat Removal System		(4,570,000 ICF)
	c. Secondary Heat Removal System		(1,916,000 ICF)
(2)	Industry Engineering	:	3,462,000 ICF
	--- Contents of Industry Engineering		
	a. Main lithium loop		(2,193,000 ICF)
	b. Primary Heat Removal System		(800,000 ICF)
	c. Secondary Heat Removal System		(469,000 ICF)
(3)	Institutional Engineering	:	929,000 ICF
	--- Contents of Institutional Engineering		
	a. Main lithium loop		(546,000 ICF)
	b. Primary Heat Removal System		(249,000 ICF)
	c. Secondary Heat Removal System		(134,000 ICF)
(4)	AFI	:	3,956,400 ICF
	--- Contents of AFI		
	a. Main lithium loop: 50% of ((1)+(2)+(3)) for EM pump, 30% for the else lithium components and 10% for the other		(2,959,400 ICF)
	b. Primary Heat Removal System: 30% of ((1)+(2)+(3)) for primary heat exchanger and 10% for the other		(745,100 ICF)
	c. Secondary Heat Removal System: 10% of ((1)+(2)+(3))		(251,900 ICF)
	Subtotal	:	24,460,400 ICF

On-Site at IFMIF :

(1)	Construction Contractor Material / Labor	:	2,296,000 ICF
	--- Contents of Const. Contractor Matíl/Lab		
	a. Main lithium loop		(1,204,000 ICF)
	b. Primary Heat Removal System		(594,000 ICF)
	c. Secondary Heat Removal System		(498,000 ICF)
(2)	AFI : 5% of (1)	:	114,800 ICF
	Subtotal	:	2,410,800 ICF

Total :

	Total Estimated Capital Cost (TEC)	:	26,871,200 ICF
	--- Contents of TEC		
	a. Main lithium loop		(16,589,600 ICF)
	b. Primary Heat Removal System		(6,987,800 ICF)
	c. Secondary Heat Removal System		(3,293,800 ICF)

WORKSHEET
WBS 3.2.3 Purification and Impurity Monitoring System

A. Summary Cost Estimate:

	Off-IFMIF Site					On-Site at IFMIF				
	Industry		Instit'			Const. Contractor		Instit'		
WBS	Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
3.2.3.	**7,234,000**	**2,154,000**	**1,051,000**	**3,791,700**	**14,230,700**	**866,000**	**0**	**0**	**43,300**	**909,300**
-.1.0.0	0	0	0	0	0	0	0	0	0	0
-.2.1.0	5,405,000	1,846,000	573,000	2,648,600	10,472,600	625,000	0	0	31,250	656,250
-.2.2.0	1,829,000	308,000	478,000	1,143,100	3,758,100	241,000	0	0	12,050	253,050

Currency Units: ICF

B. Description:

The Purification and Impurity Monitoring System consists of two main sections.

One is to purify the impurities (Hydrogen isotopes, Oxygen, Nitrogen, Berilliium-7) by using the Cold Trap and two kind of Hot Traps.

The other is the on-line and off-line monitoring system to detect these impurity levels. The on-line meters include the Hydrogen meter, Oxygen meter, Nitrogen meter and lithium resistivity monitor. However, the study and development are necessary for the meters except for Hydrogen meter. It is assumed that these costs are same as that of the Hydrogen meter.

For each components included in the purification and impurity monitoring system, two are set up for the redundancy. The nuclear grade design and materials are applied on all of the purification and impurity monitoring components.

C. Detailed WBS Listing:

3. 0. 0. 0. Lithium Purification and Impurity Monitoring System
   1. 0. 0. Assembly and Testing
      1. 0. Assembly
      2. 0. Testing
   2. 0. 0. Components
      1. 0. Lithium Purification System
      2. 0. Impurity Monitoring System

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material and Labor :

a. Lithium Purification System (WBS 3.2.3.2.1.0)

Following components (WBS level-6) are included :

1)Cold Trap, 2)Hot Trap #1 (Yttrium Getter), 3) Hot Trap #2 (Titanium Getter), 4)EM Pump, 5)Cold trap cooler (Argon gas cooling system), 6)Piping, 7)Valves, 8)Trace heater, 9)Insulation, 10)Instrumentation, 11)Radiation Shielding (for Cold Trap), 12)Flow meters and 13)Economizer

Type of Estimate : Bottoms-Up

b. Impurity Monitoring System(WBS 3.2.3.2.2.0)

Following components (WBS level-6) are included :

1)On-line meters, 2)Off-line monitors, 3)Flow meters, 4)Piping, 5)Economizer and 6)EM pump

The cost of valves of the impurity monitoring system is included in that of the Lithium purification system.

Type of Estimate : Bottoms-Up

(2) Cost of Industry Engineering :

The cost of vendor provided design and inspection engineering for each component is included.

a. Lithium Purification System

Type of Estimate : Bottoms-Up

b. Impurity Monitoring System

Type of Estimate : Bottoms-Up

(3) Cost of Institutional Engineering :

The cost of manpower (engineering, labor and technician) provided by the responsible institute for important components is included.

a. Lithium Purification System

Type of Estimate : Bottoms-Up

b. Impurity Monitoring System

Type of Estimate : Bottoms-Up

On-Site at IFMIF :

(1) Cost of Construction Contractor Material and Labor :

The cost of construction contractor provided installation labor and supervision, and the cost of verification testing labor and support are included.

a. Lithium Purification System

Type of Estimate : Bottoms-Up

b. Impurity Monitoring System

Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :			
(1)	Industry Material / Labor	:	7,234,000 ICF
	--- Contents of Industry Material / Labor		
	a. Lithium Purification System		(5,405,000 ICF)
	b. Impurity Monitoring System		(1,829,000 ICF)
(2)	Industry Engineering	:	2,154,000 ICF
	--- Contents of Industry Engineering		
	a. Lithium Purification System		(1,846,000 ICF)
	b. Impurity Monitoring System		(308,000 ICF)
(3)	Institutional Engineering	:	1,051,000 ICF
	--- Contents of Institutional Engineering		
	a. Lithium Purification System		(573,000 ICF)
	b. Impurity Monitoring System		(478,000 ICF)
(4)	AFI	:	3,791,700 ICF
	--- Contents of AFI		
	a. Lithium Purification System: 50% of ((1)+(2)+(3)) for Cold / Hot Traps, 30% for the else lithium components and 10% for the other		(2,648,600 ICF)
	b. Impurity Monitoring System: 50% of ((1)+(2)+(3)) for on-line monitors and 30% for the else lithium components		(1,143,100 ICF)
	Subtotal	:	14,230,700 ICF
On-Site at IFMIF :			
(1)	Construction Contractor Material / Labor	:	866,000 ICF
	--- Contents of Const. Contractor Matîl/Lab		
	a. Lithium Purification System		(625,000 ICF)
	b. Impurity Monitoring System		(241,000 ICF)
(2)	AFI : 5% of (1)	:	43,300 ICF
	Subtotal	:	909,300 ICF
Total :			
	Total Estimated Capital Cost (TEC)	:	15,140,000 ICF
	--- Contents of TEC		
	a. Lithium Purification System		(11,128,850 ICF)
	b. Impurity Monitoring System		(4,011,150 ICF)

WORKSHEET
WBS 3.2.4 Lithium recovery System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
10,000	2,000	1,000	6,500	19,500	0	0	0	0	0

Currency Units: ICF

B. Description:

Lithium recovery System consists of three sections - the leaked lithium recovery system, the leaked lithium detection system and lithium fire control system. However, the study and development are necessary for the recovery system and the fire control system. These costs should be estimated in the next stage.

The cost of only the electric contact type leaked lithium detector is estimated in the present stage. The costs of on-site at IFMIF are not included, but are included in the piping of the main lithium loop (WBS 3.2.2.2.1.4).

C. Detailed WBS Listing:

4. 0. 0. 0. Lithium recovery System
   1. 0. 0. Leaked lithium recovery System
   2. 0. 0. Leaked lithium Detection System
   3. 0. 0. Lithium Fire Control System

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material and Labor :
Cost of Industry region includes only the electric contact type leaked lithium detectors
Type of Estimate : Bottoms-Up

(2) Cost of Industry Engineering :
The cost of vendor provided design and inspection engineering for each component is included.
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	10,000 ICF
(2)	Industry Engineering	:	2,000 ICF
(3)	Institutional Engineering: 50% of (2)	:	1,000 ICF
(4)	AFI: 50% of ((1)+(2)+(3))	:	6,500 ICF
	Subtotal	:	19,500 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.2.5 Target Facility Control System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
6,334,0 00	915,000	18,300	726,730	7,994,030	1,039,0 00	0	0	51,950	1,090,950

Currency Units: ICF

B. Description:

All the function of the target facility are controlled by the Target Facility Control System which is linked with the Central Control System.

In the cost of the control system, following components are included: a)control system, b)ITV inspection system, c)control console of trace heaters

C. Detailed WBS Listing:

5. 0. 0. 0. Target Facility Control System
   1. 0. 0. Normal Operation Control System
   2. 0. 0. Emergency Control System

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material and Labor :
  Type of Estimate : Bottoms-Up

(2) Cost of Industry Engineering :
  The cost of vendor provided design and inspection engineering : 2.5m-y and business trip
  Type of Estimate : Bottoms-Up

On-Site at IFMIF :

(1) Cost of Construction Contractor Material and Labor :
  The cost of construction contractor provided installation labor and supervision, and the cost of verification testing labor and support are included.
  Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	6,334,000 ICF
(2)	Industry Engineering	:	915,000 ICF
(3)	Institutional Engineering: 2% of (2)	:	18,300 ICF
(4)	AFI: 10% of ((1)+(2)+(3))	:	726,730 ICF
	Subtotal	:	7,994,030 ICF

On-Site at IFMIF :

(1)	Industry Material / Labor	:	1,039,000 ICF
(2)	Industry Engineering	:	0 ICF
(3)	Institutional Engineering	:	0 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	51,950 ICF
	Subtotal	:	1,090,950 ICF

Total :

Total Estimated Capital Cost (TEC)	:	9,084,980 ICF

WORKSHEET
WBS 3.2.6 Target Facility Ventilation System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
6,291,000	629,100	12,582	1,519,327	8,452,009	0	0	0	0	0

Currency Units: ICF

B. Description:

Target Facility Ventilation System consists of two sections.

One is the lithium loop ventilation system which circulates an Argon gas inside of argon boundaries at each rooms including the lithium components. At the emergency events, this circulation system is stopped and the argon boundaries are enclosed to prevent leakage of lithium mist.

The other is the cooling loop ventilation system. This is an ordinary ventilation system which ventilate a fresh dry-air.

The on-site costs are excluded from the present cost estimations.

C. Detailed WBS Listing:

6. 0. 0. 0. Target Facility Ventilation System
1. 0. 0. Radioactive Gas Evacuation System
1. 0. Tritium Treatment Facility
2. 0. Other Radioisotope Treatment Facility
2. 0. 0. General Ventilation System

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material / Labor :

a. Cost of the lithium loop ventilation system (Argon gas circulation system)
Type of Estimate : Bottoms-Up

b. Cost of the Cooling loop ventilation system (Dry-Air Ventilation system)
Type of Estimate : Bottoms-Up

(2) Cost of Industry Engineering :

The cost of vendor provided design and inspection engineering for each component is included.
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	6,291,000 ICF
	--- Contents of Industry Material / Labor		
	a. Lithium loop ventilation system (Argon gas)		(3,748,000 ICF)
	b. Cooling loop ventilation system (Dry-Air)		(2,543,000 ICF)
(2)	Industry Engineering	:	629,100 ICF
	--- Contents of Industry Material / Labor		
	a. Lithium loop ventilation system		(374,800 ICF)
	b. Cooling loop ventilation system		(254,300 ICF)
(3)	Institutional Engineering : 2% of (2)	:	12,582 ICF
	--- Contents of Industry Material / Labor		
	a. Lithium loop ventilation system		(7,496 ICF)
	b. Cooling loop ventilation system		(5,086 ICF)

(4)	AFI :	:	1,519,327 ICF
	--- Contents of Industry Material / Labor		
	a. Lithium loop ventilation system: 30% of ((1)+(2)+(3))		(1,239,088 ICF)
	b. Cooling loop ventilation system: 10% of ((1)+(2)+(3))		(280,239 ICF)
	Subtotal	:	8,452,009 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.2.7 Maintenance System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
14,058,000	4,058,000	81,160	9,098,580	27,295,740	0	0	0	0	0

Currency Units: ICF

B. Description:

The costs of Remote Handling Equipment for Target Assembly and for Purification Elements (Cold Traps and Yttrium Hot Traps) are estimated. Following components are provided in both remote handling equipment : a)Power Manipulator, b)Crane, c)YAG laser system, d)Impact wrench e)Welding and Cutting System and f) ITV Monitors.

The costs of Mockup Facilities and Testing are excluded in the present stage.

C. Detailed WBS Listing:

7. 0. 0. 0. Maintenance System
1. 0. 0. Maintenance Procedure Development
2. 0. 0. Special Purpose Tooling
3. 0. 0. Remote Handling Equipment
4. 0. 0. Mockup Facilities and Testing

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Material / Labor :
Type of Estimate : Bottoms-Up

(2) Cost of Industry Engineering :
a) Basic planning design 24m-month,
b) Remote Handling Equipment Design 20% of a),
c) Regulation in Factory 6m-month,
d) Business trip
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	14,058,000 ICF
(2)	Industry Engineering	:	4,058,000 ICF
(3)	Institutional Engineering : 2% of (2)	:	81,160 ICF
(4)	AFI : 50% of ((1)+(2)+(3))	:	9,098,580 ICF
	Subtotal	:	27,295,740 ICF

On-Site at IFMIF : None

WORKSHEET
WBS 3.3.0 System Installation and Checkout
WBS 3.3.1 Installation

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	553,000	11,060	56,406	620,466	6,267,000	2,801,000	56,020	456,201	9,580,221

Currency Units: ICF

B. Description:

The installation and the building construction are simultaneously put into practice. The heavy components are previously brought into the under floor before the upper floor is closed.

C. Detailed WBS Listing:

1. 0. 0. 0. Installation
   1. 0. 0. Lithium Target System
   2. 0. 0. Lithium Cooling system
   3. 0. 0. Lithium recovery System
   4. 0. 0. Target Facility Control System
   5. 0. 0. Target Facility Ventilation System
   6. 0. 0. Target Facility Power System
   7. 0. 0. Other Support Facilities
   8. 0. 0. Maintenance System

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Engineering :
Labor cost for the installation schedule and arrangements for the installation machine parts : 3m-y
Type of Estimate : Bottoms-Up

On-Site at IFMIF :

(1) Cost of Construction Contractor Material / Labor :
Following items are included :
a) Installation Labor
b) Labor cost for the indirect works of the office head, installation manager and technical director,
c) Cost for temporary crane and office,
d) Insurance fee and expenses.
Type of Estimate : Bottoms-Up

(2) Cost of Construction Contractor Engineering :
Labor cost for the on-site design engineers.
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	0 ICF
(2)	Industry Engineering	:	553,000 ICF
(3)	Institutional Engineering: 2% of (2)	:	11,060 ICF
(4)	AFI: 10% of ((1)+(2)+(3))	:	56,406 ICF
	Subtotal	:	620,466 ICF

On-Site at IFMIF :

(1)	Industry Material / Labor	:	6,267,000 ICF
(2)	Industry Engineering	:	2,801,000 ICF
(3)	Institutional Engineering: 2% of (2)	:	56,020 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	456,201 ICF
	Subtotal	:	9,580,221 ICF

Total :

	Total Estimated Capital Cost (TEC)	:	10,200,687 ICF

WORKSHEET
WBS 3.3.2 Verification Testing

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	181,000	3,620	9,231	193,851	291,000	291,000	5,820	29,391	617,211

Currency Units: ICF

B. Description:

This item includes following costs:

a) The planning of the various regulation tests such as the position measurement of piping, components and operation test of each component after the installation is completed (Off-Site).

b) The on-site design and training (On-site Engineering) and On-site Labor (Mat/Lab).
Both labor costs of (2) and (3) were averaged and the same unit cost was applied.

C. Detailed WBS Listing:

2. 0. 0. 0. Verification Testing

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Engineering :
Planning for the regulation and testing: 12m-month
Type of Estimate : Bottoms-Up

On-Site at IFMIF :

(1) Cost of Construction Contractor Material / Labor :
Works for the regulation and testing: 20m-month
Type of Estimate : Bottoms-Up

(2) Cost of Construction Contractor Engineering :
On-Site design: 20m-month
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	0 ICF
(2)	Industry Engineering	:	181,000 ICF
(3)	Institutional Engineering: 2% of (2)	:	3,620 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	9,231 ICF
	Subtotal	:	193,851 ICF

On-Site at IFMIF :

(1)	Industry Material / Labor	:	291,000 ICF
(2)	Industry Engineering	:	291,000 ICF
(3)	Institutional Engineering: 2% of (2)	:	5,820 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	29,391 ICF
	Subtotal	:	617,211 ICF

Total :

Total Estimated Capital Cost (TEC)	:	811,062 ICF

WORKSHEET
WBS 3.3.3 Startup

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'			Const. Contractor		Instit'		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	372,000	7,440	18,97 2	398,412	581,000	915,000	18,300	75,715	1,590,015

Currency Units: ICF

B. Description:

This item includes following costs:

a) The planning of the target system test operation (Off-Site).

b) The on-site design and training (On-site Engineering) and On-site Labor (Mat/Lab).

Both labor costs were averaged and the same unit cost was applied.

C. Detailed WBS Listing:

3. 0. 0. 0. Startup

D. Costing Rationale:

Off-IFMIF Site :

(1) Cost of Industry Engineering:
The planning of the target system test operation: 24m-month
Type of Estimate : Bottoms-Up

On-Site at IFMIF :

(1) Cost of Construction Contractor Material / Labor :
On-Site Labor : 40m-month
Type of Estimate : Bottoms-Up

(2) Cost of Construction Contractor Engineering :
The on-site design and training : 60m-month
Type of Estimate : Bottoms-Up

E. Detailed Costing:

Off-IFMIF Site :

(1)	Industry Material / Labor	:	0 ICF
(2)	Industry Engineering	:	372,000 ICF
(3)	Institutional Engineering: 2% of (2)	:	7,440 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	18,972 ICF
	Subtotal	:	398,412 ICF

On-Site at IFMIF :

(1)	Industry Material / Labor	:	581,000 ICF
(2)	Industry Engineering	:	915,000 ICF
(3)	Institutional Engineering: 2% of (2)	:	18,300 ICF
(4)	AFI: 5% of ((1)+(2)+(3))	:	75,715 ICF
	Subtotal	:	1,590,015 ICF

Total :

Total Estimated Capital Cost (TEC)	:	1,988,427 ICF

Cost Estimating Worksheets

for

WBS 4.0

Accelerator Facility

IFMIF Accelerator Equipment Cost Summary:

Introduction:

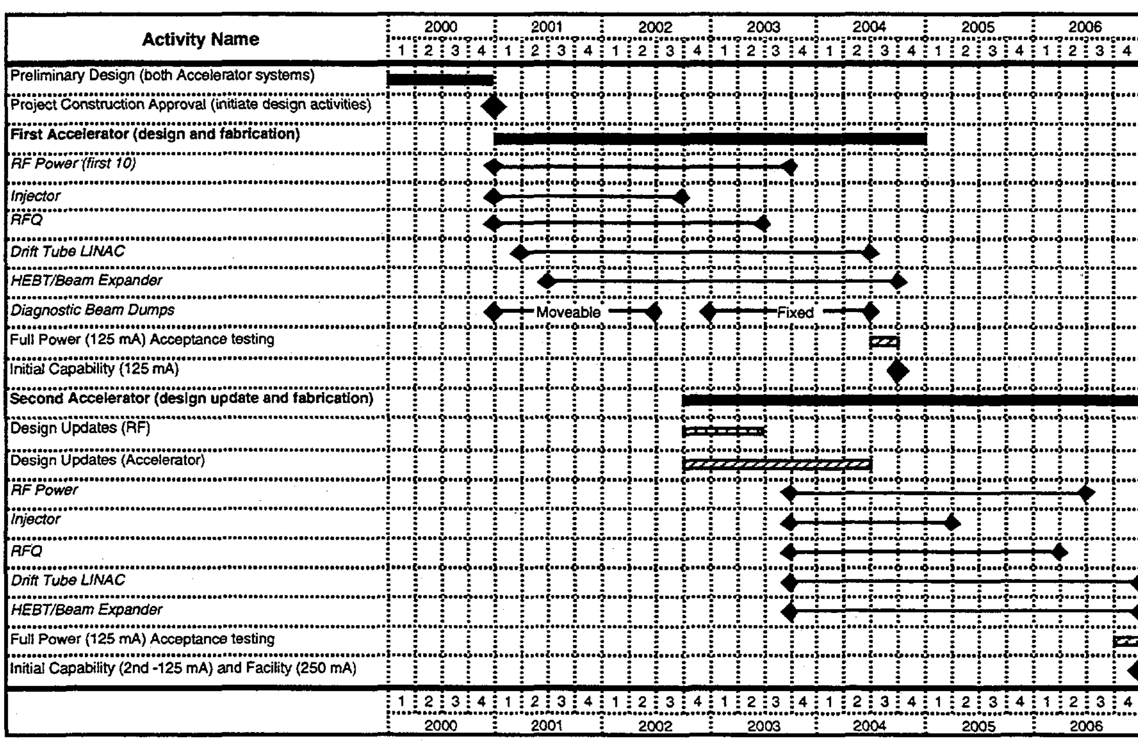
This section contains material that might be useful in the introductory sections before the basis of estimate sheets. This introductory section contains the following:

- An accelerator master schedule derived from the IFMIF program master schedule
- A list of major assumptions
- A Summary Table of Accelerator Costs
- A brief listing of what effort is contained in each part of the cost estimate.

This document is intended to be used in conjunction with the interim CDA report and the design update information generated at the last workshop (held at JAERI, Tokai, Japan). No tunnel or RF hall costs are reported here, only accelerating equipment. The costs for the development program (WBS 4.4), for the period 1997-2000, are defined by the report at Tokai and are included here for completeness.

Master Schedule :

The cost estimate for the IFMIF program covers the period after the close of the CDA activities through the point where a facility based on two 125mA deuteron accelerators, capable of supplying particles at 40 MeV, is commissioned. Preliminary design is scheduled for 2000, with six years required to complete the design, eventually fabricating, installing, and checking out and commissioning the equipment. The top level schedule covering this period is shown below (lower level schedules for each accelerator individually are included at the close of this section):



Major Assumptions used in compiling cost estimates :

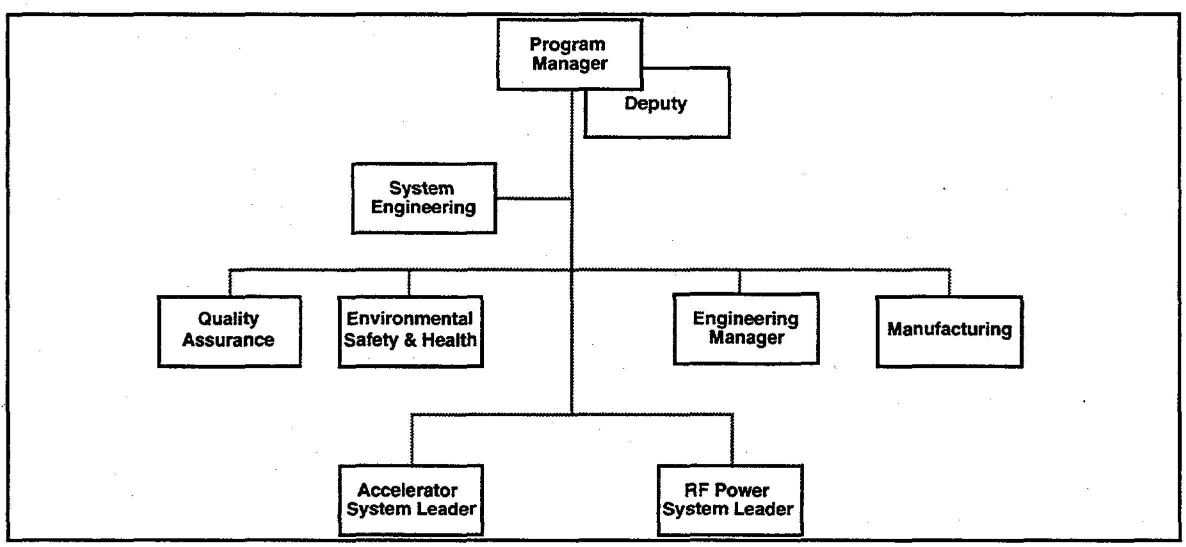
- All technology feasibility issues resolved prior to preliminary design
- Costs complied without a separate milestone to commit funds for the second accelerator
- 1996 costs reported, 8% fee added
- Single shift operation (147 man-hours per man-month)
- Five labor grades considered

Program management:	$150/hr
Physics support:	$120/hr
Engineering (all disciplines):	$100/hr
Technician:	$82/hr
Craft:	$25/hr

- 15% premium pay for work at IFMIF site
- Electric rate for installation and checkout: $0.10/kWe-hr
- Material costs based on vendor estimates, 10% reduction in material costs expected at negotiation

Brief Explanation of WBS contents:

WBS 4.1 Accelerator Facility Management - employs the following type of organizational structure with varying amounts of personnel in each "box" dependent on the activities of the project.



WBS 4.2 Subsystems - This section of the estimate contains all resources necessary to complete the design of the accelerator as well as fabricate and ship it to the IFMIF site. Implicit in the estimate is a plan where most accelerator components are developed, and operationally checked out, in the US then shipped to the IFMIF site for final assembly. Further, all the non-recurring costs associated with developing the equipment is book kept against the first accelerator. Examples of these are the final design engineering activities and "cold model" test program for the RFQ and DTL portions of the

accelerator. The second accelerator estimate contains only the recurring costs associated with producing the second accelerator. Further the material costs are based on a purchase of enough equipment for two accelerators. This allows, in some cases, a better overall unit price because of the larger purchase. The only possible exception is a small allocation in the second accelerator WBS elements to incorporate design upgrades uncovered in completing the first accelerator. Lastly, the first accelerator estimate contains costs attributable to the fixed and moveable diagnostic beam dumps.

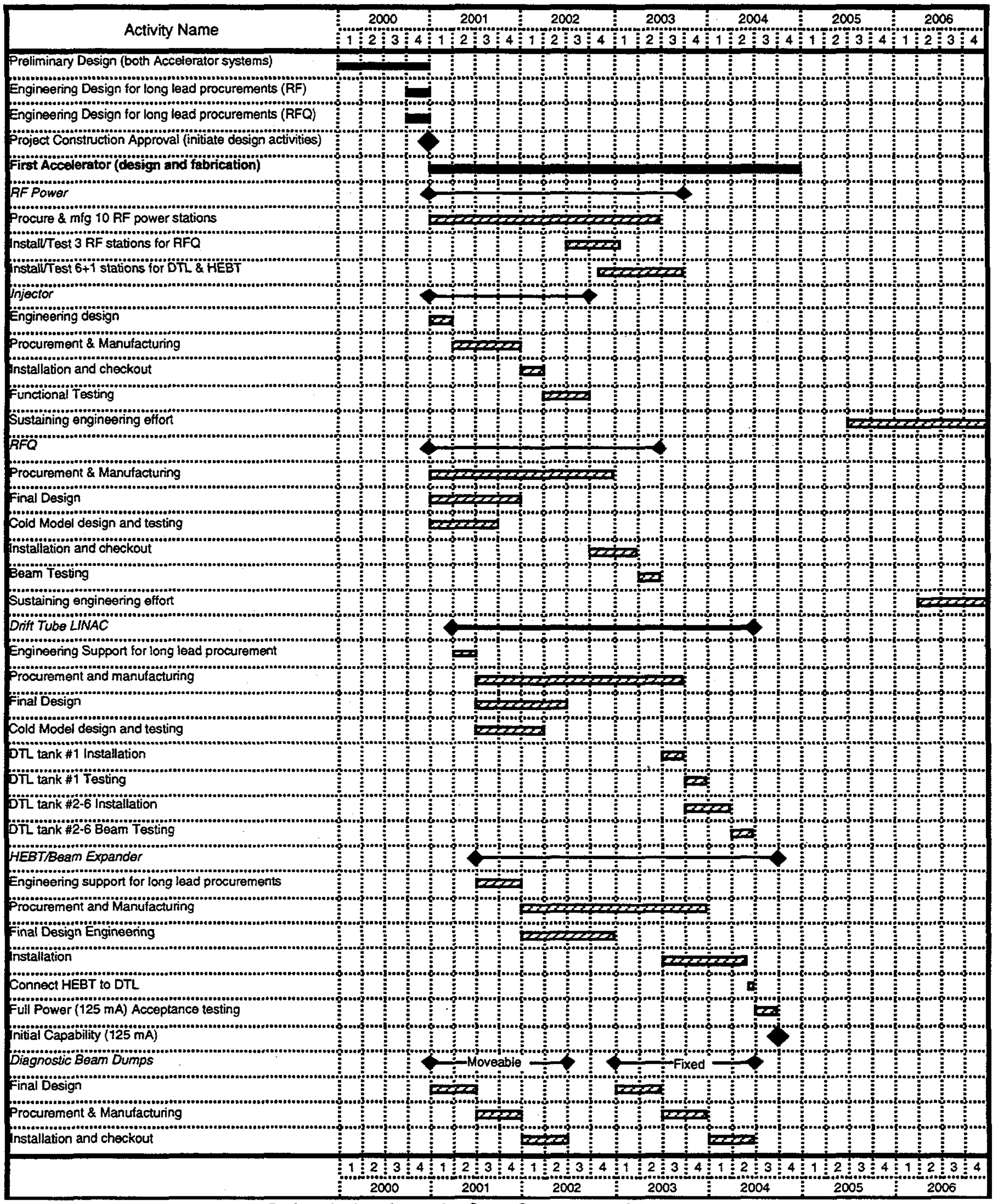
WBS 4.3 Subsystem Installation and Checkout - The estimates reflect the staged manner in which the accelerators will be brought on line. Basically for each accelerator, injector operation will be verified first, followed by the RFQ, then the first DTL tank. After which, DTL tanks 2 - 8 will be installed and operation verified. Next the beam will be passed through the HEBT, tuned, then to the lithium targets when ready. Starting in parallel with the first accelerator injector effort is an RF test stand which will operate a test tube CW as long as possible to begin building a operational database on the tubes.

The major activity linking the two accelerators is RF power installation and checkout. The current plan is to maintain an constant rate of RF station installation and checkout. When the work on the first accelerator RF power system is completed, crews will focus on the RF power system for the second accelerator. Accelerator equipment installation will be paced to match this flow.

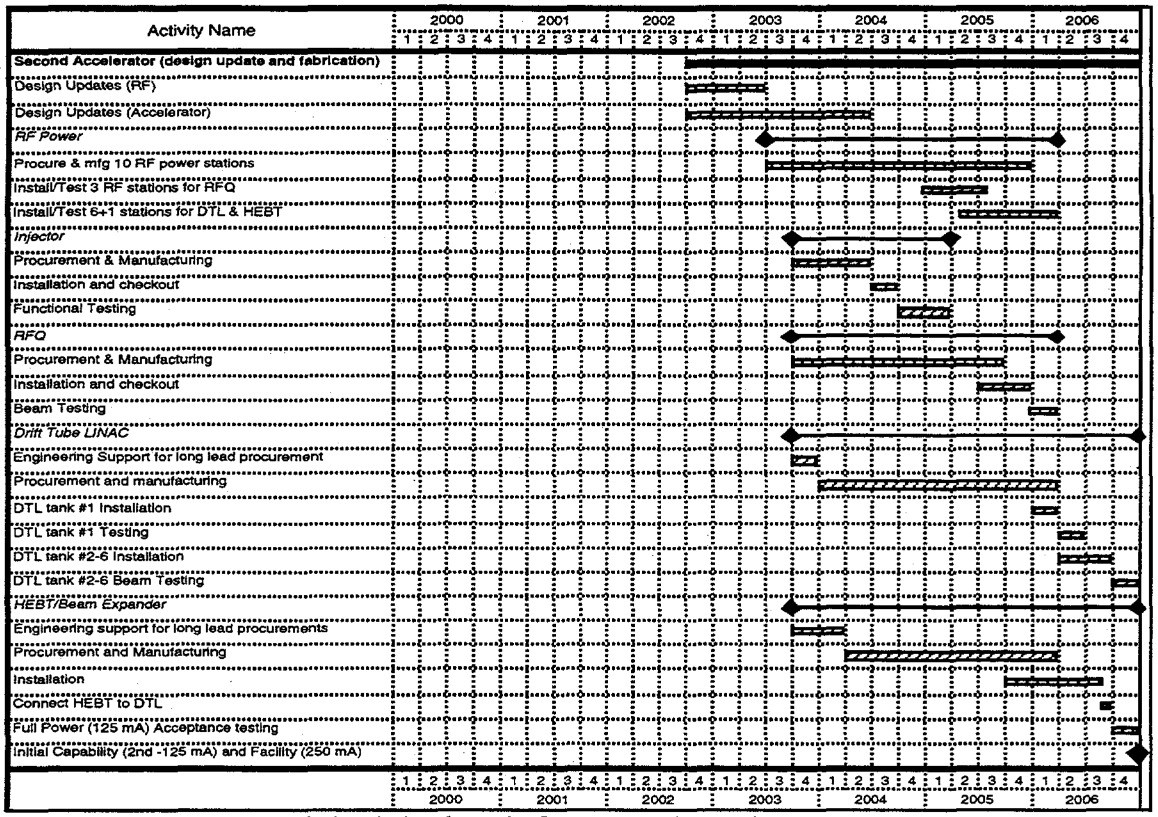
<u>Summary of Relevant Experience:</u>

- *Beam Experiment Aboard Rocket - BEAR*: where Northrop Grumman delivered an Radio Frequency Quadrupole, its power supply, and the external skin for the launch device.
- *Ramped Gradient Drift Tube Linac - RGDTL:* A program where Northrop Grumman completed the design and eventually fabricated one complete accelerating tank to Los Alamos National Laboratory specification.
- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.
- *Relativistic Heavy Ion Collider - RHIC*: a collider program where Northrop Grumman was selected as the manufacturer of the long superconducting main dipole magnets.
- *Compact Infra Red Free Electron Laser - CIRFEL*: a program where Northrop Grumman has developed a compact FEL for industrial and university use.
- *ASR-9 and ARSR-4 commercial radar systems* a ground based radar system for airport surveillance for commercial aircraft.
- *VHF 14 kW pulsed radar transmitter* experiment airborne radar system built together with MIT and Lincoln labs

Level 1. 2. 3. 4. 5. 6. 7.	Name	Off Site Industry Mat/Lab	Off Site Industry Eng	Off Site Instit Eng	Off Site AFI	Off Site Total	On Site Industry Mat/Lab	On Site Industry Eng	On Site Instit Eng	On Site AFI	On Site Total
4. 0. 0.0. 0. 0.0.	Accelerator Facility										
1.0. 0. 0.0. 0.	*Accelerator Facility Management*		*18,022*		*6,308*	*24,330*					
1.0. 0. 0.0.	Project Managment and Administration		8,000		2,800	10,800					
2.0. 0. 0.0.	Systems Engineering		5,140		1,799	6,939					
3.0. 0. 0.0.	Environmental Safety & Health Documentation		2,504		876	3,380					
4.0. 0. 0.0.	Quality Assurance		2,378		832	3,210					
2.0. 0. 0.0. 0.	*Subsystems*	*166,847*	*59,490*	*9,222*	*82,464*	*318,023*					
1. 0. 0.0. 0.	*Accelerator Equipment Preliminary Design (injector thru HEBT)*		*11,621*	*2,905*	*5,084*	*19,610*					
2. 0. 0.0. 0.	*Accelerator Equipment Physics (injector thru HEBT)*		*4,944*	*2,119*	*2,472*	*9,535*					
3. 0. 0.0. 0.	*Accelerator #1 (Castor)*	*84,651*	*28,902*	*3,644*	*41,041*	*158,238*					
1. 0. 0.0.	Injector System	2,230	1,057	243	1,240	4,770					
2. 0. 0.0.	Radiofrequency Quadrupole System	9,045	2,218	357	4,070	15,690					
3. 0. 0.0.	Drift Tube Linac System	14,734	7,030	673	7,853	30,290					
4. 0. 0.0.	HEBT System	7,380	4,020	350	4,110	15,860					
5. 0. 0.0.	RF Drive Loop		2,220	70	800	3,090					
6. 0. 0.0.	Accelerator & HEBT Thermal Control Engineering		2,090		750	2,840					
7. 0. 0.0.	RF Power System	51,262	10,267	1,951	22,218	85,698					
1. 0.0.	RF Control Systems	5,282	395	175	2,048	7,900					
2. 0.0.	RF Predriver Systems	3,320	411	115	1,346	5,192					
3. 0.0.	RF Driver and Final Power Amplifier Systems	24,483	1,783	812	9,477	36,555					
4. 0.0.	RF transport	5,968	1,307	380	2,678	10,333					
5. 0.0.	RF Cavity Resonace Control System	1,061	356	44	511	1,972					
6. 0.0.	RF Switchgear Systems	1,655	35	53	570	2,313					
7. 0.0.	Cooling Systems	5,790	217	186	2,167	8,360					
8. 0.0.	RF Station Control & Monitoring Systems	966	628	50	576	2,220					
9. 0.0.	Integration Equipment and Services	2,737	432	136	1,157	4,462					
4. 0. 0.0. 0.	*Accelerator #2 (Pollux)*	*76,380*	*6,162*		*28,884*	*111,426*					
1. 0. 0.0.	Design Updates		520		180	700					
2. 0. 0.0.	Injector System	1,260	140		480	1,880					
3. 0. 0.0.	Radiofrequency Quadrupole System	6,900	380		2,550	9,830					
4. 0. 0.0.	Drift Tube Linac System	12,640	640		4,650	17,930					
5. 0. 0.0.	HEBT System	7,593	857		2,960	11,410					
6. 0. 0.0.	RF Power System	47,987	3,625		18,064	69,676					
1. 0.0.	RF Control Systems	4,951	98		1,767	6,816					
2. 0.0.	RF Predriver Systems	3,245	69		1,160	4,474					
3. 0.0.	RF Driver and Final Power Amplifier Systems	22,367	1,658		8,409	32,434					
4. 0.0.	RF transport	5,499	184		1,989	7,672					
5. 0.0.	RF Cavity Resonace Control System	1,039	55		383	1,477					
6. 0.0.	RF Switchgear Systems	1,322	53		481	1,856					
7. 0.0.	Cooling Systems	5,667	36		1,996	7,699					
8. 0.0.	RF Station Control & Monitoring Systems	1,401	100		525	2,026					
9. 0.0.	Integration Equipment and Services	2,496	78		901	3,475					
5. 0. 0.0. 0.	*Beam Calibration Dumps*	*5,133*	*994*	*412*	*2,291*	*8,830*					
1. 0. 0.0.	Moveable Beam Dump	2,165	422	94	939	3,620					
2. 0. 0.0.	Fixed Beam Dump	2,968	572	318	1,352	5,210					
6. 0. 0.0. 0.	*Accelerator System Control*	*683*	*4,581*	*142*	*1,892*	*7,298*					
6. 0. 0.0. 0.	*Accelerator Support Systems*		*2,286*		*800*	*3,086*					
3.0. 0. 0.0. 0.	*Subsystem Installation and Checkout*						*38,271*	*5,678*	*3,045*	*16,520*	*63,514*
1. 0. 0.0. 0.	*Accelerator #1 (Castor) Installation and Checkout*						*20,715*	*3,036*	*1,499*	*8,909*	*34,159*
1. 0. 0.0.	Injector system						765	85	54	316	1,220
2. 0. 0.0.	RFQ system						741	63	26	290	1,120
3. 0. 0.0.	DTL Tank#1 system						676	72	30	272	1,050
4. 0. 0.0.	DTL Tanks #2-#8 system						2,295	242	100	923	3,560
5. 0. 0.0.	HEBT systems ("Abel", "Baker", and "Charlie")						3,584	398	166	1,452	5,600
6. 0. 0.0.	RF power system						6,301	571	286	2,505	9,663
7. 0. 0.0.	Beam Dumps						1,511	176	75	690	2,452
8. 0. 0.0.	Full Power Acceptance Test (125 mA)						4,074	1,429	762	2,193	8,458
9. 0. 0.0.	Accelerator Control System						768			268	1,036
2. 0. 0.0. 0.	*Accelerator #2 (Pollux) Installation and Checkout*						*17,556*	*2,642*	*1,546*	*7,611*	*29,355*
1. 0. 0.0.	Injector system						746	83	53	309	1,190
2. 0. 0.0.	RFQ system						706	63	38	283	1,090
3. 0. 0.0.	DTL Tank#1 system						631	67	43	259	1,000
4. 0. 0.0.	DTL Tanks #2-#8 system						2,142	225	144	879	3,390
5. 0. 0.0.	HEBT systems ("Abel", "Baker", and "Charlie")						3,167	346	220	1,307	5,040
6. 0. 0.0.	RF power system						5,329	429	286	2,115	8,159
7. 0. 0.0.	Full Power Acceptance Testing (250 mA)						4,074	1,429	762	2,193	8,458
8. 0. 0.0.	Accelerator Control System						762			266	1,028
4.0. 0. 0.0. 0.	*Subsystem Development*										*25,000*



Schedule details for first accelerator



Schedule details for second accelerator

WORKSHEET
WBS 4.1 Accelerator Facility Management

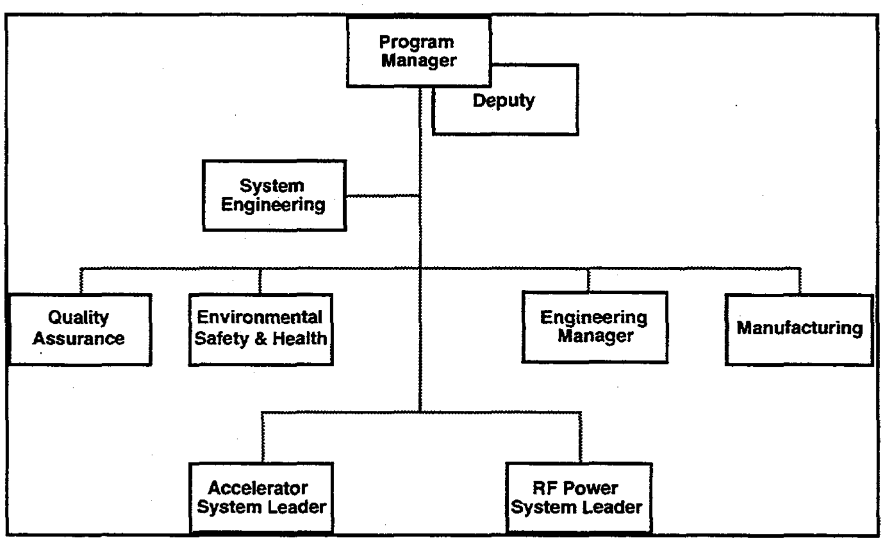
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	18,022	--	6,308	24,330	--	--	--	--	--

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to manage and coordinate the lower level tasks contained in the accelerator facility effort as well coordinate between the accelerator segment activities and the rest of the project. The functional disciplines included in this estimate, and their hierarchical relationship, are shown in the figure below:



It should be understood that the quantity of individuals in each of these areas is proportional to the amount of activities underway at any one time. Further, for accounting purposes only, the deputy program manager, and the accelerator and RF system leaders are book kept under 4.1.1," Project Management and Administration" and, the Engineering Manager and Manufacturing resources are compiled in WBS 4.1.2," Systems Engineering."

C. Detailed WBS Listing: (without AFI)

	Total
4.1.1: Project Management and Administration	8,000
4.1.2: Systems Engineering	5,140
4.1.3: Environmental Safety & Health	2,504
4.1.4: Quality Assurance	2,378

D. Costing Rationale:

The size and composition of the team required to perform the management of the accelerator segment, as well as provide coordination within the IFMIF project, is based upon Northrop Grumman experience producing accelerator components on other programs. Some examples are:

- *Beam Experiment Aboard Rocket - BEAR*: where Northrop Grumman delivered an Radio Frequency Quadrupole, its power supply, and the external skin for the launch device.
- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.
- Relativistic Heavy Ion Collider - RHIC: a collider program where Northrop Grumman was selected as the manufacturer of the long superconducting main dipole magnets.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

This WBS element details only labor charges. As stated earlier, the number and composition of the staff represented here varies depending on the level of activity and phase of the rest of the accelerator (between the years 2000 and 2006). Instead of expressing the month by month expenditures expected, only the resulting full time equivalent (FTE) number of personnel will be expressed for each 4.1.X level WBS element. Further, the estimate was complied under the following assumptions:

Work hours per month:	147
Hourly rate (ICF) for program management personnel:	150
Hourly rate (ICF) for engineering type personnel:	100
Fee:	8%

	FTE
4.1.1: Project Management and Administration	4.00
4.1.2: Systems Engineering	2.57
4.1.3: Environmental Safety & Health	1.25
4.1.4: Quality Assurance	1.19

WORKSHEET
WBS 4.2 Subsystems

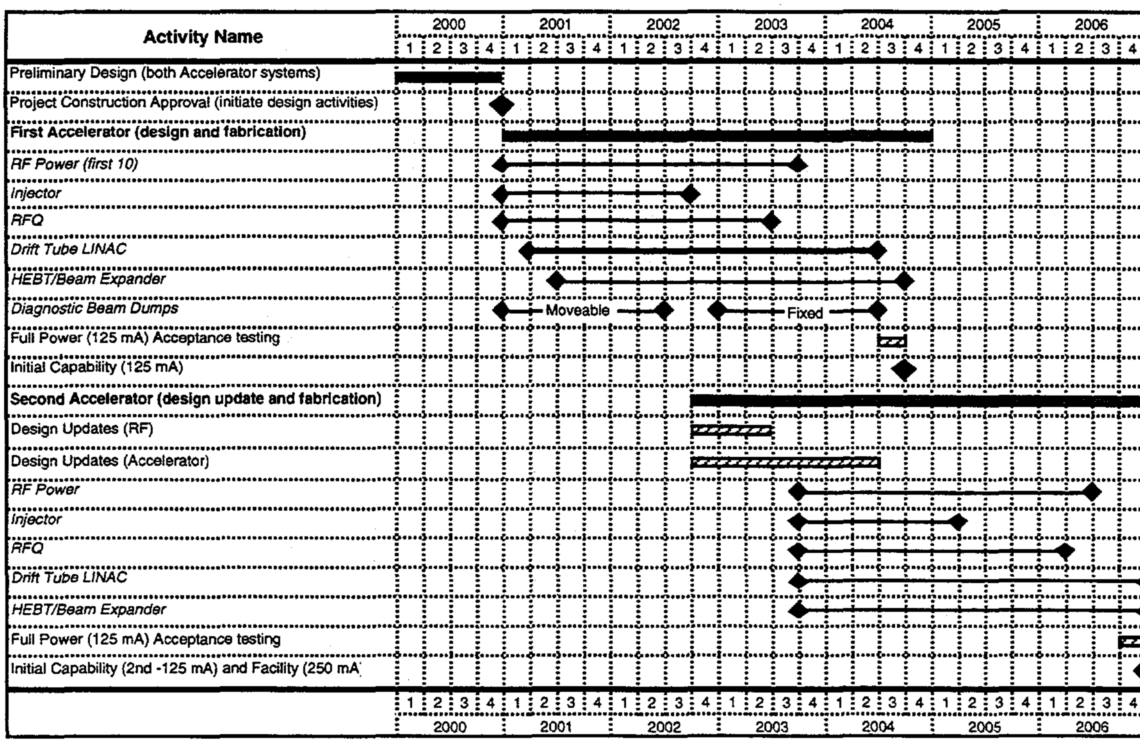
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
169,364	59,053	9,222	83,487	321,126	--	--	--	--	--

Units: Kilo ICF

B. Description:

This WBS element worksheet contains summary figures of lower level worksheets whose activities span the period of time from the close of the technology development program to the point at which the facility is producing 250 mA of CW deuterium at 40 MeV. The top level schedule of activities is shown in the figure below:



C. Detailed WBS Listing: (without any AFI)

		Total
4.2.1:	Accelerator Equipment Preliminary Design	14,526
4.2.2:	Accelerator Equipment Physics Support	7,063
4.2.3:	Accelerator #1 (Castor) Equipment	117,607
4.2.4:	Accelerator #2 (Pollux) Equipment	84,216
4.2.5:	Accelerator Beam Calibration Dumps	6,539
4.2.6:	Accelerator Systems Control	5,406
4.2.7:	Accelerator Support Systems	2,286

D. Costing Rationale:

See lower level WBS element worksheets

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

See lower level WBS element worksheets

WORKSHEET
WBS 4.2.1 Accelerator Equipment Preliminary Design

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	11,621	2,905	5,084	19,610	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This task will focus on utilizing the design information developed from the engineering validation phases (1997 through 1999) to develop a consistent preliminary design for the entire accelerator system. The subsystems included in this investigation are:

- Injector
- Radio Frequency Quadrupole (RFQ)
- Drift Tube Linac (DTL)
- Radio Frequency (RF) drive loop
- High Energy Beam Transport (HEBT)
- Accelerator & HEBT Thermal Control
- Accelerator Support
- Data Acquisition and Control
- RF Power
- Beam Calibration Dumps
- Accelerator System Control
- Accelerator Support

The major results will include, but not be limited to, the following:

- completed preliminary engineering performance analysis (mechanical, stress, thermal, vacuum, diagnostics, RF, etc.) of all components
- baseline configuration with identification of alternatives/backup technology where appropriate
- deployment of formal design control procedures and development of detailed interface control documents
- optimized subcontracting plan (including identification of all procurement key dates)
- completed procurement specifications (bid packages) for long lead items
- draft drawings and specifications for all components

C. Detailed WBS Listing:

None developed in the definition of this estimate

D. Costing Rationale:

Northrop Grumman's past experience on similar programs was utilized to develop the composition of the multi-talented engineering team required to produce the results described above in the allotted time (one year). Some examples are:

- *Beam Experiment Aboard Rocket - BEAR*: where Northrop Grumman delivered an Radio Frequency Quadrupole, its power supply, and the external skin for the launch device.
- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.
- Relativistic Heavy Ion Collider - RHIC: a collider program where Northrop Grumman was selected as the manufacturer of the long superconducting main dipole magnets.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

For each subsystem listed above, a team of engineers was estimated which could deliver the desired results. Next, the teams were considered as a whole and areas where sharing of talents would occur were identified and the required number of personnel was decremented to reflect the resource sharing. The resulting number of full time equivalent (FTE) personnel per month, over the one year preliminary design period, is shown in the table below:

(note this estimate contains a summary figure which includes both laboratory and industry engineering)

Skill/Discipline	FTE (per month)
Physics Design Liaison	2.30
Source RF Design	0.13
RF engineering	5.30
Mechanical Design	13.00
Structural Support	3.00
Stress Analysis	5.11
Vacuum	2.25
Thermal/ECS	6.25
Diagnostics & Instrumentation	5.50
Magnet Design	4.50
Dynamic Analysis	4.00
Electrical Engineering	4.00
Data Acquisition Hardware	5.00
Data Acquisition Software	5.00
Manufacturing/Produceability	4.00
System Engineering	6.90
TOTAL:	**76.24**

All engineering disciplines were estimated at 100 ICF/hour at 147 man hours per man-month with an 8 % fee.

WORKSHEET
WBS 4.2.2 Accelerator Physics Design Support

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	4,944	2,119	2,472	9,535	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

During the development of the design, from preliminary to final configurations through fabrication, a constant physics analysis supporting function is required to help resolve design and manufacturing difficulties. Design areas for this support mostly fall in continually assessing the configuration performance when more and more detail information becomes available. Areas of support during fabrication include resolving difficulties between the selection of existing hardware (at close to specification) or a decision to develop new hardware. During installation, checkout, and commissioning a physics presence is required to help resolve difficulties in startup by interpreting data and suggesting corrective actions.

C. Detailed WBS Listing:

None developed in the definition of this estimate

D. Costing Rationale:

Northrop Grumman's past experience on similar programs was utilized to develop the composition of the physics personnel supported by dedicated engineering talent that would be required to produce the results described above.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

To estimate this staff function, a review of the underlying accelerator activities was undertaken to understand the potential extent of physics support requirements. The results of this analysis indicated that a level of effort of 4 physicists, with half a man engineering support, would be required throughout the program. This estimate includes both industry and laboratory involvement, but no detailed breakout of the tasks were developed.

The hourly rate for engineering support is 100 ICF/hour and the hourly rate for physicists is 120 ICF/hour. For each type of labor, a total of 147 man-hours per man-month was used.

WORKSHEET
WBS 4.2.3 Accelerator #1 (Castor)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
85,498	28,465	3,644	41,182	158,789	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate is a summary level compilation of lower level estimates. As a whole this estimate expresses the total resources required to complete the final design of the first accelerator, develop and execute all procurements in support of fabrication, eventually reaching the point where the accelerator is installed and checked out ready for commissioning in the facility.

C. Detailed WBS Listing:

WBS #		Cost
4.2.3.1:	Injector System	3,064
4.2.3.2:	Radio Frequency Quadrupole System	15,690
4.2.3.3:	Drift Tube Linac System	30,290
4.2.3.4:	High Energy Beam Transport (HEBT) System	18,117
4.2.3.5:	Radio Frequency Drive Loop System	3,090
4.2.3.6:	Accelerator & HEBT Thermal Control System	2,840
4.2.3.7:	RF Power Supply System	85,698
	Total:	158,789

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently supplied rough order of magnitude prices.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

See lower WBS worksheets

WORKSHEET
WBS 4.2.3.1 Injector

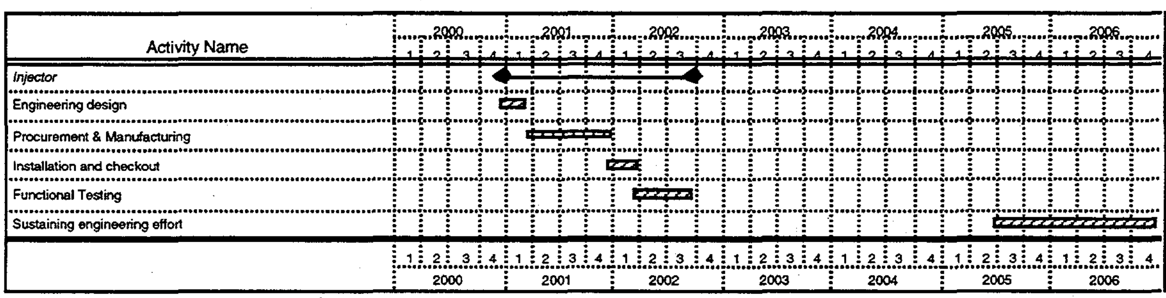
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,407	620	243	794	3,064	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The injector portion of the accelerator is fully described in reference 1. This worksheet documents the necessary resources to deliver two full injector assemblies, as well an a additional spare ion source, in support of the first accelerator (nicknamed Castor). This estimate also assumes all technology feasibility issues surrounding the injector system are resolved and a baseline injector architecture has emerged from the prior engineering validation phase. The master schedule for the Castor injector system is shown below:



This worksheet details the necessary resource for the Engineering Design, Procurement & Manufacturing, and Sustaining Engineering lines of the schedule. The installation and checkout activities, as well as the functional testing estimates, are contained in WBS 4.3.1.1 Injector.

C. Detailed WBS Listing:

None established

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. Some examples of this are the Continuous Wave Deuterium Demonstrator accelerator program where Northrop Grumman was the prime accelerator equipment supplier, and our experience in manufacturing and operating our internal research accelerators.

To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into three major categories: industrial engineering, institutional support, and fabrication labor.

Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to 5.5 full time equivalent (FTE) personnel over the three months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month. The engineering disciplines included in this estimate are:

- Source RF Design
- Mechanical Design
- Electrical design
- Support Structure Design
- Vacuum Design
- Magnet Design
- Thermal Analysis
- Environmental Control
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Sustaining Labor:

Initial estimates of the cycling of personnel between the first and second accelerator hardware elements, including their respective installation and checkout, showed gaps in activities. These gaps are detrimental to maximizing the information and skill learned during the first accelerator activities. To avoid losing the knowledge base, a sustaining engineering line is included. This will enable a continuous availability of injector knowledge from beginning to end of the program. The schedule shown above indicates that an 18 month span for this activity in which 2.5 FTE engineers were estimated at 100 ICF per hours and 147 man hours per man month.

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and returned a draft subcontracting plan which included differentiation between purchased items and internally fabricated items. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece was for the manufacturing department to make an estimate of the assembly tasks. The result of this effort yielded a staff of 2.5 FTE technicians together with 3.7 FTE engineers over the nine months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, the engineers at 100 ICF per hour, and both considering 147 man hours per man month. An 8% fee was added to the figures to reflect industrial participation. The engineering skills to be employed during the fabrication task are:

- Liaison Engineering
- Mechanical Design
- Electrical Design
- Quality Control
- Tool Design

Institutional Labor:

Based upon previous programs to develop injector systems an allowance of 1.0 FTE for the entire design, fabrication and installation and checkout process was reported. Like the Industry engineering talent, the Institutional labor will be billed at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 418 kilo ICF [** denotes refurbished hardware from the EVP program].

Component	Cost (Kilo ICF)	
Source and RF Power Supply **		200
Low Energy Beam Transport (LEBT) **		85
Magnet Power Supplies	60	
Operational Control Equipment and Software		20
Vacuum Equipment and Services	40	
Thermal Control Equipment and Services		5
Structural Support and Shielding Equipment		8
TOTAL:	418	

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.2 Radio Frequency Quadrupole (RFQ) System

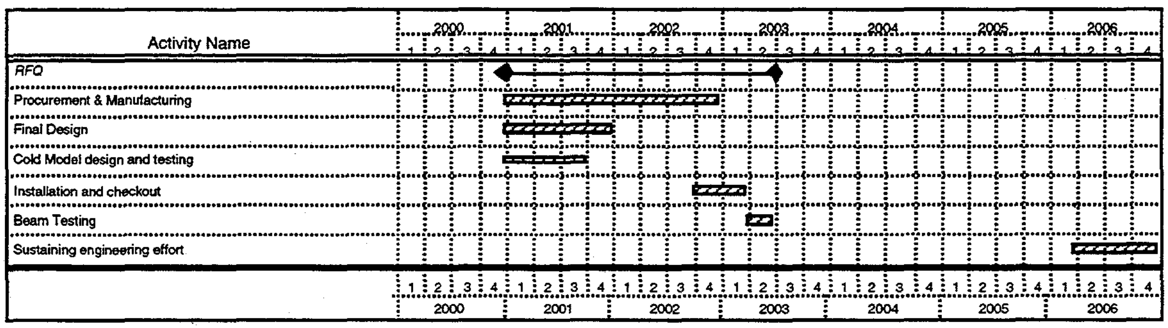
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
9,045	2,218	357	4,070	15,690	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The RFQ portion of the accelerator is fully described in reference 1. This worksheet documents the necessary resources to deliver one 12 meter long, 8 MeV RFQ, in support of the first accelerator (nicknamed Castor). This estimate also assumes all technology feasibility issues are resolved in respect to the RFQ. The master schedule for the Castor RFQ system is shown below:



This worksheet details the necessary resources for the Procurement & Manufacturing, Final Design, Cold Model Design and Test, and Sustaining Engineering lines of the schedule. The installation and checkout activities, as well as the functional testing estimates, are contained in WBS 4.3.1.2 Radio Frequency Quadrupole.

C. Detailed WBS Listing:

None established

D. Costing Rationale:

The labor estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. Some examples are:

- *Beam Experiment Aboard Rocket - BEAR*: where Northrop Grumman delivered an Radio Frequency Quadrupole, its power supply, and the external skin for the launch device.

- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system (including the cryogenic RFQ).
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.

To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into three major categories: industrial engineering, institutional support, and fabrication labor The schedule for this component is shown above

Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to 6.63 full time equivalent (FTE) personnel over the 12 months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month, with an 8% fee. The engineering disciplines included in this estimate are:

- RF Design
- Mechanical Design
- Electrical design
- Support Structure Design
- Vacuum Design
- Thermal Analysis
- Environmental Control
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Cold Model:

Previous experience demonstrated the need to construct and test a full scale low power aluminum version of the RFQ to verify the electric field distribution, the field stability and to ensure adequate tuning range. Further, some of the details in the RFQ must be empirically developed. Examples of these details are the vane end cuts (which allow the magnetic field to wrap around the vane), the end wall dipole stabilizers size and position, and to properly size the RF drive iris openings. Previous experience dictates that a 2.0 FTE engineers (of which 0.5 FTE is from institutional support) together with 2.0 FTE technicians are required over the 9 months scheduled for this task. In parallel, a budget of 212 kilo ICF is provided to cover the cold model material requirements (aluminum and machining services).

Sustaining Labor:

Initial estimates of the cycling of personnel between the first and second accelerator hardware elements, including their respective installation and checkout, showed gaps in activities. These gaps are detrimental to maximizing the information and skill transfer between accelerator activities. To avoid losing the knowledge base, a sustaining engineering line is included. This enables a continuous availability of injector knowledge from beginning to end of the program. The schedule shown above indicates that an nine month span for this activity in which 2.5 FTE engineers were estimated at 100 ICF per hours and 147 man hours per man month, with an 8% fee.

Fabrication Labor:

Northrop Grumman produceability/manufacturing group reviewed the requirements and returned a draft subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department provided was an estimate of the assembly tasks. The result of this effort yielded a staff of 13.8 FTE technicians together with 3.68 FTE engineers over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, the engineers at 100 ICF per hour, and both considering 147 man hours per man month with an 8% fee. The engineering skills to be employed during the fabrication task are:

- Liaison Engineering
- Mechanical Design
- Electrical Design
- Quality Control
- Tool Design

Institutional Labor:

Based upon previous programs to develop RFQ accelerating systems an allowance of 2.0 FTE for the entire cold modeling and final design efforts was included. Like the Industry engineering talent, the Institutional labor will be billed at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 3000 kilo ICF.

Component	Cost (Kilo ICF)
Oxygen Free High Conductivity (OFHC) Copper	240
RF drive loops	580
Electroforming services	1,170
Miscellaneous hardware & services	1,010
(Vacuum, Thermal, Stress, Structural support, etc.)	
TOTAL:	3,000

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.3 Drift Tube Linac (DTL) System

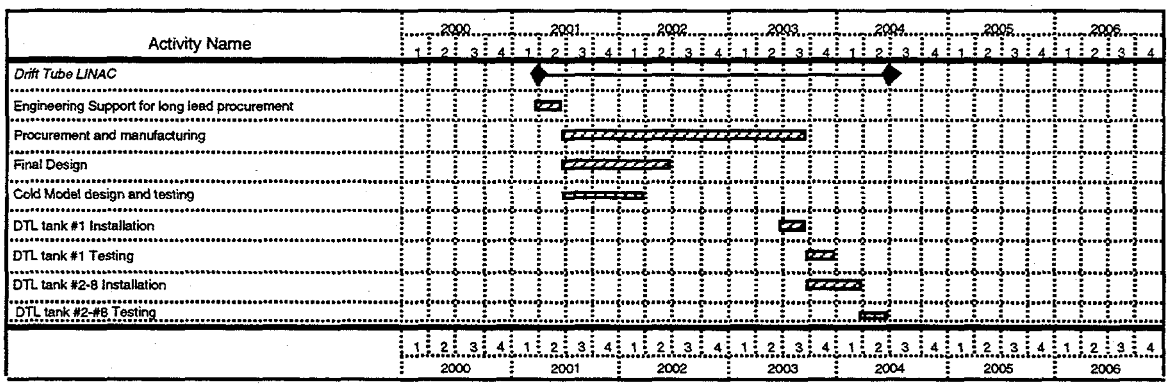
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
14,734	7,030	673	7,853	30,290	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The technical aspects of the DTL accelerating system of the accelerator is fully described in reference 1. This worksheet uses this information to develop a listing of the necessary resource to deliver eight DTL tanks in support of the first accelerator (nicknamed Castor). This estimate also assumes all technology feasibility issues are resolved in respect to the DTL system prior to preliminary design (in the year 2000). The master schedule for the Castor DTL system is shown below:



This worksheet details the necessary resource for the Long Lead Procurement Support, Procurement & Manufacturing, Final Design, Cold Model Design and Test, and Sustaining Engineering lines of the schedule. The installation and checkout activities, as well as the functional testing estimates, are contained in WBS 4.3.1.3 DTL Tank #1 and WBS 4.3.1.4 DTL Tanks #2-#8.

C. Detailed WBS Listing (costs expressed with apportioned AFI):

WBS		Cost (kICF)
4.2.3.3.1:	Cold Model Design & Test	1,800
4.2.3.3.2:	Final Design of DTL system (Tanks #1-#8)	6,020
4.2.3.3.3:	Tank #1	3,348
4.2.3.3.4:	Tank #2	2,930
4.2.3.3.5:	Tank #3	2,835
4.2.3.3.6:	Tank #4	2,740
4.2.3.3.7:	Tank #5	2,686
4.2.3.3.8:	Tank #6	2,673
4.2.3.3.9:	Tank #7	2,633
4.2.3.3.10:	Tank #8	2,630
	TOTAL:	30,290

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. Some examples of the experience are:

- *Ramped Gradient Drift Tube Linac - RGDTL:* A program where Northrop Grumman completed the design and eventually fabricated one complete accelerating tank to Los Alamos National Laboratory sepcification.
- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.

To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into three major categories: industrial engineering, institutional support, and fabrication labor.

Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to 22 full time equivalent (FTE) personnel, of which 1.5 FTE are from institutional engineering, over the 12 months allotted for the effort. The industrial engineering labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines included in this estimate are:

- RF Design
- Mechanical Design
- Electrical design
- Support Structure Design
- Vacuum Design
- Thermal Analysis
- Environmental Control
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Cold Model:

Previous experience demonstrated the need to construct and test a full scale low power aluminum version of a DTL tank to verify the electric field distribution, the field stability provided by the post couplers and to ensure adequate tuning range. The tanks to be modeled include the first where the accelerating gradient is ramped and the second where the gradient is constant. The cold model will be constructed is such a manner as to allow it to be configured to represent either. Previous experience dictates that 2.0 FTE engineers (of which 0.5 FTE is from institutional support) together with 2.0 FTE technicians are required over the 12 months scheduled for this task. In parallel, a budget of 644 kilo ICF is provided to cover the cold model material requirements (aluminum and machining services).

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and returned a draft subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks. The result of this effort yielded a staff of 12.75 FTE technicians over the 36 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Seller Oversight Labor:

The DTL manufacturing plan includes a significant number of procured items that will be produced in large quantity. In support of this a separate team of individuals will be required to ensure the subcontracted work is being properly executed. The list of the skill types required is shown below. The schedule shown above indicates that an three years span for this activity in which approximately 4.0 FTE engineers were estimated at 100 ICF per hours and 147 man hours per man month with an 8% fee.

- Quality Control
- Methods

- Production Management/Controls
- Tool Design
- Liaison Engineering

Institutional Labor:

As discussed previously in this worksheet (Design Labor and Cold Model), the institutional labor estimate was based upon previous programs to develop DTL systems. An allowance of 2.0 FTE for the entire cold modeling and final design efforts was included. Like the Industry engineering talent, the Institutional labor will be billed at 100 ICF per hour and 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 8,257 kilo ICF.

Purchased material for each tank

Drift Tubes
Drift tube magnets
Vacuum system equipment & Services
Oxygen Free High Conductivity (OFHC) Copper for tank shell
Endwalls with magnets
Tank support system
Rail Tuners
RF drive loops
Post couplers
Drift tube support girder
Inter-tank focusing quadrupole package
Miscellaneous hardware

Material Breakdown by tank (without AFI)

	Cost (Kilo ICF)
Tank #1	1,390
Tank #1	1,100
Tank #1	1,006
Tank #1	1,000
Tank #1	960
Tank #1	950
Tank #1	930
Tank #1	920
TOTAL:	8,257

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.4 High Energy Beam Transport (HEBT)

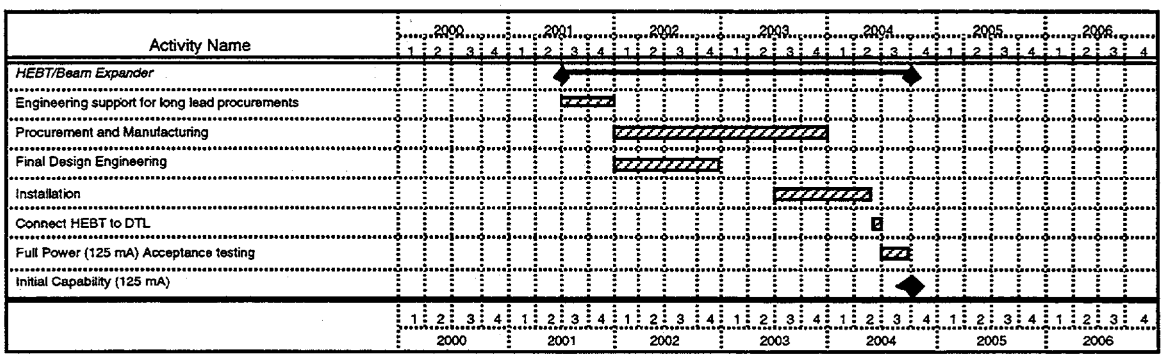
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
9,050	4,020	350	4,697	18,117	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The technical aspects of the HEBT system of the accelerator are fully described in reference 1. This worksheet uses this information to develop a listing of the necessary resources to deliver three transport lines (one to each lithium target and one to the fixed facility beam dump) in support of the first accelerator (nicknamed Castor). This estimate also assumes all technology feasibility issues are resolved in respect to the HEBT system prior to preliminary design (in the year 2000). The master schedule for the Castor HEBT system is shown below:



This worksheet will detail the necessary resources for the Long Lead Procurement Support, Procurement & Manufacturing, Final Design, Cold Model Design and Test, and Sustaining Engineering lines of the schedule. The installation and checkout activities, as well as the functional testing estimates, are contained in WBS 4.3.1.5 HEBT systems.

C. Detailed WBS Listing:

None developed in support of this costing activity

D. Costing Rationale:

Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, information from the past accelerating programs was updated with information collected from suppliers in the various areas who were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into three major categories: industrial engineering, institutional support, and fabrication labor.

Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to 12 full time equivalent (FTE) personnel, of which 1.25 FTE are from institutional engineering, over the 18 months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines included in this estimate are:

- RF Design
- Mechanical Design
- Electrical Design
- Magnet Design
- Support Structure Design
- Vacuum Design
- Thermal Analysis
- Environmental Control
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and returned a draft subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. The later type were the cavities for the momentum compactors and energy dispersion. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks. The result of this effort yielded a staff of 5.3 FTE technicians, together with 3.0 engineers, over the 12 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, the engineers at 100 ICF per man hour, both considering 147 man hours per man month with an 8% fee.

Seller Oversight Labor:

The HEBT manufacturing plan includes a significant number of procured items (magnets , diagnostics, power supplies, etc.) that will be produced in large quantity. In support of this a separate team of individuals will be required to ensure the subcontracted work is being properly executed. The list of the skill types required is shown below. The schedule shown above indicates that an three years span for this activity in which approximately 2.50 FTE engineers were estimated at 100 ICF per hours and 147 man hours per man month with an 8% fee.

- Quality Control
- Methods
- Production Management/Controls
- Tool Design
- Liaison Engineering

Institutional Labor:

As discussed previously in this worksheet (Design Labor and Cold Model), the institutional labor estimate was based upon previous programs to develop HEBT systems an allowance of 1.25 FTE for the entire final design effort. Like the Industry engineering talent, the Institutional labor will be billed at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 8,240 kilo ICF (without any AFI).

Purchased Item	Cost (kICF)
Beam Tube, Flanges, Bellows, etc.	210
RF Cavities	1,610
Support/Alignment Structure	290
Quadrupole magnets: 6" long x 5" dia bore	250
Quadrupole magnets: 16" long x 5" dia bore	360
Quadrupole magnets: 24" long x 5" dia bore	950
Octupole magnets: 16" long x 3.5" dia bore	780
Dipole (45°) magnets: 5" gap	660
Dipole (10°) magnets: 5" gap	340
Magnet Power Supplies	1,670
Energy Spread Monitors	320
Phase Spread Monitors	150

Video Profile Monitor	80
Microstriplines	570
TOTAL	8,240

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.5 Radio Frequency (RF) Drive Loop

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	2,220	70	800	3,090	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This worksheet details a separate effort to develop a production versions of the RF drive loops required throughout the accelerator. The RFQ will require 12 drive loops of 3 1/8 inch coax type (max power ~250kW) capacity, while the DTL and HEBT will require 43 drive loops of the 6 1/8 inch coax type (max power ~500 kW). In total, each accelerator in the facility requires a total of 55 drive loops. The technical aspects and configuration of these drive loops is described in reference 1. This worksheet uses this information to develop a listing of the necessary resources to carry out a final design on the two major types. This estimate also assumes all technology feasibility issues are resolved in respect to the drive loops prior to the beginning of preliminary design (in the year 2000).

C. Detailed WBS Listing:

None developed in support of this costing activity

D. Costing Rationale:

This estimate is comprised of only of labor. Northrop Grumman's past experience developing similar drive loops for both our internal beam line, as well as drive loops for other accelerator programs was utilized to develop the labor estimates.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

This estimate is comprised completely of labor. Institutional help is required to complete the effort.

Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 6.0 full time equivalent (FTE) personnel, of which 0.2 FTE are from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines included in this estimate are:

- RF Design
- Mechanical Design
- Electrical Design
- Vacuum Design
- Thermal Analysis
- Produceability
- System Engineering

F. References:

1. ORNL/M-4908, “IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report”

WORKSHEET
WBS 4.2.3.6 Accelerator & HEBT Thermal Control

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	2,090	--	750	2,840	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This worksheet details a separate effort to provide thermal control of the accelerator and HEBT. While each accelerating component, as well as the HEBT, have embedded thermal analysis efforts, the effort captured here focuses on interfacing between the separate accelerator requirements and the facility. This task is especially useful in minimizing the variety of connections and control loops because it treats the accelerator collectively. After completing the final design, this estimate also provides resource to maintain an engineering presence throughout the fabrication of the accelerator and HEBT components to maintain continuity in the engineering database. Lastly, since this task does not involve any subsystem or component development no institutional support is envisioned.

C. Detailed WBS Listing:

None developed in support of this costing activity

D. Costing Rationale:

This estimate is comprised of only of labor. Northrop Grumman's past experience developing similar systems for our internal beam line, as well as other accelerator programs, was utilized to develop the labor estimates.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 3.5 full time equivalent (FTE) personnel over the 24 months that accelerator and HEBT design activities are being executed. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines included in this estimate are:

- Mechanical Design
- Thermal/Environmental Control System Analysis
- Produceability
- System Engineering

WORKSHEET
WBS 4.2.3.7 Radio Frequency (RF) Power System

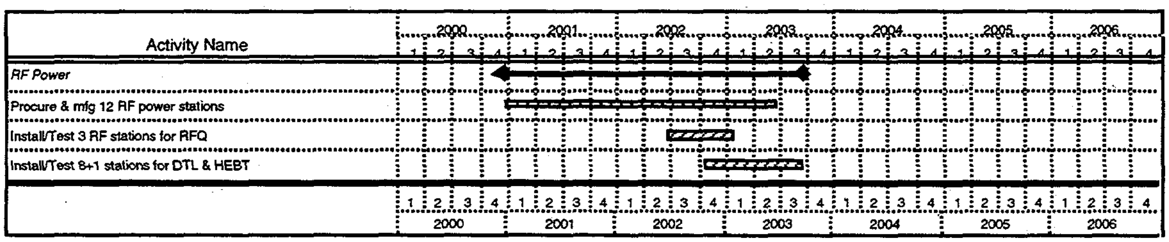
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
51,262	10,267	1,951	22,218	85,698	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This worksheet contains a top level summary of the costs to design, fabricate, functionally test, and ship an RF power system for the first accelerator (Castor) to the IFMIF site. The technical features of this system are described in detail in reference 1. This estimate assumes that during the engineering validation phase (1997-1999) all technology feasibility issues surrounding the RF power system are resolved. Further, the cost estimate assumes the development tube used during the engineering validation phase will be available for use in the IFMIF facility. The master schedule of activities is:



This worksheet differs from the other summary level cost sheets because it contains a separate estimate from the lower level WBS elements. The cost estimate at this level represents the top level documentation of the RF Station, and includes administration functions such as program management, systems engineering, support engineering, financial controllers, engineering aides for project support, project travel during the design and construction phase, contracts management, report data and other miscellaneous activities not related to the specific hardware design tasks described in the lower level RF power system WBS element worksheets.

C. Detailed WBS Listing (costs shown before addition of AFI):

WBS		Cost (kICF)
4.2.3.7:	RF Power System	4,703
4.2.3.7.1:	RF Control	5,852
4.2.3.7.2:	RF Predriver	3,846
4.2.3.7.3:	RF Driver and Final Amplifier	27,078
4.2.3.7.4:	RF Transport	7,653
4.2.3.7.5:	Cavity Resonance Control System	1,461
4.2.3.7.6:	Switchgear	1,743
4.2.3.7.7:	Cooling	6,193

4.2.3.7.8:	RF Station Monitoring and Control	1,644
4.2.3.7.9:	Integration Equipment and Services	3,303
	TOTAL (without AFI):	63,500

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Westinghouse Electronic Systems and Sensors Group) and components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate, for the managerial work performed at this level of WBS, is based on engineering experience associated with management of large scale design and development programs of similar complexity such as the Northrop Grumman production ASR-9 and ARSR-4 radar systems. The management defined here differs from the top level RF system manager defined in WBS 4.1 *Accelerator Facility Management*. The management personnel here will focus on the integration of the many separate efforts with the RF power system, and not on the integration of the RF to accelerator activities.

After review, the labor effort required equates to 2.35 FTE over the project seven year period (2000 through 2006). These personnel will be estimated at the project manager rate of 150 ICF/hour and 147 man hours per man month with an 8% fee.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.1 Radio Frequency (RF) Control Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
5,282	395	175	2,048	7,900	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system control components to the IFMIF site for installation and checkout. A detailed description of the specification of this system is contained in reference 1. In summary, this element interfaces with the RF station monitor & control subsystem, and the cavity resonance control subsystem, and maintains the phasing of the RF delivered by the high power RF amplification chain for proper RFQ, DTL, and HEBT operation. The elements estimated include a RF reference source, a RF reference distribution chain, the cavity field control system, a downconverter, a vector detection-modulation circuitry, a microcontroller and bus interface to the host computer, upconverter interface to the high power RF amplifier, and associated packaging and cooling.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to 0.75 full time equivalent (FTE) personnel, of which 0.25 FTE are from institutional engineering, over the 45 months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines included in this estimate are:

- RF Design
- Mechanical Design
- Electrical Design
- Support Structure Design
- Vacuum Design
- Thermal Analysis
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of 7.45 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.25 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The first unit cost for this component is 255 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 2,709 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.2 Radio Frequency (RF) Predriver Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
3,320	411	115	1,346	5,192	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system predriver components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, the RF Predriver is a high gain, 175 MHz solid state amplifier responsible for boosting the low level RF signal source up to the 3.0 kW needed by the driver stage of the RF amplifier chain. The Predriver is composed of two three stage amplifiers which when combined provide over 50 dB of gain. The Predriver output is isolated from the tetrode driver RF input, and incorporates fail-soft architecture for improved availability.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The labor estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from the Northrop Grumman production VHF 14 kW pulsed communications transmitter, with a 1.5 complexity factor to adapt the circuitry and packaging for CW operation at 3.0 kW.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 1.0 full time equivalent (FTE) personnel, of which 0.25 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- RF Design
- Mechanical Design
- Electrical Design
- Support Structure Design
- Vacuum Design
- Thermal Analysis
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 3.75 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.25 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The first unit cost for this component is 212 kilo ICF, which for the 12 sets required by the accelerator translates to a total cost for the material portion of this estimate of 2,196 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.3 Radio Frequency (RF) Driver & Final Power Amplifier Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
24,483	1,783	812	9,477	36,555	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system driver and final power amplifier components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, the RF final amplifier provides over 13 dB of gain to bring the RF drive up to 1.0 MW of CW power as needed by either the RFQ, DTL, or HEBT configurations. Similar in architecture to the RF driver, the final amplifier is composed of a 1000 kW output tube (Eimac 4CM2500KG tetrode or equivalent) and cavity assembly, along with its power conditioning, monitor, control, protection, and cooling interface components. The tetrode output is directly coupled to a matched cavity which directs the output RF to the appropriate RF transport chain..

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 1.0 full time equivalent (FTE) personnel, of which 0.25 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- RF Design
- Mechanical Design
- Electrical Design
- Support Structure Design
- Vacuum Design
- Thermal Analysis
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

This component will be procured as a unit. As a result there are no Northrop Grumman fabrication labor associated with the manufacture of this component.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.25 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 2310 kilo ICF, which for the 12 sets required by the accelerator translates to a total cost for the material portion of this estimate of 24,483 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.4 RF Transport Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
5,968	1,305	380	2,678	10,333	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This WBS element contains the necessary allocations to cover the design, procurement, and checkout of the various RF transport elements prior to shipment to the IFMIF facility for installation and checkout. The full technical details of the configuration is contained in reference 1. Most of the elements of the RF transport system (with the exception of the circulator) are catalog items. The circulator, at the IFMIF operating frequency and power level, will need modest development during the engineering validation phase of the program. A base assumption for this estimate is that all technical feasibility issues are resolved prior to any work covered by the allocations here.

C. Detailed WBS Listing:

4.2.3.7.4.1 RF Station To RFQ
4.2.3.7.4.1.1 Coax
4.2.3.7.4.1.2 COUPLERS (1- 19" & 2 - 14" Per Station)
4.2.3.7.4.1.3 Splitters
4.2.3.7.4.1.4 Windows
4.2.3.7.4.2 RF Station To DTL
4.2.3.7.4.2.1 Coax
4.2.3.7.4.2.2 COUPLERS (1- 19" & 2 - 14" Per Station)
4.2.3.7.4.2.3 Splitters
4.2.3.7.4.2.4 Windows
4.2.3.7.4.3 RF Station To HEBT
4.2.3.7.4.3.1 Coax
4.2.3.7.4.3.2 COUPLERS (1 - 14" & 3 - 9" Per Station)
4.2.3.7.4.3.3 Splitters
4.2.3.7.4.3.4 Windows
4.2.3.7.4.4 Circulators (19" Y-Junction)
4.2.3.7.4.5 Filters (19")
4.2.3.7.4.6 Low Power Couplers
4.2.3.7.4.7 RF Dummy Loads
4.2.3.7.4.8 Air Pressurization & Distribution

D. Costing Rationale:

The estimate is comprised of mostly of procured material, but some small amount of technician labor is included to cover basic functional checkout of the equipment at the RF vendor prior to shipment to the IFMIF site. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the RF transport elements are procured items, and the estimates were based on commercial catalog data and vendor quotes per the defined configuration and layout of the transport chain. Engineering effort for the design and specification of the RF transport configuration and for component specifications is also included.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 4.25 full time equivalent (FTE) personnel, of which 2.0 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- RF Transport Design
- Mechanical Design
- Thermal Analysis
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 2.0 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF transport systems similar to the specifications for the IFMIF ones, an allowance of 2.0 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The list of components included is fully described in reference 1, but a short summary list of the major types of components is included below. The total cost for the hardware list is 5,504 kilo ICF.

- Coax transport line (19, 14, 9, and 3 inch size)
- Directional couplers (various sizes)
- Harmonic filters (various sizes)
- Multi-port hybrid splitters (various sizes and number of ports)
- Circulator and loads
- RF Windows

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.5 Cavity Resonance Control Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,061	356	44	511	1,972	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system cavity resonance control system components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, this subsystem is required to minimize distortion of the beam within the accelerator cavities, the system will sample the beam via a 6-port hybrid, and via a microcontroller, control the flow of cooling liquid to maintain the correct cavity temperature that will in turn tune the cavity to the desired frequency.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from engineering estimates based on use of reflectometer applications for radar measurements and mechanical/thermal experience with proportional flow control loops, liquid cooling equipment, and flow monitor detection of similar complexity on various Northrop Grumman production radar systems..

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 1.0 full time equivalent (FTE) personnel, of which 0.10 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- Mechanical Design
- Thermal Analysis
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 1.25 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.10 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 65 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 672 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.6 Switchgear Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,655	35	53	570	2,313	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system switchgear components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, this worksheet includes all low level switchgear, voltage transformers, and AC power distribution necessary for proper RF station operation which is not included in the procured driver and final RF amplifier high voltage power supplies. It is assumed that the initial step-down transformers from the primary power transmission lines are provided as part of the site facility switchyard.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The labor estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from engineering experience associated with the integration of liquid cooled, high power, remotely controlled RF sources of similar complexity on various Northrop Grumman production radar systems.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 0.25 full time equivalent (FTE) personnel, of which 0.15 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- Mechanical Design
- Thermal Analysis
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 0.65 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.15 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 141 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 1458 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.7 Cooling Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
5,790	217	186	2,167	8,360	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system cooling components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, this worksheet includes separate cooling loops in each RF station to provide temperature, flow, and pressure interlocks, and include a distribution pump system and manifold with flow regulators, coolant conditioning and filtering, and a liquid-to-liquid heat exchanger to transfer heat to the IFMIF site cooling system.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from vendor quotes on procured items such as the heat exchanger, plumbing, pumps and manifolds, and is also based on engineering experience associated with liquid cooling of high power radar systems which are similar in complexity.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 1.1 full time equivalent (FTE) personnel, of which 0.5 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- Mechanical Design
- Thermal Analysis
- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 4.3 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.5 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 443 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 4,585 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.8 Radio Frequency (RF) Station Control & Monitoring Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
966	628	50	576	2,220	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system station control and monitoring components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, this worksheet includes the integrated control and monitoring function to maintain the proper operation of the complete RF station, and also provides remote digital information transfer to the master IFMIF control system via data bus interconnections. A central microprocessor will provide the local control and monitor display and interface within each RF station.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from the Northrop Grumman production ASR-9 radar remote monitoring subsystem, which is of similar complexity to the RF station environment.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 1.5 full time equivalent (FTE) personnel, of which 0.1 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- Instrumentation/Diagnostics
- Produceability
- System Engineering

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 2.0 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.1 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 35 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 356 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.3.7.9 Integration Equipment and Services

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
2,737	432	136	1,157	4,460	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and utilize the RF system integration equipment prior to any equipment being shipped to the to the IFMIF site. A detailed description and specification of this system is contained in reference 1. In summary, this worksheet includes the equipment needed to install and setup the RF stations and RF transport elements of the IFMIF system for a test before they are shipped to the site. The items in this task are those which are manufactured and/or used in the testing of the equipment prior to shipment.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from the engineering experience obtained from the integration of high power radar transmitters in various Northrop Grumman production systems, and the quote prepared for the 1.0 MW S-band RF source for the Arecibo Observatory in Puerto Rico.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 1.75 full time equivalent (FTE) personnel, of which 0.5 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee.

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 6.5 FTE technicians, and 3.0 FTE craft labor over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, while the craft were estimated at 25 ICF per hour, and both at 147 man hours per man month with an 8% fee.

Institutional Labor (Engineering):

Based upon past experience in developing RF control systems similar to the specifications for the IFMIF ones, an allowance of 0.5 FTE for the entire design effort (preliminary and final) was included. Like the Industry engineering talent, the Institutional labor was estimated at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 35 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 357 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4 Accelerator #2 (Pollux)

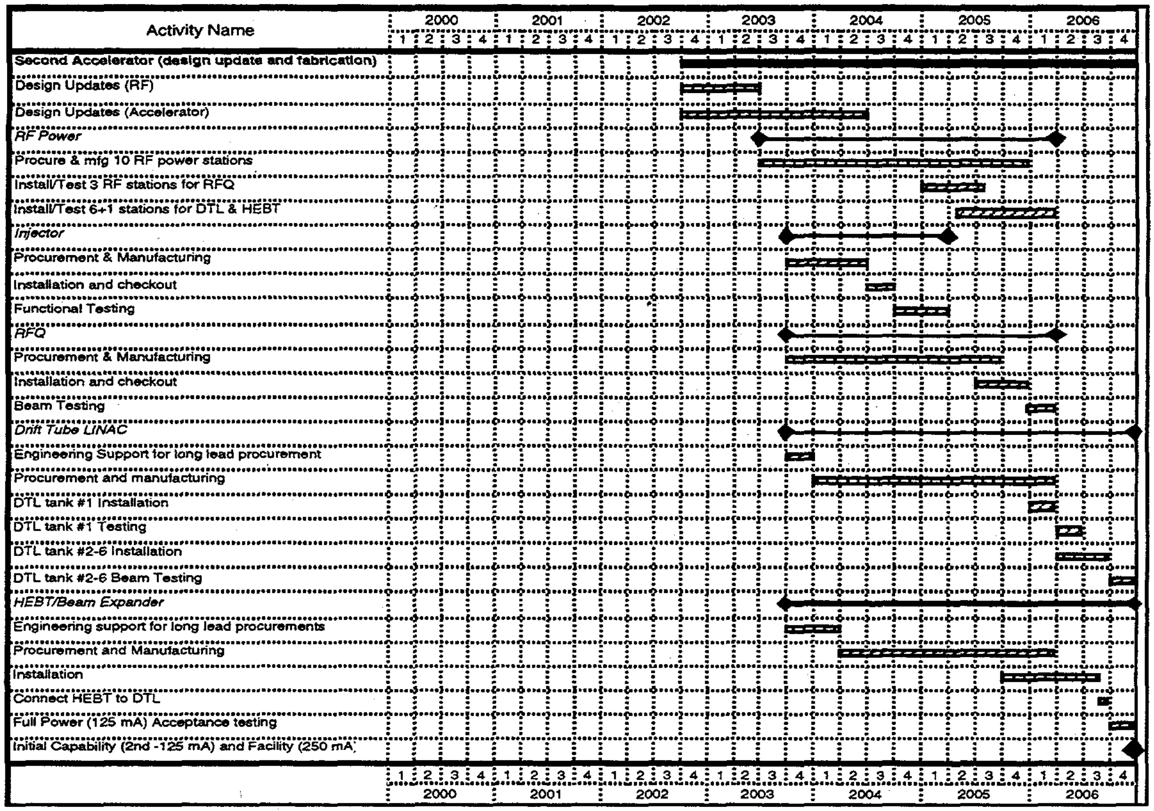
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
78,050	6,162	--	29,766	113,982	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate is a summary level compilation of lower level estimates. As a whole this estimate expresses the total resources required to update the design with lessons learned from the first accelerator, then to produce a second accelerator. Other than this exception there is no other design work included in this estimate. Further, the labor estimates employed here assume the experience gained in fabricating and fielding the first accelerator is maintained and applied to the benefit of the second accelerator. Lastly, because of the experience gained on the first accelerator, the labor estimates here assume that the second accelerator system can be built entirely by industry without the any laboratory oversight. The top level schedule for the second accelerator is:



C. Detailed WBS Listing:

WBS #		Cost
4.2.3.1:	Design Updates	700
4.2.3.2:	Injector System	1,880
4.2.3.3:	Radio Frequency Quadrupole System	9,830
4.2.3.4:	Drift Tube Linac System	17,930
4.2.3.5:	High Energy Beam Transport (HEBT) System	13,662
4.2.3.6:	RF Power Supply System	69,980
	Total:	113,978

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently supplied rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

See lower WBS worksheets

WORKSHEET
WBS 4.2.4.1 Design Updates

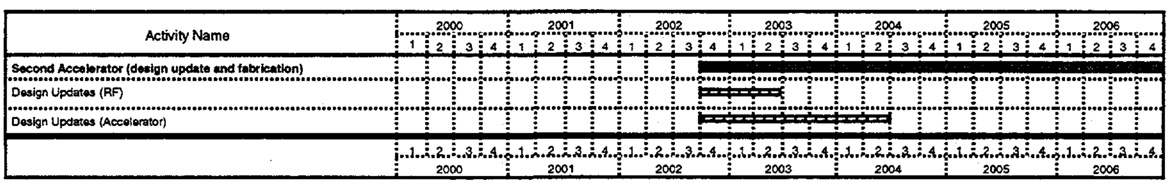
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	520	--	180	700	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This worksheet documents the necessary manpower to update the design of the second accelerator (Pollux) to reflect experience gained from the fabrication and check out of the first accelerator system (Castor). It is anticipated that this task will contain only industrial engineering labor hours due to the nature of the design updates expected. The schedule for these activities is shown below.



C. Detailed WBS Listing:

None used in the preparation of this estimate

D. Costing Rationale:

The labor estimate was developed from Northrop Grumman experience on other similar programs.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

As stated previously, this is a labor only task. A 1.0 full time equivalent (FTE) engineer is assigned to each major subsystem for the activity duration. These personnel were costed at the engineering rate of 100 ICF per hour and 147 man hours per man month with an 8% fee.

WORKSHEET
WBS 4.2.4.2 Injector

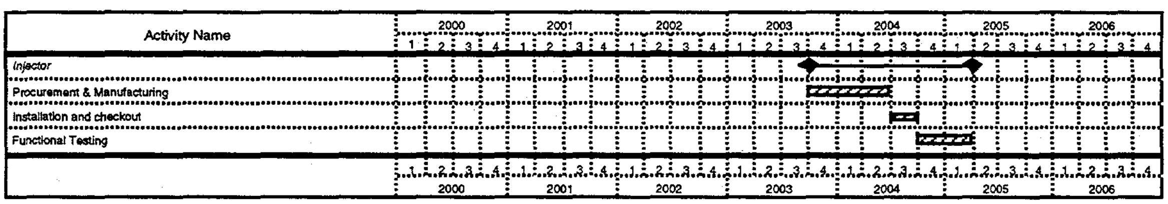
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,260	140	--	480	1,880	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The injector portion of the accelerator is fully described in reference 1. This worksheet documents the necessary resources to deliver two full injector assemblies, as well an additional spare ion source, in support of the second accelerator (Pollux). This estimate also assumes that the injector design for the first accelerator is maintained with little or no modifications. Any modifications will not require further engineering analysis before commencing with the fabrication and pre-shipment checkout. All design upgrade engineering will be accomplished under WBS 4.2.4.1 *Design Upgrade* activities. Further, this estimate assumes that the assembly experience gained during the Castor accelerator work will reduce some of the assembly labor necessary for the Pollux injector system. The master schedule governing the activities of this worksheet is shown below:



C. Detailed WBS Listing:

None established

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into two major categories: industrial support engineering and fabrication labor.

Industrial Support Engineering:

1.0 full time equivalent (FTE) engineer is provided to support the fabrication effort as well as provide capability to address any difficulties which may arise. This support is scheduled to extend over the nine months required to field the injector system. This labor is estimated at 100 ICF per hours and 147 man hours per man month with an 8% fee.

Fabrication Labor:

The draft subcontracting plan developed for the first accelerator was modified to reflect the expected savings in labor and fabrication time for the follow on effort for the second accelerator. The result of this effort yielded a staff of 3.0 FTE technicians together with 2.0 FTE engineers over the nine months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, the engineers at 100 ICF per hour, and both considering 147 man hours per man month with an 8% fee. The engineering skills to be employed during the fabrication task are:

- Liaison Engineering
- Mechanical Design
- Electrical Design
- Quality Control

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 670 kilo ICF.

Component	Cost (Kilo ICF)
Source and RF Power Supply	330
Low Energy Beam Transport (LEBT)	207
Magnet Power Supplies	60
Operational Control Equipment and Software	20
Vacuum Equipment and Services	40
Thermal Control Equipment and Services	5
Structural Support and Shielding Equipment	8
TOTAL:	670

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.3 Radio Frequency Quadrupole (RFQ) System

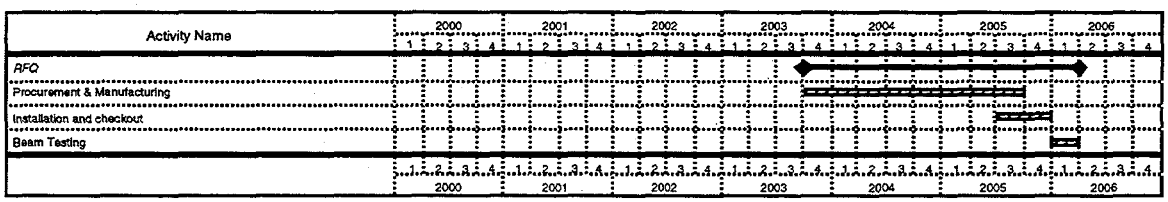
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
6,900	380	--	2,550	9,830	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The RFQ portion of the accelerator is fully described in reference 1. This worksheet documents the necessary resource to deliver one 12 meter long, 8 MeV RFQ, in support of the second accelerator (Pollux). This estimate also assumes that the experience base developed during the fabrication of the first accelerator RFQ can be transferred to the second accelerator and utilized to reduce the associated manpower required. The master schedule for the Pollux RFQ system is shown below:



C. Detailed WBS Listing:

None established

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into two major categories: industrial support engineering and fabrication labor.

Industrial Support Engineering Labor:

An allowance of 1.0 full time equivalent (FTE) personnel is included to help oversee the procurement activities and address any difficulties that arise. This activity is scheduled to extend over the full 24 months of the procurement and manufacturing effort shown in the schedule above. The engineer were estimated at 100 ICF per hours and 147 man hours per man month with an 8% fee.

Fabrication Labor:

Utilizing the experience gained from the first RFQ fabrication an estimate was developed to express the amount of savings that could be realized. The result of this effort yielded a staff of 6.4 FTE technicians together with 5.0 FTE engineers over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, the engineers at 100 ICF per hour, and both considering 147 man hours per man month with an 8% fee. The engineering skills to be employed during the fabrication task are:

- Liaison Engineering
- Mechanical Design
- Electrical Design
- Quality Control

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 3000 kilo ICF.

Component	Cost (Kilo ICF)
Oxygen Free High Conductivity (OFHC) Copper	240
RF drive loops	580
Electroforming services	1,170
Miscellaneous hardware & services (Vacuum, Thermal, Stress, Structural support, etc.)	1,010
TOTAL:	3,000

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.4 Drift Tube Linac (DTL) System

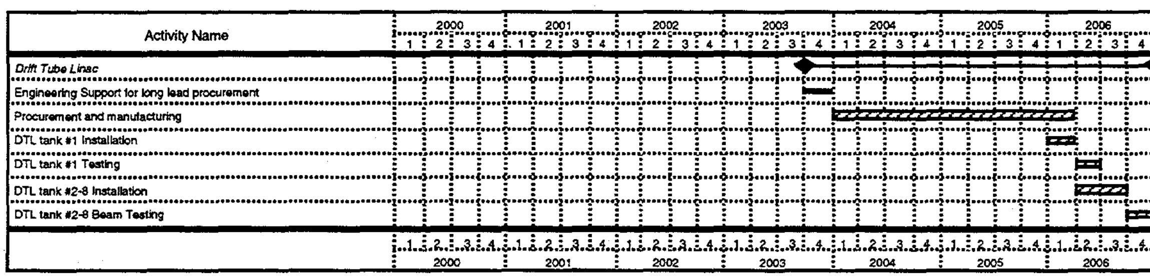
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
12,640	640	--	4,650	17,930	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The technical aspects of the DTL accelerating system is fully described in reference 1. This worksheet uses this information, together with the information contained in WBS 4.2.3.3 *Drift Tube Linac System* (for first accelerator), to develop a listing of the necessary resource to deliver eight DTL tanks in support of the second accelerator (Pollux). This estimate assumes that the experience gained during the first accelerator manufacture will be employed for this accelerator and a resulting savings in fabrication labor will be realized. Further, any engineering modifications driven from the experience will be incorporated in the design under the WBS 4.2.4.1 *Design Updates* activities. The master schedule for the Pollux DTL system is shown below:



C. Detailed WBS Listing (costs expressed with apportioned AFI):

WBS		Cost (kICF)
4.2.4.4.1:	Tank #1	2,580
4.2.4.4.2:	Tank #2	2,420
4.2.4.4.3:	Tank #3	2,250
4.2.4.4.4:	Tank #4	2,190
4.2.4.4.5:	Tank #5	2,150
4.2.4.4.6:	Tank #6	2,130
4.2.4.4.7:	Tank #7	2,090
4.2.4.4.8:	Tank #8	2,080
	TOTAL:	13,280

D. Costing Rationale:

The labor estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into two major categories: industrial support engineering and fabrication labor.

Industrial Support Engineering:

The DTL manufacturing plan includes a significant number of procured items that will be produced in large quantity. In support certain engineering skills will be required to ensure the subcontracted work is being properly executed. The list of the skill types required is shown below. The schedule shown above indicates that an three years span for this activity in which approximately 1.0 FTE engineers were estimated at 100 ICF per hours and 147 man hours per man month with an 8% fee.

- Quality Control
- Methods
- Production Management/Controls
- Liaison Engineering

Fabrication Labor:

The draft subcontracting plan created for the first accelerator DTL system was reviewed and modified for use on the second accelerator. The embedded fabrication labor was then modified to reflect the experience from producing the first series of DTL accelerating tanks. The result of this effort yielded a staff of 5.0 FTE technicians, together with 2.5 engineers, over the 36 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, the engineers at 100 ICF per man hour, and both at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 8,080 kilo ICF.

Purchased material for each tank

Drift Tubes
Drift tube magnets
Vacuum system equipment & Services
Oxygen Free High Conductivity (OFHC) Copper for tank shell
Endwalls with magnets
Tank support system
Rail Tuners
RF drive loops
Post couplers
Drift tube support girder
Inter-tank focusing quadrupole package
miscellaneous hardware

Material Breakdown by tank (without AFI)

	Cost (Kilo ICF)
Tank #1	1,250
Tank #1	1,140
Tank #1	1,020
Tank #1	970
Tank #1	940
Tank #1	930
Tank #1	920
Tank #1	910
TOTAL:	8,080

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.5 High Energy Beam Transport (HEBT)

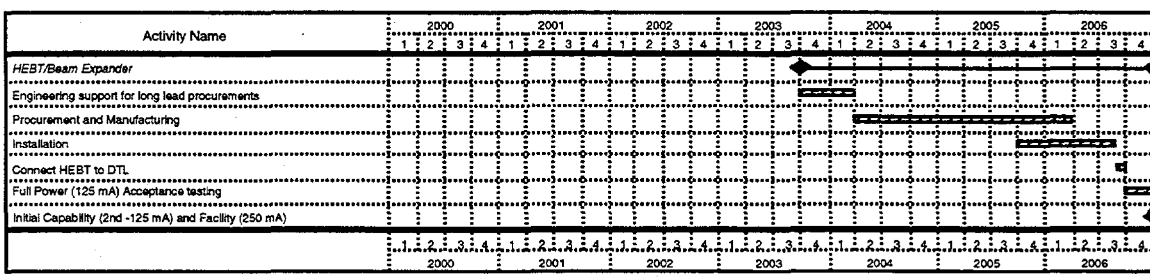
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
9,263	857	--	3,542	13,662	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The technical aspects of the HEBT system of the accelerator are fully described in reference 1. This worksheet uses this information developed in WBS 4.2.3.4 *High energy Beam Transport* to estimate the necessary resources to deliver three transport lines (one to each lithium target and one to the fixed facility beam dump) in support of the second accelerator (Pollux). This estimate also assumes the experience gained in manufacturing the first HEBT system will be used to produce a savings in fabrication labor for the Pollux HEBT. The master schedule for the Pollux HEBT system is shown below:



C. Detailed WBS Listing:

None developed in support of this costing activity

D. Costing Rationale:

This estimate is comprised of two major portions, labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, information from the past accelerating programs was updated with information collected from suppliers in the various areas who were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into two major categories: industrial support engineering and fabrication labor.

Industrial Support Engineering Labor:

The HEBT manufacturing plan includes a significant number of procured items (magnets , diagnostics, power supplies, etc.) that will be produced in large quantity. In support of this a separate team of individuals will be required to ensure the subcontracted work is being properly executed. The list of the skill types required is shown below. The schedule shown above indicates that a 27 month span for this activity in which approximately 2.00 FTE engineers were estimated at 100 ICF per hours and 147 man hours per man month with an 8% fee.

- Quality Control
- Methods
- Production Management/Controls
- Liaison Engineering

Fabrication Labor:

The draft subcontracting plan prepared for the first HEBT was modified to reflect the savings in fabrication labor that due to the experience of fabricating the first accelerators HEBT. The result of this effort yielded a staff of 4.0 FTE technicians, with support form 2.0 FTE engineers, over the 12 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, with the engineers at 100 ICF per man hour, both considering 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware identified below. The total cost for the material portion of this estimate was 8,420 kilo ICF (without any AFI).

Purchased Item	Cost (kICF)
Beam Tube, Flanges, Bellows, etc.	210
RF Cavities	1,610
Support/Alignment Structure	290
Quadrupole magnets: 6" long x 5" dia bore	250
Quadrupole magnets: 16" long x 5" dia bore	360
Quadrupole magnets: 24" long x 5" dia bore	950
Octupole magnets: 16" long x 3.5" dia bore	780
Dipole (45°) magnets: 5" gap	660
Dipole (10°) magnets: 5" gap	340

Magnet Power Supplies	1,670
Energy Spread Monitors	320
Phase Spread Monitors	150
Video Profile Monitor	80
Microstriplines	570
TOTAL	8,420

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6 Radio Frequency (RF) Power System

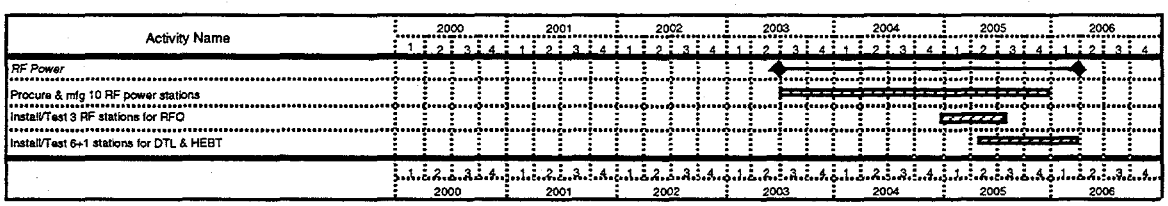
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
47,987	3,652	--	18,064	69,676	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This worksheet contains a top level summary of the costs to design, fabricate, test, and ship out an RF power system for the second accelerator (Pollux). The technical features of this system are described in detail in reference 1. This estimate assumes that during the engineering validation phase (1997-1999) all technology feasibility issues surrounding the RF power system are resolved. Further, the cost estimate assumes the development tube used during the engineering validation phase will be available for use in the IFMIF facility. The master schedule activities is:



This worksheet differs from the other summary level cost sheets because it has a separate estimate from the lower level WBS elements. The cost estimate at this level represents the top level documentation of the RF Station, and includes administration functions such as program management, systems engineering, support engineering, financial controllers, engineering aides for project support, project travel during the design and construction phase, contracts management, report data and other miscellaneous activities not related to the specific hardware design tasks described in the lower level RF power system WBS element worksheets.

C. Detailed WBS Listing (costs shown before addition of AFI):

WBS		Cost (kICF)
4.2.3.7:	RF Power System	1,294
4.2.3.7.1:	RF Control	5,049
4.2.3.7.2:	RF Predriver	3,314
4.2.3.7.3:	RF Driver and Final Amplifier	24,025
4.2.3.7.4:	RF Transport	5,866
4.2.3.7.5:	Cavity Resonance Control System	1,094
4.2.3.7.6:	Switchgear	1,375
4.2.3.7.7:	Cooling	5,703

4.2.3.7.8:	RF Station Monitoring and Control	1,501
4.2.3.7.9:	Integration Equipment and Services	2,574
	TOTAL (without AFI):	51,800

D. Costing Rationale:

Like the system for the Castor accelerator this estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate, for the managerial work performed at this level of WBS, is based on engineering experience associated with management of large scale design and development programs of similar complexity such as the Northrop Grumman production ASR-9 and ARSR-4 radar systems. The management defined here differs from the top level RF system manager defined in WBS 4.1 *Accelerator Facility Management*. The management personnel here will focus on the integration of the many separate efforts with the RF power system, and not on the management of the RF to accelerator activities.

After review, the labor effort required equates to 1.5 FTE over the project seven year period (2000 through 2006). These personnel will be estimated at the project manager rate of 150 ICF/hour and 147 man hours per man month with an 8% fee.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.1 Radio Frequency (RF) Control Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
4,951	98	--	1,767	6,816	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system control components to the IFMIF site for installation and checkout. A detailed description of the specification of this system is contained in reference 1. In summary, this element interfaces with the RF station monitor & control, and the cavity resonance control system, and maintains the phasing of the RF delivered by the high power RF amplification chain for proper RFQ, DTL, and HEBT operation. The elements estimated include a RF reference source, a RF reference distribution chain, the cavity field control system, a downconverter, a vector detection-modulation circuitry, a microcontroller and bus interface to the host computer, upconverter interface to the high power RF amplifier, and associated packaging and cooling.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

Like the system for the Castor accelerator this estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to maintain the design material to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to 0.25 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor was calculated at the engineering rate of

100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines included in this estimate are:

- Mechanical Design
- Electrical Design

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of 6.75 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The first unit cost for this component is 255 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 2,469 kilo ICF.

F. References:

1. ORNL/M-4908, “IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report”

WORKSHEET
WBS 4.2.4.6.2 Radio Frequency (RF) Predriver Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
3,245	69	--	1,160	4,474	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system predriver components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, the RF Predriver is a high gain, 175 MHz solid state amplifier responsible for boosting the low level RF signal source up to the 3.0 kW needed by the driver stage of the RF amplifier chain. The Predriver is composed of two three stage amplifiers which when combined provide over 50 dB of gain. The Predriver output is isolated from the tetrode driver RF input, and incorporates fail-soft architecture for improved availability.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

Like the system for the Castor accelerator this estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from the Northrop Grumman production VHF 14 kW pulsed communications transmitter, with a 1.5 complexity factor to adapt the circuitry and packaging for CW operation at 3.0 kW.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to maintain the design material to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 0.2 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- RF Design
- Mechanical Design
- Electrical Design

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 3.75 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 212 kilo ICF, which for the 12 sets required by the accelerator translates to a total cost for the material portion of this estimate of 2,053 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.3 Radio Frequency (RF) Driver & Final Power Amplifier Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
22,367	1,658	--	8,409	32,434	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system driver and final amplifier components to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, the RF Final Amplifier provides over 13 dB of gain to bring the RF drive up to 1.0 MW of CW power as needed by either the RFQ, DTL, or HEBT configurations. Similar in architecture to the RF Driver, the final amplifier is composed of a 1000 kW output tube (Eimac 4CM2500KG tetrode or equivalent) and cavity assembly, along with its power conditioning, monitor, control, protection, and cooling interface components. The tetrode output is directly coupled to a matched cavity which directs the output RF to the appropriate RF Transport chain..

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

Like the system for the Castor accelerator this estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks maintain the design material to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 4.25 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- RF Design
- Mechanical Design
- Electrical Design
- Instrumentation and Diagnostics
- Systems Engineering

Fabrication Labor:

This component will be procured as a unit. As a result there are no Northrop Grumman fabrication labor associated with the manufacture of this component.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 2310 kilo ICF, which for the 12 sets required by the accelerator translates to a total cost for the material portion of this estimate of 22,367 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.4 RF Transport Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
5,499	184	--	1,989	7,672	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This WBS element contains the necessary allocations to cover the design, procurement, and checkout of the various RF transport elements prior to shipment to the IFMIF facility for installation and checkout. The full technical details of the configuration is contained in reference 1. Most of the elements of the RF transport system (with the exception of the circulator) are procured items. The circulator, at the IFMIF operating frequency and power level, will need modest development during the engineering validation phase of the program. A base assumption for this estimate is that all technical feasibility issues are resolved prior to any work covered by the allocations here.

C. Detailed WBS Listing:

4.2.4.6.4.1	RF Station To RFQ
4.2.4.6.4.1.1	Coax
4.2.4.6.4.1.2	COUPLERS (1- 19" & 2 - 14" Per Station)
4.2.4.6.4.1.3	Splitters
4.2.4.6.4.1.4	Windows
4.2.4.6.4.2	RF Station To DTL
4.2.4.6.4.2.1	Coax
4.2.4.6.4.2.2	COUPLERS (1- 19" & 2 - 14" Per Station)
4.2.4.6.4.2.3	Splitters
4.2.4.6.4.2.4	Windows
4.2.4.6.4.3	RF Station To HEBT
4.2.4.6.4.3.1	Coax
4.2.4.6.4.3.2	COUPLERS (1 - 14" & 3 - 9" Per Station)
4.2.4.6.4.3.3	Splitters
4.2.4.6.4.3.4	Windows
4.2.4.6.4.4	Circulators (19" Y-Junction)
4.2.4.6.4.5	Filters (19")
4.2.4.6.4.6	Low Power Couplers
4.2.4.6.4.7	RF Dummy Loads
4.2.4.6.4.8	Air Pressurization & Distribution

D. Costing Rationale:

Like the system for the Castor accelerator this estimate is comprised of mostly of procured material, but some small amount of technician labor is included to cover basic functional checkout of the equipment at the RF vendor prior to shipment to the IFMIF site. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the RF transport elements are procured items, and the estimates were based on commercial catalog data and vendor quotes per the defined configuration and layout of the transport chain. Engineering effort for the design and specification of the RF transport configuration and for component specifications is also included.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to maintain the design material to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 0.5 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month. The engineering disciplines involved in this estimate are:

- RF Transport Design
- Mechanical Design

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 1.5 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The list of components included are fully described in reference 1, but a short summary list of the major types of components is included below. The total cost for the hardware list is 5,229 kilo ICF.

- Coax transport line (19, 14, 9, and 3 inch size)
- Directional couplers (various sizes)
- Harmonic filters (various sizes)
- Multi-port hybrid splitters (various sizes and number of ports)
- Circulator and loads
- RF Windows

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.5 Cavity Resonance Control Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1039	55	--	383	1,477	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system cavity resonance control components for the second accelerator to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. Like the system for the first accelerator, this subsystem is required to minimize distortion of the beam within the accelerator cavities, the system will include a resonance control system which will sample the beam via a 6-port hybrid, and via a microcontroller control the flow of cooling liquid to maintain the correct cavity temperature that will in turn tune the cavity to the desired frequency.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from on engineering estimates based on use of reflectometer applications for radar measurements and mechanical/thermal experience with proportional flow control loops, liquid cooling equipment, and flow monitor detection of similar complexity on various Northrop Grumman production radar systems..

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to maintain the design material to enable the fabrication of a second set of equipment (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 0.15 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor

was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering disciplines involved in this estimate are:

- Mechanical Design

Fabrication Labor:

The draft subcontracting plan, created for the first accelerator, was modified for the second accelerator. This included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 1.3 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The unit cost for this component is 65 kilo ICF, which, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 649 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.6 Switchgear Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,322	53	--	481	1,856	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system switchgear components for the second accelerator to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. Like the system for the first accelerator, this worksheet includes all low level switchgear, voltage transformers, and AC power distribution necessary for proper RF station operation which is not included in the procured Driver and Final RF amplifier high voltage power supplies. It is assumed that the initial step-down transformers from the primary power transmission lines are provided as part of the site facility switchyard.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from engineering experience associated with the integration of liquid cooled, high power, remotely controlled RF sources of similar complexity on various Northrop Grumman production radar systems.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to maintain the design material to enable the fabrication of a second set of equipment (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 0.15 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor

was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering discipline involved in this estimate are:

- Mechanical Design

Fabrication Labor:

Northrop Grumman produceability/manufacturing used the draft subcontracting plan from generated for the first accelerator as guidance in determining a delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 0.6 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The first unit cost (in respect to the first accelerator) for this component is 141 kilo ICF, which, for the second 12 sets required by the second accelerator, translates to a total cost for the material portion of this estimate of 1125 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.7 Cooling Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
5,667	36	--	1,996	7,699	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system cooling components for the second accelerator to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. Like the first accelerator, this worksheet includes separate cooling loops in each RF station to provide temperature, flow, and pressure interlocks, and include a distribution pump system and manifold with flow regulators, coolant conditioning and filtering, and a liquid-to-liquid heat exchanger to transfer heat to the IFMIF site cooling system.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from vendor quotes on procured items such as the heat exchanger, plumbing, pumps and manifolds, and is also based on engineering experience associated with liquid cooling of high power radar systems which are similar in complexity.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to maintain the design material to enable the fabrication of a second set of equipment (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 0.1 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor

was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering discipline involved in this estimate are:

- Mechanical Design

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subsystem requirements and drafted a preliminary subcontracting plan which included delineation between purchased items and internally fabricated ones. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 4.0 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The first unit cost (for the first accelerator) for this component is 443 kilo ICF, which, for the 12 sets required by the second accelerator, translates to a total cost for the material portion of this estimate of 4,585 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.8 Radio Frequency (RF) Station Control & Monitoring Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1,401	100	--	525	2,026	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system station control and monitoring components for the second accelerator to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. Like the equipment for the first accelerator, this worksheet includes the integrated control and monitoring function to maintain the proper operation of the complete RF station, and also provides remote digital information transfer to the master IFMIF control system via data bus interconnections. A central microprocessor will provide the local control and monitor display and interface within each RF station.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from the Northrop Grumman production ASR-9 radar remote monitoring subsystem, which is of similar complexity to the RF station environment.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to maintain the design material to enable the fabrication of a second set of equipment (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 0.25 full time equivalent (FTE) personnel over the 24 months allotted for the effort. All of this labor

was calculated at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee. The engineering discipline involved in this estimate are:

- Instrumentation/Diagnostics

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the draft subcontracting plan created for the first accelerator to delineate between purchased items and internally fabricated ones for the second accelerator. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 3.0 FTE technicians over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The first unit cost (in the first accelerator) for this component is 35 kilo ICF, which considering lot savings, for the 12 sets required by the second accelerator, translates to a total cost for the material portion of this estimate of 345 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report"

WORKSHEET
WBS 4.2.4.6.9 Integration Equipment and Services

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
2,496	78	--	901	3,475	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, test, and ship the RF system integration equipment for the second accelerator to the IFMIF site for installation and checkout. A detailed description and specification of this system is contained in reference 1. In summary, this worksheet includes the equipment needed to install and setup the RF Stations and RF Transport elements of the IFMIF system for a test before they are shipped to the site. The items in this task are those which are manufactured and/or used in the testing of the equipment prior to shipment.

C. Detailed WBS Listing:

None developed for this estimate

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering high power RF systems (through the recently acquired Former Westinghouse Electronic Systems and Sensors Group) components on similar programs was utilized to develop the labor estimates. Predominately, the costs were developed from the engineering experience obtained from the integration of high power radar transmitters in various Northrop Grumman production systems, and the quote prepared for the 1.0 MW S-band RF source for the Arecibo Observatory in Puerto Rico.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Design Labor (Engineering):

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to approximately 1.75 full time equivalent (FTE) personnel, of which 0.5 FTE support is from institutional engineering, over the 24 months allotted for the effort. All of this labor was calculated at

the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee.

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the subcontracting plan for the first accelerator for guidance in determining a delineation between purchased items and internally fabricated ones for the second accelerator system. For the components that would be internally fabricated estimates of the required labor and material were generated. For the purchased items, vendors were solicited to provide rough order of magnitude costs. The last piece of information from the manufacturing department was an estimate of the assembly tasks.

The result of this effort yielded a staff of approximately 5.5 FTE technicians, and 2.5 FTE craft labor over the 24 months that this task is scheduled to span. The technicians were estimated at 80 ICF per hour, while the craft were estimated at 25 ICF per hour, and both at 147 man hours per man month with an 8% fee.

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes on the hardware. The first unit cost (in the first accelerator) for this component is 35 kilo ICF, which considering a combined purchase, for the 12 sets required by the accelerator, translates to a total cost for the material portion of this estimate of 345 kilo ICF.

F. References:

1. ORNL/M-4908, "IFMIF, International Fusion Materials Irradiation Facility, Conceptual Design Activity, Interim Report".

WORKSHEET
WBS 4.2.5 Beam Calibration Dumps

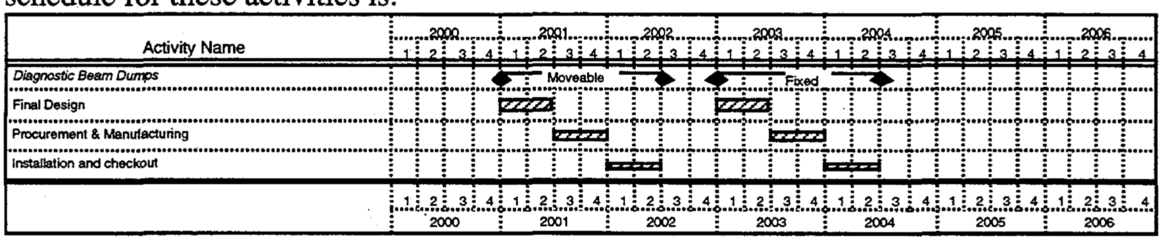
A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
5,133	994	412	2,291	8,830	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate is a summary level compilation of lower level estimates. It expresses the resources necessary to complete delivery of both a moveable diagnostic beam dump system (capable of accepting 13 W/cm^2), and the facility fixed diagnostic beam dump capable of accepting 2% of the full energy CW deuterium 125 mA beam. This estimate covers the work between the beginning of preliminary design and the point at which the facility is commission to operate at 40 MeV and 250 mA. The master schedule for these activities is:



C. Detailed WBS Listing: (with AFI included)

WBS #		Cost
4.2.5.1: Moveable Beam Dump		3,620
4.2.5.2: Fixed Beam Dump		5,210
	Total:	8,836

D. Costing Rationale:

This estimate is comprised of two major portions: labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

See lower WBS worksheets

WORKSHEET
WBS 4.2.5.1 Moveable Beam Calibration Dump

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
2,165	422	94	939	3,620	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the allocations required to design, fabricate, and test a moveable diagnostic beam dump assembly. After which the assembly will be shipped to the IFMIF site and re-assembled [WBS 4.3.7 Beam Dump Installation and Checkout contains the labor necessary to accomplish the re-assembly]. The assembly can be broken into two major pieces, the diagnostic package and the beam dump. The diagnostic package will include a long drift section where the beam will be interrogated at three stations with video profile monitors, and two stations where microstriplines will be installed to make time of flight measurements. The combination of the two types of measurements enables calculations to determine the beam divergence and emmittance as it exists the accelerator. The dump section consists of two major pieces also, the first being a series of electromagnetic solenoids which blow up the beam from a few millimeters to tens of centimeters. This expanded beam then passes to a slanted ceramic tile beam dump. The tiles radiate the deposited heat to an actively cooled back plate. The maximum design heat deposition is to be less than, or equal to, 13 kW/cm^2.

C. Detailed WBS Listing:

None established

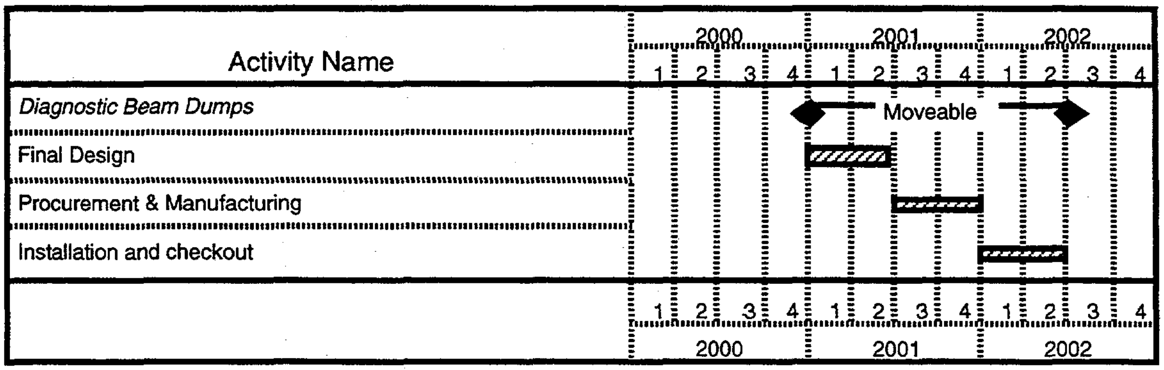
D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into three major categories: industrial engineering, institutional support, and fabrication labor The schedule for this component is:



Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to four full time equivalent (FTE) personnel over the six months allotted for the effort. These were all billed at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee.

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and returned an estimate of the necessary labor to fabricate the known pieces of this component (listed above). The result of this effort yielded a staff of 7.54 FTE over the six months that this task is scheduled to span. These personnel were estimated at 80 ICF per hour and 147 man hours per man month with an 8% fee.

Institutional Labor:

Based upon previous programs to develop diagnostic packages an allowance of 0.5 FTE for the entire design and fabrication process was included . Like the industry engineering resource, the Institutional labor will be billed at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes. The resulting total cost is 2,165 kilo ICF.

WORKSHEET
WBS 4.2.5.2 Fixed Beam Calibration Dump

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
2,968	572	318	1,352	5,210	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This estimate documents the resources required to design, fabricate, and test a the fixed diagnostic beam dump assembly. After which the components will be disassembled and shipped to the IFMIF site and re-assembled [WBS 4.3.7 Beam Dump Installation and Checkout contains the labor necessary to accomplish the re-assembly]. The beam dump can be broken into two major pieces, the diagnostic package and the beam dump. The diagnostic package will includes both thermal imaging video cameras as well as visible light spectrum cameras. The combination of the two types of measurements will enable determination of the beam characteristics as it exists the high energy beam transport. The final receptacle for the beam will be a slant faced ceramic tiled beam stop modeled after the FMIT design. The tiles radiate the deposited heat to an actively cooled back plate. This beam stop will be designed to accept <2% duty factor of the full energy 125 mA deuterium beam.

C. Detailed WBS Listing:

None established

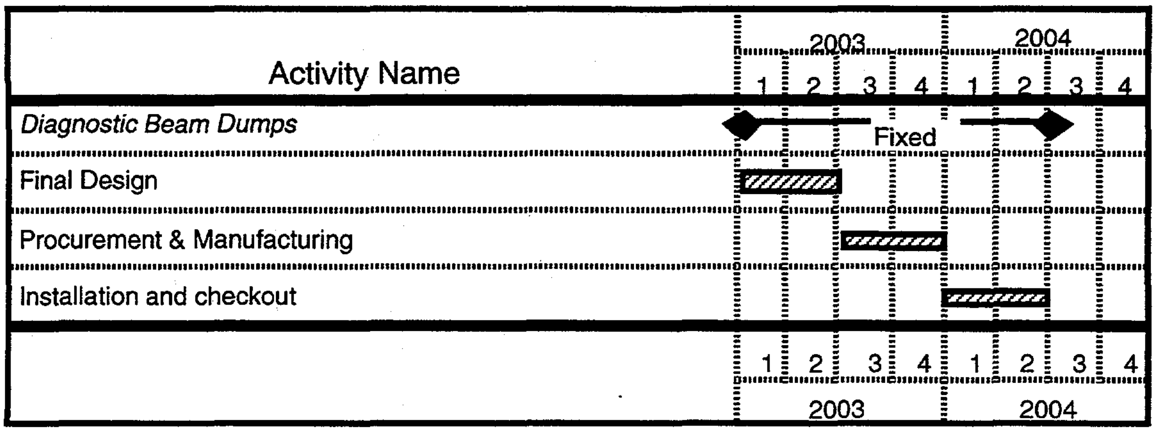
D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering accelerating components on similar programs, coupled to the existing material on the FMIT beam stop, was utilized to develop the labor estimates. To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate is comprised of two major parts, labor and material. The labor falls into three major categories: industrial engineering, institutional support, and fabrication labor The schedule for this component is:



This worksheet details the resources in the Final Design and Procurement and Manufacturing lines of the schedule. The resource to cover the installation and check out, as well as functional testing are included in WBS 4.3.1.7.2 Fixed Diagnostic Beam Dump.

Design Labor:

A review of the necessary tasks to complete the design work and produce the required information to enable the fabrication (drawings, specifications, subcontracting plans, etc.) dictated a mix of engineering talent that equated to six full time equivalent (FTE) personnel over the six months allotted for the effort. These were all billed at the engineering rate of 100 ICF per man hour and 147 man hours per man month with an 8% fee.

Fabrication Labor:

Northrop Grumman produceability/manufacturing reviewed the requirements and returned an estimate of the necessary labor to fabricate the known pieces of this component (listed above). The result of this effort yielded a staff of 9.50 FTE over the six months that this task is scheduled to span. These personnel were estimated at 80 ICF per hour and 147 man hours per man month with an 8 % fee.

Institutional Labor:

Based upon previous programs to develop diagnostic packages an allowance of 1.0 FTE for the entire design and fabrication process was included. Like the industry engineering resource, the institutional labor will be billed at 100 ICF per hour and 147 man hours per man month

Material:

The existing level of detail surrounding the device provided enough information to contact vendors concerning rough order of magnitude quotes for the hardware. The total cost for the material was 2,968 kilo ICF.

WORKSHEET
WBS 4.2.6 Accelerator System Control

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
683	4,581	142	1,892	7,297	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

The overall instrumentation and control system configuration for the IFMIF accelerators is conceived as an independent, stand-alone system for each accelerator line, with shared services for safety monitoring/response and local data archiving/evaluation. A graphic of the architecture intended is included at the close of this worksheet. Each beam line control consists of a primary station for operational monitoring and control feedback, supported by three sub-control stations: injector/LEBT, RFQ/DTL, and HEBT. Common to the two systems is the safety interlock logic and status display, and a diagnostic/evaluation station and storage system. This configuration will provide autonomous control in all phases - installation, test, commissioning and preliminary operation. During full facility operation each accelerator station will serve as a control pass-through to the master or central computer control.

Each of the nine computer stations for instrumentation monitoring and control is costed similarly. Computer hardware and displays, operating and station software, network equipment and protocol software and station-specific items, such as signal processing crates, safety logic and displays, parameter evaluation and presentation software are estimated from vendor-supplied catalogs of like-type items. EPICS has been assumed to be the operational control and processing software; license supplied at no charge. Labor for software development is assumed to be a mix of laboratory and vendor-supplied personnel. Effort in system design and planning, logic development, sensor calibration and installation procedures are incorporated in the first accelerator, scaled with the estimated number of channels to be processed. Duplicated software development and calibration tasks for the second accelerator are assumed to 'learn' from the first, and thus a 50% gain in those efforts has been included.

Spares requirements are predicated on the probability of failure and the criticality of the component. Specific note is made of the diagnostic station computer hardware which is intentionally configured as a reserve for any substation.

C. Detailed WBS and Cost Listing (without AFI included):

Subsystem	Purchased Material	Industrial Engineering	Institutional Engineering
Castor Accelerator Control Station	88.3	1,105.8	34.2
Pollux Accelerator Control Station	88.3	552.9	17.1
Castor Injector/LEBT Substation	49.4	221.4	6.8
Pollux Injector/LEBT Substation	49.4	110.7	3.4
Castor RFQ/DTL Substation	106.1	885.6	27.4
Pollux RFQ/DTL Substation	106.1	442.8	13.7
Castor HEBT Substation	87.2	664.2	20.5
Pollux HEBT Substation	87.2	332.1	10.3
Castor/Pollux Evaluation/Backup Substation	20.5	265.4	8.2
Total: Castor Accelerator	351.5	3,142.3	97.2
Total: Pollux Accelerator	331.0	1,438.5	44.5

D. Costing Rationale:

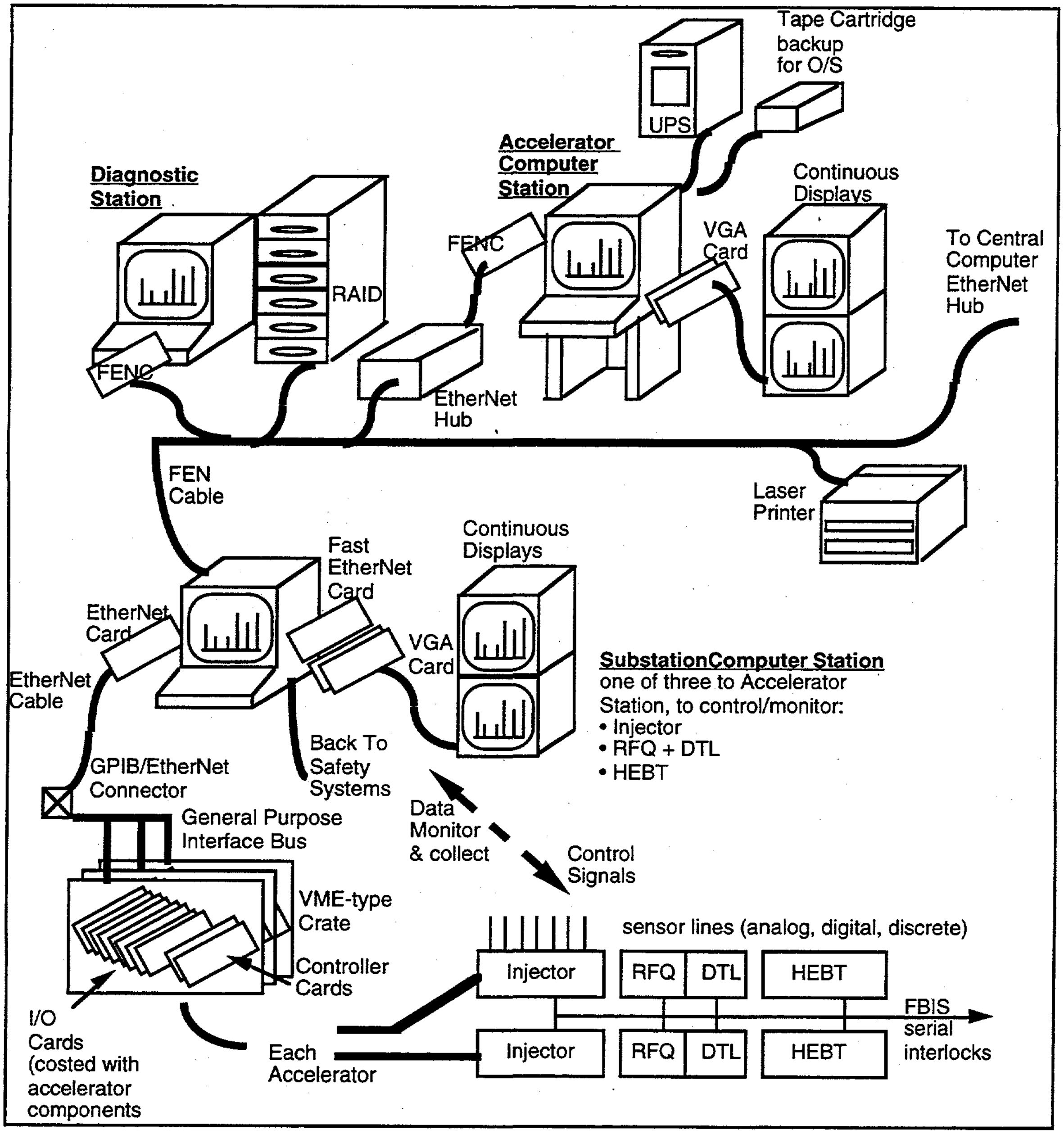
The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering control systems on other complex physics problems was used to extrapolate the labor estimates. Examples of these programs are:

- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.
- *Relativistic Heavy Ion Collider - RHIC*: a collider program where Northrop Grumman was selected as the manufacturer of the long superconducting main dipole magnets.
- *Compact Infra Red Free Electron Laser - CIRFEL*: a program where Northrop Grumman has developed a compact FEL for industrial and university use.

To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

D. Proposed Architecture:



WORKSHEET
WBS 4.2.7 Accelerator Support Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	2,286	--	800	3,086	--	--	--	--	--

Units: Kilo ICF

B. Task Description:

This task is focused on providing the necessary labor provide support covering the host of equipment racks that connect the accelerating equipment (power supplies, control cards, diagnostics, and instrumentation) to the appropriate system components. This effort is tracked independent of the individual accelerating components because the correct architecture will span all accelerating components. The exception to this, is the hardware necessary to house the connections. The estimate of these resources is contained in the miscellaneous hardware section of the accelerating component estimates (WBS 4.2.3.X.X and 4.2.4.X.X).

C. Detailed WBS Listing:

None used in the preparation of this estimate

D. Costing Rationale:

The labor estimate was developed from Northrop Grumman experience on other similar programs.

Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

Considering the type and quantity of accelerating components in this design a level load of two electrical engineers over the entire span of the program starting at the close of preliminary design is required. These are costed at the standard engineering rate of 100 ICF per man hour, 147 man-hours per man month, and an 8% fee.

WORKSHEET
WBS 4.3.1 Accelerator #1 (Castor) Installation and Checkout

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	20,715	3,036	1,499	8,909	34,159

Units: Kilo ICF

B. Description:

This account contains a summary estimate for the installation and checkout of the first accelerator equipment at the IFMIF site. A baseline assumption for this estimate is that the individual accelerating components are functionally checkout at the equipment vendor before shipment to the IFMIF site.

C. Detailed WBS Listing:

This element is comprised of the following lower level estimates which are detailed on separate worksheets:

1.	0.	0.	0.	Injector system
2.	0.	0.	0.	RFQ system
3.	0.	0.	0.	DTL Tank#1 system
4.	0.	0.	0.	DTL Tanks #2-#8 system
5.	0.	0.	0.	HEBT systems ("Abel", "Baker", and "Charlie")
6.	0.	0.	0.	RF power system
7.	0.	0.	0.	Beam Dumps
	1.	0.	0.	Moveable Beam Dump
	2.	0.	0.	Fixed Beam Dump
8.	0.	0.	0.	Full Power Acceptance Test (125 mA)

D. Costing Rationale:

See lower level detail sheets

Type of Estimate: Bottoms up
Allowance for Indeterminates: 35%

E. Detailed Costing:

See lower level detail sheets

WORKSHEET
WBS 4.3.1.1 Injector System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	765	85	54	316	1,220

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to begin unpacking the injector equipment (including the RF power supply) at the site, and finish with its complete installation, assembly and checkout. This task assumes the accelerator tunnel construction is completed and the room is ready for equipment installation.

The installation sequence begins with two parallel efforts, one focused on installing the ion source, the other focused on installing the necessary drive power for the source. Both activities are working toward a point where the source operation (with H2+, at modest pulsed current ~50 mA) can be verified. A major portion of this effort is spent on integrating the ion source/RF subsystems with the accelerator control system. After stable beam is extracted from the source, the low energy beam transport will be installed and beam will be transmitted through it. The operational characteristics of the injector will then be investigated and system performance optimized. The transmitted beam will range from low duty factor modest current (tens of mA) to CW with full current.

Preliminary estimates of the AC power requirements for the source are 0.058 MWe (including magnet power supplies). Based on recent Northrop Grumman experience on the Contraband Detector System program (a very similar source), this operational level should be reached within the first month. Once established, till the end of the testing, the injector should be operated as much as possible to build an operability/availability database.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the injector system is based upon Northrop Grumman experience in commissioning similar in systems.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor estimates are from experience on similar programs. This experience dictated a certain type of team would be needed to perform the activities. The team is led by an engineer reporting to project management, with the balance of the team comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The injector installation and checkout is scheduled to extend over three quarters (9 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2	Quarter 3
Engineers	1	1	1
Technicians	5	5	5
Craft labor	5	3	3

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the source are 0.058 MWe (including magnet power supplies). Experience indicates this operational level should be reached within the first month. From there on, till the end of the testing, the injector should be operated as much as possible to build an availability database. Over a quarter this turns out to be:

40hrs/week X 12weeks/quarter X 0.058 MWe= 27.84 MWehr/quarter

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.1.2 RFQ System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	741	63	26	290	1,120

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to begin with unpacking the RFQ equipment at the site, eventually ending with its complete installation, assembly and checkout. This task assumes that the injector testing is complete and its operation has been characterized. Further the accelerator tunnel construction is completed and the room is ready for equipment installation.

The first step in the RFQ installation process is the remove all the shipping bracing from the accelerating cavity. This is followed by an alignment check prior to physical installation of the RFQ on its mounts in the tunnel. Next, the connection to the LEBT is completed and accelerator alignment is once again checked. Once the RFQ is in place, all the exterior cooling, vacuum, instrumentation, and RF feed hook-up will be connected. In parallel with the RFQ installation work a separate team of personnel will focus on the installation of the three RF power stations that will supply power to the RFQ. The RF activity will interface with the accelerator at the RF window on the RFQ structure. [Note: the estimate covering the RF activities is included in WBS 4.3.1.6 "RF Power Systems", but a discussion of the activities is included for clarity.]

After installation of the RFQ and power stations are complete, the RFQ requires conditioning before beam can be transmitted. Conditioning is accomplished by first pulsing the RF power system into the cavity at increasing levels of power until the cavity is capable of accepting full power. After which the cavity will be subjected to CW power operation, still with no transmitted beam, until it reaches a vacuum equilibrium. The conditioning process will take approximately two weeks to reach CW operation and to sufficiently prepare the structure for beam.

Next, the injector will be run with H2+ at low duty factor/low current as in the initial injector tests. Transmission through the RFQ will be checked against predicted values and corrective action taken. After which beam duty factor and current will be increased until the maximum power limit of the portable beam diagnostic dump is reached. After a stable transmitted beam is achieved, the cavity will be adjusted to achieve peak efficiency.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the RFQ system is based upon Northrop Grumman experience in commissioning similar systems. Some of these programs are:

- *Beam Experiment Aboard Rocket - BEAR*: where Northrop Grumman delivered an Radio Frequency Quadrupole, its power supply, and the external skin for the launch device.
- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicated that a certain type of team would be needed to perform the activities. The team is comprised of an engineer leading a team of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The RFQ installation and checkout is scheduled to extend over four quarters (12 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 1	Quarter 1	Quarter 1
Engineers	1	0.75	0.5	0.25
Technicians	3	3	3	3
Craft labor	5	3	2	1

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the RFQ consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. For budgeting, 75% max power is considered over this period. This equates to:

5.772MWe X 0.75 = 4.329 MWe over 80 hrs or 346.32 MWehr

For beam testing, the RFQ will be operated at 20% duty factor (~31 mA peak current), for 50% of the period (1 week in operation, 1 week in adjustment, etc.). The additional power, over and above the injector is:

40hrs/week X 6 weeks ops/quarter X 5.772MWe = 1385 MWehr/quarter

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.1.3 DTL Tank #1 System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	676	72	30	272	1,050

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to begin unpacking the first Drift Tube Linac (DTL) equipment at the site, and finish with its complete installation, assembly and checkout. This task assumes that the injector and RFQ testing is complete and operation through these components has been characterized. Further, the accelerator tunnel construction is completed and the room is ready for equipment installation.

The first step in the DTL tank installation process is to unpack and re-align the accelerating cavity. Unlike the injector and RFQ, the DTL will be shipped with an elaborate internal brace to minimize the amount of site alignment required. After which, the physical installation of the DTL on its mounts in the tunnel can begin. Optical alignment checks will be employed to ensure proper connection between the DTL and the RFQ. Having accomplished this, all the exterior cooling, vacuum, instrumentation, and RF feed hook-ups will be connected. In parallel with the DTL installation work a separate team of personnel will focus on the installation of the RF power station that will supply power to the DTL tank. The RF activity will interface with the accelerator at the RF window on the DTL structure. [Note: the estimate covering the RF activities is included in WBS 4.3.1.6 "RF Power Systems" element, but a discussion of the activities is included for clarity.]

After installation of the DTL and its power station are complete, the DTL will enter a conditioning phase similar to the RFQ. Conditioning is accomplished by first pulsing the RF power system into the cavity, at increasing levels of power, until the cavity is capable of accepting full power. After which the cavity will be subjected to CW power operation, still with no transmitted beam, and allowed to reach vacuum equilibrium. The conditioning process will take approximately two weeks in total. The cavity is now ready for beam.

Similar to the beam line components before it, the DTL will begin by transmitting a low current pulsed beam, eventually ramping up to the current limit of the moveable beam dump (~50 kW). After a stable transmitted beam is achieved, the cavity will be adjusted to achieve peak efficiency.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the first DTL tank system is based upon Northrop Grumman experience in commissioning similar systems. Some examples are:

- *Beam Experiment Aboard Rocket - BEAR*: where Northrop Grumman delivered an Radio Frequency Quadrupole, its power supply, and the external skin for the launch device.
- *Ramped Gradient Drift Tube Linac - RGDTL:* A program where Northrop Grumman completed the design and eventually fabricated one complete accelerating tank to Los Alamos National Laboratory sepcification.
- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The DTL tank #1 installation and checkout is scheduled to extend over one quarter (3 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1
Engineers	2.1
Technicians	10
Craft labor	15

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the DTL consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. For budgeting, 75% max power is considered over this period. This equates to:

2.25 MWe X 0.75 = 1.688 MWe over 80 hrs or 135.04 MWehr

Next an estimate of the beam-on testing is required. Unlike the Injector and RFQ, the full current/energy beam discharged from this cavity cannot be handled by the beam dump. The limit for the moveable dump has been set at the CW power output of the RFQ with H2+ (~50 kW). For the increased energy, the DTL tank must be operated at low duty factor (~25%) duty factor to accelerate enough current, yet still maintain the power deposited on the beam dump. The additional power required per quarter for the DTL (assuming 1 week operation followed by 1 week adjustments) is:

40hrs/week X 6 weeks ops/quarter X [2.25 MWe X 25%] 135.0 MWehr/quarter

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.1.4 DTL Tanks #2 - #8 System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	2295	242	100	923	3,560

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to begin with unpacking the second through eighth Drift Tube Linac (DTL) tanks from their shipping frames at the site, and ending with their complete installation, assembly, and checkout. This task assumes that the injector, RFQ, and first DTL tank installation and testing is complete and beam operation through these components has been characterized and optimized. Further, this estimate assumes accelerator tunnel construction is fully completed and the room is ready for accelerator equipment installation.

The first step in the DTL tank installation and checkout process is to unpack and re-align the accelerating cavities. Unlike the injector and RFQ, the DTL tanks will be shipped with elaborate internal bracing to minimize the amount of site alignment required. After which, the physical installation of the DTL tanks on their mounts in the tunnel can begin. Optical alignment checks will be employed to ensure proper connection between the DTL tanks and the previously installed beam line components. Having accomplished structural installation, all the exterior cooling, vacuum, instrumentation, and RF feed hookups will be connected. In parallel with the DTL installation work a separate team of personnel will focus on the installation of the RF power stations for these accelerating cavities. The RF activity will interface with the accelerator at the RF window on the DTL tanks. [Note: the estimate covering the RF activities is not included in this WBS element, but rather detailed in WBS 4.3.6 RF Power System.]

After complete hook-up of the DTL tanks cavity conditioning activities can commence. Conditioning is accomplished by slowly ramping the RF power transmitted to the cavity from low duty factor/low power until the cavity can accept full power in a CW mode. Having reached CW power levels, still with no transmitted beam, the cavity is allowed to reach equilibrium. The whole conditioning process will take approximately two weeks to reach CW operation. Once the cavity has been conditioned it is ready for beam transmission.

Similar to the beam line components before it, DTL tanks 2-8 will begin by transmitting low current pulsed beam, eventually moving up to the current limit of the moveable beam dump. After a stable transmitted beam is achieved, each cavity will be adjusted to achieve peak efficiency. Unlike the components before it, tanks 2-8 will be tested as a unit.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the DTL tanks 2-8 accelerating system is based upon Northrop Grumman experience in commissioning similar systems. Some examples are:

- *Ramped Gradient Drift Tube Linac - RGDTL:* A program where Northrop Grumman completed the design and eventually fabricated one complete accelerating tank to Los Alamos National Laboratory sepcification.
- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The DTL tank 2-8 system installation and checkout is scheduled to extend over two quarters (6 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2
Engineers	3.5	3.5
Technicians	18	18
Craft labor	30	30

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the DTL tank 2-8 system consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. For budgeting, 75% max power is considered over this period. This equates to:

10.554 MWe X 0.75 = 7.916 MWe over 80 hrs or 633.24 MWehr

Next an estimate of the beam-on testing is required. Unlike the Injector and RFQ system the full current/energy beam discharged from this cavity cannot be handled by the beam dump. The limit for the moveable dump has been set at the CW power output of the RFQ with H2+ (~50 kW). For the increased energy out of tank #8, the accelerator must be operated at less than 10% (~12.5 mA peak current) duty factor to maintain the power deposited on the beam dump. The additional power required per quarter for the DTL tank system (assuming 1 week operation followed by 1 week of adjustments) is:

40hrs/week X 12 weeks ops X [10.554 MWe X 10%] = 506.6 MWehr

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.1.5 High Energy Beam Transport (HEBT) Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	3,584	398	166	1452	5,600

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to complete the installation, assembly, and checkout of the three HEBT lines for the first accelerator at the IFMIF site. This task assumes that the accelerator installation and testing is complete and beam operation through these components has been characterized and optimized. Further, this estimate assumes turning room construction is fully completed and the hall is ready for HEBT equipment installation. Lastly, this estimate assumes the fixed diagnostic dump is installed, checked out, and ready for use.

The installation process begins by assembling the ~60 meters of beam tube from the accelerator to the fixed diagnostic beam dump, blanking off the other two branches to the lithium targets. Interspersed in each beam pipe are a approximately 13 RF cavities (for bunching and energy dispersion) which need to be positioned correctly in the turning room to mate up with structural supports as well as the drive lines from the RF power station. Next to be installed are the various vacuum pumps distributed among the transport line. After completion of this activity, the beam tube and RF cavities can be pumped to operational levels, and RF cavity conditioning can commence. Similar to the accelerator cavities the buncher and energy dispersion cavities will be subjected to a series of varying RF power levels from low power pulsed to full power CW levels. When the cavities can sustain full power RF, they are ready to be used to transport beam to the diagnostic dump.

The next step in the process is the installation of the 25 magnets around the beam pipe, with all the associated connections to control & monitoring, cooling, and power supplies. Once completed the HEBT is ready for beam.

After testing/optimization is complete on the beam line to the diagnostic dump, efforts will shift toward installing the remaining equipment for the transport sections to the lithium targets. The steps employed will be the same as used to install the transport line to the diagnostic dump (first beam tube/cavity/vacuum installation, followed by conditioning, and magnet installation). When completed the HEBT is ready for testing with beam into any of the targets.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the HEBT system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The HEBT system installation and checkout is scheduled to extend over four quarters (12 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Engineers	2.75	2.75	2.75	2.75
Technicians	15	15	15	15
Craft labor	25	25	25	25

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the HEBT system consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. This equates to:

1.44 MWe X 3 beam lines = 4.32 MWe over 80 hrs or 345.6 MWehr

Next an estimate of the beam-on testing is required. This is comprised of 2 weeks operation at 2.5% duty factor as well as 1 week at full power. The additional HEBT power required over the needs of the accelerator is:

120 hrs X [1.44 MWe] = 172.8 MWehr

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.1.6 RF Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	6,301	571	286	2,505	9,663

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to complete the installation, assembly, and checkout of the RF power system for the first accelerator and HEBT system at the IFMIF site. This task assumes each RF station has been pre-assembled and tested by the RF prime subcontractor, then disassembled and shipped to the IFMIF site. Further, this estimate assumes RF hall is fully completed and is ready for equipment installation.

The installation process will be sequenced to provide fully operational power stations to support the accelerating cavity efforts. One exception however will be the power station for the HEBT. This power station is from the development program and will be transferred to the IFMIF site and put into operation as soon as possible to continue to build an operational database on the RF equipment as well as provide an excellent platform for operator training.

The steps in the installation process begin with the unpacking of the equipment. The equipment forming the switchgear, transformer/rectifier and crowbar subsystems will be installed and connected to the electric feeds from the facility substation and tested. Next, the balance of the system equipment (with the exception of the RF transport between the circulator output and the accelerating cavities will be installed and checked out. In parallel with this work, the station control and monitoring subsystem will be installed and checked out. Having completed this phase of the buildup the station can be commissioned and operated into a dummy load, with a local RF source, to begin to condition the station (typically requiring 72 hours constant operation). Commencing somewhere in the middle of this activity will be another effort to install the ~20 meters of RF transport line from the accelerating cavity in the tunnels up to the RF power station on the floor above the tunnel. Once the transport connection is made to the power station the entire RF power station can be tested into the accelerating structure. The performance of station will be assessed against established values and any necessary optimization performed.

This process is repeated for each station. In parallel with the station installation and checkout the global RF source will be installed. Once operational this source will replace the local source used for station commissioning.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the RF power system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The RF Power system installation and checkout is scheduled to extend over six quarters (18 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6
Engineers	3	3	3	3	3	3
Technicians	15	15	15	15	15	15
Craft labor	20	20	20	20	20	20

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the RF power system consist of three parts: , test bed operation, new station conditioning, and beam operation. The estimates of the power required for beam operation are tracked against each accelerating component WBS (4.3.1.1 "Injector Systems" through 4.3.1.5 " DTL tanks #2-#8 System"). Leaving only the conditioning and test bed operational period for inclusion in this estimate. Each power station will require ~1.5 MWe for max. power conditioning, therefore:

$$1.5 \text{ MWe} \times 12 \text{ stations} \times 72 \text{ hours} = 1{,}296 \text{ MWehr}$$

Operating the HEBT power station at representative levels until required for HEBT commissioning equates to 8760 hours of operation into the dummy load or:

$$8760 \text{ hrs} \times [1.5 \text{ MWe}] = 13{,}140 \text{ MWehr}$$

The electric rate used in calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.1.7 Beam Dump Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	1,511	176	75	690	2,452

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to complete the installation, assembly, and checkout of the two diagnostic beam dumps (fixed and moveable) at the IFMIF site. This task assumes that both beam dumps have been pre-assembled and tested, then disassembled and shipped to the IFMIF site.

The moveable dump will be capable of accepting up to 13 kW/cm^2 of deposited power. The fixed dump will be designed to accept 125 kW (2.5% of full energy beam) of deposited power. Both designs are derivatives of the FMIT design which contains a slanted beam face covered in ceramic tiles backed by a water tube thermal control system. The fixed dump will include provisions for IR video of the target face used in beam diagnostics.

The fixed dump will be installed at a later period in the program. It will require approximately six months in total for each diagnostic dump to accomplish the assembly and installation as well as the connection of the vacuum, cooling, and instrumentation hook-ups.

C. Detailed WBS Listing: (including apportioned AFI)

	Total
4.3.1.7.1: Moveable Beam Dump	710
4.3.1.7.2: Fixed Beam Dump	1,742

D. Costing Rationale:

The size and composition of the team required to install and commission the diagnostic dump systems is based upon Northrop Grumman experience in commissioning similar devices.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate was developed by examining the design requirements, and preliminary configuration of the two dumps, then generating labor estimates to support the installation at the site. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The installation and checkout of each diagnostic dump is scheduled to extend over 2 quarters (6 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Moveable Beam Dump:

Skill type	Quarter 1	Quarter 2
Engineers	1.5	1.5
Technicians	3	3
Craft labor	5	5

Fixed Beam Dump:

Skill type	Quarter 1	Quarter 2
Engineers	5	5
Technicians	8	8
Craft labor	5	5

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

WORKSHEET
WBS 4.3.1.8 Full Power Acceptance Test (125 mA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	4,074	1,429	762	2,193	8,458

Units: Kilo ICF

B. Description:

This estimate covers the resources necessary to operate the accelerator system, at varying power levels, until stable operation at full power and current is achieved. This estimate details the labor and electricity required to reach full power operation. The schedule for the entire procedure, from initial low current operation, through full current deuterium operation is scheduled to extend over six months. This period of time will allow ample time to address any difficulties encountered during the commissioning process.

C. Detailed WBS Listing:

No lower definition exists

D. Costing Rationale:

The size and composition of the team required to install and commission the diagnostic dump systems is based upon Northrop Grumman experience in commissioning similar devices.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The costs for this activity are broken into two parts: electrical usage and support labor.

Electricity: [a rate of 0.1 kICF/kWehr was used in the cost calculation]
This activity is scheduled to cover 6 months and ramp from full current 2.5% duty cycle H2+ operation to CW deuterium operation. The estimate includes 50 % operations (@2.5% duty) the first month, full operation for the second through forth month (@2.5% duty), transitioning to CW operation for the last two months. All of this will be done on a 5-day, 40 hr work week. This yields:

1st month:	19.30 MW X 0.025X 20 hrs/week X 4 weeks =	39 MWehrs
2nd month:	19.30 MW X 0.025X 40 hrs/week X 4 weeks =	77 MWehrs
3rd month:	19.30 MW X 0.025X 40 hrs/week X 4 weeks =	77 MWehrs
	First Quarter Total:	193 MWehrs
4th month:	19.30 MW X 0.025X 40 hrs/week X 4 weeks =	77 MWehrs
5th month:	19.30 MW X 40 hrs/week X 4 weeks =	3088 MWehrs
6th month:	19.30 MW X 40 hrs/week X 4 weeks =	3088 MWehrs
	Second Quarter Total:	6253 MWehrs
	TOTAL FOR EFFORT:	6446 MWehrs

Assuming the baseline electric rate is 0.1 ICF/kWehr yields a cost for this of:
(6446e3 kWehr x 0.1 ICF/kWehr)/1e3 ICF/kilo ICF = 645 kilo ICF

Associated Labor:

Projections of the staff required to support commissioning operations were obtained from Northrop Grumman experience commissioning other beam lines. Some of these projects are:

The size and composition of the team required to support the activities were broken into three major categories: institutional engineering, industrial engineering, and technician. After examining the major tasks required the respective full time equivalent personnel in these categories were calculated to be 8 institutional engineers, 15 industrial engineers, and 45 technicians.

WORKSHEET
WBS 4.3.1.9 Accelerator System Control

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	767.7	--	--	268.3	1,036

Units: Kilo ICF

B. Task Description:

On-site materials/labor encompasses that effort needed for installation, integration and testing of computer, data transfer and instrumentation signal processing equipment. Hardware installation for the accelerator station, three substations and a diagnostic station includes: computer processors, displays, data storage and interface equipment; signal query and processing racks; network bus, router and interfaces; instrumentation cabling, trays and other furniture. Software installation includes station operating system, base applications, network protocols, developed control logic (EPICS routines) and sensor calibration databases.

By far the largest expenditure of effort will be signal calibration of the individual sensor outputs and the establishment of a real-time database for such. Integration and testing of sensor signals for computer monitoring and evaluation, feedback control logic and signal processing, safety interlock parameters and logic will also be a significant on-site effort.

C. Detailed WBS and Cost Listing (without AFI included):

Subsystem	Cost (kICF)
Accelerator Control Station	28.9
Injector/LEBT Substation	91.6
RFQ/DTL Substation	366.5
HEBT Substation	274.9
Castor/Pollux Evaluation/Backup Substation	5.9
Total:	767.7

D. Costing Rationale:

The estimate is comprised of labor only. Northrop Grumman's past experience commissioning control systems on other complex physics programs was used to extrapolate the labor estimates. Examples of these programs are:

- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.
- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.
- *Compact Infra Red Free Electron Laser - CIRFEL:* a program where Northrop Grumman has developed a compact FEL for industrial and university use.

Allowance for Indeterminates: 35% based on technical risk

WORKSHEET
WBS 4.3.2 Accelerator #2 (Pollux) Installation and Checkout

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	17,556	2,642	1,546	7,611	29,355

Units: Kilo ICF

B. Description:

This account contains a summary estimate for the installation and checkout of the second accelerator equipment at the IFMIF site. As with the first accelerator, a baseline assumption for this estimate is that the individual accelerating components are functionally checkout at the equipment vendor before shipment to the IFMIF site. Further, the labor estimates contained herein reflect savings from the experience with the first accelerator (WBS 4.3.1).

C. Detailed WBS Listing:

This element is comprised of the following lower level estimates which are detailed on separate worksheets:

2. 0. 0. 0. 0.	Accelerator #2 (Pollux) Installation and Checkout
1. 0. 0. 0.	Injector system
2. 0. 0. 0.	RFQ system
3. 0. 0. 0.	DTL Tank#1 system
4. 0. 0. 0.	DTL Tanks #2-#8 system
5. 0. 0. 0.	HEBT- systems ("Abel", "Baker", and "Charlie")
6. 0. 0. 0.	RF power system
7. 0. 0. 0.	Full Power Acceptance Testing (250 mA)

D. Costing Rationale:

See lower level detail sheets

Type of Estimate: Bottoms up
Allowance for Indeterminates: 35%

E. Detailed Costing:

See lower level detail sheets

WORKSHEET
WBS 4.3.2.1 Injector System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	745.5	83	53	308.5	1,190

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to unpack the injector equipment (including its RF power supply) at the site, complete its installation, assembly and checkout, then perform an acceptance test on it to ensure operation within specified parameters. This task assumes the accelerator tunnel construction is completed and the room is ready for equipment installation.

The installation sequence begins with two parallel efforts, one focused on installing the ion source, the other focused on installing the necessary drive power for the source. Both activities are working toward a point where the source operation (with H2+, at modest pulsed current ~50 mA) can be verified. A major portion of this effort is spent on integrating the ion source/RF subsystems with the accelerator control system. After stable beam is extracted from the source, the low energy beam transport will be installed and beam will be transmitted through it. The operational characteristics of the injector will then be investigated and system performance optimized. The transmitted beam will range from low duty factor modest current (tens of mA) to CW with full current.

Preliminary estimates of the AC power requirements for the source are 0.058 MWe (including magnet power supplies). Based on recent Northrop Grumman experience on the Contraband Detector System program (a very similar source), this operational level should be reached within the first month. Once established, till the end of the testing, the injector should be operated as much as possible to build an operability/availability database.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the injector system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor estimates are from experience on similar programs. This experience dictated a certain type of team would be needed to perform the activities. The team is led by an engineer reporting to project management, with the balance of the team comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The injector installation and checkout is scheduled to extend over three quarters (9 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2	Quarter 3
Engineers	1	1	1
Technicians	4.5	4.5	4.5
Craft labor	5	3	3

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the source are 0.058 MWe (including magnet power supplies). Experience indicates this operational level should be reached within the first month. From there on, till the end of the testing, the injector should be operated as much as possible to build an availability database. Over a quarter this turns out to be:

40hrs/week X 12weeks/quarter X 0.058 MWe= 27.84 MWehr/quarter

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.2.2 RFQ System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	706	63	38	283	1,090

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to begin with unpacking the RFQ equipment at the site, eventually ending with its complete installation, assembly and checkout. This task assumes that the injector testing is complete and its operation has been characterized. Further the accelerator tunnel construction is completed and the room is ready for equipment installation.

The first step in the RFQ installation process is the remove all the shipping bracing from the accelerating cavity. This is followed by an alignment check prior to physical installation of the RFQ on its mounts in the tunnel. Next the connection to the LEBT is completed and accelerator alignment is once again checked. Once the RFQ is in place, all the exterior cooling, vacuum, instrumentation, and RF feed hook-up will be connected. In parallel with the RFQ installation work a separate team of personnel will focus on the installation of the three RF power stations that will supply power to the RFQ. The RF activity will interface with the accelerator at the RF window on the RFQ structure. [Note: the estimate covering the RF activities is included in WBS 4.3.1.6 "RF Power Systems", but a discussion of the activities is included for clarity.]

After installation of the RFQ and power stations are complete, the RFQ requires conditioning before beam can be transmitted. Conditioning is accomplished by first pulsing the RF power system into the cavity at increasing levels of power until the cavity is capable of accepting full power. After which the cavity will be subjected to CW power operation, still with no transmitted beam, until it reaches a vacuum equilibrium. The conditioning process will take approximately two weeks to reach CW operation and to sufficiently prepare the structure for the beam.

Next, the injector will be run with H2+ at low duty factor/low current as in the initial injector tests. Transmission through the RFQ will be checked against predicted values and corrective action taken. After which beam duty factor and current will be increased until the maximum power limit of the portable beam diagnostic dump is reached. After a stable transmitted beam is achieved, the cavity will be adjusted to achieve peak efficiency.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the RFQ system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicated that a certain type of team would be needed to perform the activities. The team is comprised of an engineer leading a team of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The RFQ installation and checkout is scheduled to extend over four quarters (12 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 1	Quarter 1	Quarter 1
Engineers	1	0.75	0.5	0.25
Technicians	2.75	2.75	2.75	2.75
Craft labor	5	3	2	1

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the RFQ consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. For budgeting, 75% max power is considered over this period. This equates to:

5.772MWe X 0.75 = 4.329 MWe over 80 hrs or 346.32 MWehr

For beam testing, the RFQ will be operated at 20% duty factor (~31 mA peak current), for 50% of the period (1 week in operation, 1 week in adjustment, etc.). The additional power, over and above the injector is:

40hrs/week X 6 weeks ops/quarter X 5.772MWe = 1385 MWehr/quarter

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.2.3 DTL Tank #1 System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	631	67	43	259	1,000

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to begin unpacking the first Drift Tube Linac (DTL) equipment at the site, and finish with its complete installation, assembly and checkout. This task assumes that the injector and RFQ testing is complete and operation through these components has been characterized. Further, the accelerator tunnel construction is completed and the room is ready for equipment installation.

The first step in the DTL tank installation process is to unpack and re-align the accelerating cavity. Unlike the injector and RFQ, the DTL will be shipped with an elaborate internal brace to minimize the amount of site alignment required. After which, the physical installation of the DTL on its mounts in the tunnel can begin. Optical alignment checks will be employed to ensure proper connection between the DTL and the RFQ. Having accomplished this, all the exterior cooling, vacuum, instrumentation, and RF feed hook-ups will be connected. In parallel with the DTL installation work a separate team of personnel will focus on the installation of the RF power station that will supply power to the DTL tank. The RF activity will interface with the accelerator at the RF window on the DTL structure. [Note: the estimate covering the RF activities is included in WBS 4.3.2.6 “RF Power Systems” element, but a discussion of the activities is included for clarity.]

After installation of the DTL and its power station are complete, the DTL will enter a conditioning phase similar to the RFQ. Conditioning is accomplished by first pulsing the RF power system into the cavity, at increasing levels of power, until the cavity is capable of accepting full power. After which the cavity will be subjected to CW power operation, still with no transmitted beam, and allowed to reach vacuum equilibrium. The conditioning process will take approximately two weeks in total. The cavity is now ready for beam.

Similar to the beam line components before it, the DTL will begin by transmitting a low current pulsed beam, eventually ramping up to the current limit of the moveable beam dump (~50 kW). After a stable transmitted beam is achieved, the cavity will be adjusted to achieve peak efficiency.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the first DTL tank system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The DTL tank #1 installation and checkout is scheduled to extend over one quarter (3 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1
Engineers	2.1
Technicians	9
Craft labor	13

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the DTL consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. For budgeting, 75% max power is considered over this period. This equates to:

2.25 MWe X 0.75 = 1.688 MWe over 80 hrs or 135.04 MWehr

Next an estimate of the beam-on testing is required. Unlike the Injector and RFQ, the full current/energy beam discharged from this cavity cannot be handled by the beam dump. The limit for the moveable dump has been set at the CW power output of the RFQ with H_2^+ (~50 kW). For the increased energy, the DTL tank must be operated at low duty factor (~25%) duty factor to accelerate enough current, yet still maintain the power deposited on the beam dump. The additional power required per quarter for the DTL (assuming 1 week operation followed by 1 week adjustments) is:

40hrs/week X 6 weeks ops/quarter X [2.25 MWe X 25%] 135.0 MWehr/quarter

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.2.4 DTL Tanks #2 - #8 System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	2,142	225	144	879	3,390

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to begin with unpacking the second through eighth Drift Tube Linac (DTL) tanks from their shipping frames at the site, and ending with their complete installation, assembly, and checkout. This task assumes that the injector, RFQ, and first DTL tank installation and testing is complete and beam operation through these components has been characterized and optimized. Further, this estimate assumes accelerator tunnel construction is fully completed and the room is ready for accelerator equipment installation.

The first step in the DTL tank installation and checkout process is to unpack and re-align the accelerating cavities. Unlike the injector and RFQ, the DTL tanks will be shipped with elaborate internal bracing to minimize the amount of site alignment required. After which, the physical installation of the DTL tanks on their mounts in the tunnel can begin. Optical alignment checks will be employed to ensure proper connection between the DTL tanks and the previously installed beam line components. Having accomplished structural installation, all the exterior cooling, vacuum, instrumentation, and RF feed hookups will be connected. In parallel with the DTL installation work a separate team of personnel will focus on the installation of the RF power stations for these accelerating cavities. The RF activity will interface with the accelerator at the RF window on the DTL tanks. [Note: the estimate covering the RF activities is not included in this WBS element, but rather detailed in WBS 4.3.6 RF Power System.]

After complete hook-up of the DTL tanks cavity conditioning activities can commence. Conditioning is accomplished by slowly ramping the RF power transmitted to the cavity from low duty factor/low power until the cavity can accept full power in a CW mode. Having reached CW power levels, still with no transmitted beam, the cavity is allowed to reach equilibrium. The whole conditioning process will take approximately two weeks to reach CW operation. Once the cavity has been conditioned it is ready for beam transmission.

Similar to the beam line components before it, DTL tanks 2-8 will begin by transmitting low current pulsed beam, eventually moving up to the current limit of the moveable beam dump. After a stable transmitted beam is achieved, each cavity will be adjusted to achieve peak efficiency. Unlike the components before it, tanks 2-8 will be tested as a unit.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the DTL tanks 2-8 accelerating system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Factored from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The DTL tank 2-8 system installation and checkout is scheduled to extend over two quarters (6 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2
Engineers	3.5	3.5
Technicians	16	16
Craft labor	26	26

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the DTL tank 2-8 system consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. For budgeting, 75% max power is considered over this period. This equates to:

10.554 MWe X 0.75 = 7.916 MWe over 80 hrs or 633.24 MWehr

Next an estimate of the beam-on testing is required. Unlike the Injector and RFQ system the full current/energy beam discharged from this cavity cannot be handled by the beam dump. The limit for the moveable dump has been set at the CW power output of the RFQ with H2+ (~50 kW). For the increased energy out of tank #8, the accelerator must be operated at less than 10% (~12.5 mA peak current) duty factor to maintain the power deposited on the beam dump. The additional power required per quarter for the DTL tank system (assuming 1 week operation followed by 1 week of adjustments) is:

40hrs/week X 12 weeks ops X [10.554 MWe X 10%] = 506.6 MWehr
The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.2.5 High Energy Beam Transport (HEBT) Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	3,167	346	220	1,307	5,040

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to complete the installation, assembly, and checkout of the three HEBT lines for the second accelerator. This task assumes that the accelerator installation and testing is complete and beam operation through these components has been characterized and optimized. Further, this estimate assumes turning room construction is fully completed and the hall is ready for HEBT equipment installation. Lastly, this estimate assumes the fixed diagnostic dump is installed, checked out, and ready for use.

The installation process begins by assembling the ~60 meters of beam tube from the accelerator to the fixed diagnostic beam dump, blanking off the other two branches to the lithium targets. Interspersed in the beam pipe are a total of 13 RF cavities (for bunching and energy dispersion) which need to be positioned correctly in the turning room to mate up with structural supports as well as the drive lines from the RF power station. Next to be installed are the various vacuum pumps distributed among the transport line. After completion of this activity, the beam tube and RF cavities can be pumped to operational levels, and RF cavity conditioning can commence. Similar to the accelerator cavities the buncher and energy dispersion cavities will be subjected to a series of varying RF power levels from low power pulsed to full power CW levels. When the cavities can sustain full power RF, they are ready to be used to transport beam to the diagnostic dump.

The next step in the process is the installation of the 25 magnets around the beam pipe, with all the associated connections to control & monitoring, cooling, and power supplies. Once completed the HEBT is ready for beam.

After testing/optimization is complete on the beam line to the diagnostic dump, efforts will shift toward installing the remaining equipment for the transport sections to the lithium targets. The steps employed will be the same as used to install the transport line to the diagnostic dump (first beam tube/cavity/vacuum installation, followed by conditioning, and magnet installation). When completed the HEBT is ready for testing with beam into any of the targets.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the HEBT system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The HEBT system installation and checkout is scheduled to extend over four quarters (12 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Engineers	2.75	2.75	2.75	2.75
Technicians	14	14	14	14
Craft labor	20	20	20	20

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the HEBT system consist of two parts: cavity conditioning and beam operation. The conditioning period starts with low power pulsed operation and continues by lengthening both pulse duration and increasing power levels until CW full power operation is achieved. A conservative estimate of the time required to get the cavity conditioned is 2 weeks. This equates to:

1.44 MWe X 3 beam lines = 4.32 MWe over 80 hrs or 345.6 MWehr

Next an estimate of the beam-on testing is required. This is comprised of 2 weeks operation at 2.5% duty factor as well as 1 week at full power. The additional HEBT power required over the needs of the accelerator is:

120 hrs X [1.44 MWe] = 172.8 MWehr

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.2.6 RF Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	5,239	429	286	2,115	8,159

Units: Kilo ICF

B. Description:

This WBS element contains estimates of the necessary resources to complete the installation, assembly, and checkout of the RF power system for the first accelerator and HEBT system at the IFMIF site. This task assumes each RF station has been pre-assembled and tested by the RF prime subcontractor, then disassembled and shipped to the IFMIF site. Further, this estimate assumes RF hall is fully completed and is ready for equipment installation.

The installation process will be sequenced to provide fully operational power stations to support the accelerating cavity efforts.

The steps in the installation process begin with unpacking the equipment. The equipment forming the switchgear, transformer/rectifier and crowbar subsystems will be installed and connected to the electric feeds from the facility substation and tested. Next, the balance of the system equipment (with the exception of the RF transport between the circulator output and the accelerating cavities will be installed and checked out. In parallel with this work, the station control and monitoring subsystem will be installed and checked out. Having completed this phase of the buildup the station can be commissioned and operated into a dummy load, with a local RF source, to begin to condition the station (typically requiring 72 hours constant operation). Commencing somewhere in the middle of this activity will be another effort to install the ~20 meters of RF transport line from the accelerating cavity in the tunnels up to the RF power station on the floor above the tunnel. Once the transport connection is made to the power station the entire RF power station can be tested into the accelerating structure. The performance of station will be assessed against established values and any necessary optimization performed.

This process is repeated for each station. In parallel with the station installation and checkout the global RF source will be installed. Once operational this source will replace the local source used for station commissioning.

C. Detailed WBS Listing:

No lower level WBS elements

D. Costing Rationale:

The size and composition of the team required to install and commission the RF power system is based upon Northrop Grumman experience in commissioning similar systems.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The estimate contains two major portions: labor and electricity. The labor calculation was developed using experience from similar programs which indicates that a certain type of team would be needed to perform these activities. The team is led by engineers reporting to program management, and comprised of skilled technicians and craft laborers (riggers, fitters, electricians, plumbers, etc.). The RF Power system installation and checkout is scheduled to extend over six quarters (18 months) and will include the following full time equivalent number of personnel working on the effort from each area:

Skill type	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6
Engineers	3	3	3	3	3	3
Technicians	15	15	15	15	15	15
Craft labor	20	20	20	20	20	20

The respective rates for these categories of labor are:

engineering	100 ICF/man-hour
technician	80 ICF/man-hour
craft	25 ICF/man-hour

The costs were compiled using a 15% premium to cover short term placement of individuals to the IFMIF site. Further, the costs were complied using 147 man-hours/ man-month with an 8% fee added.

Preliminary estimates of the AC power requirements for the HEBT system consist of three parts: , test bed operation, new station conditioning, and beam operation. The estimates of the power required for beam operation are tracked against each accelerating component WBS (4.3.1.1 "Injector Systems" through 4.3.1.5 " DTL tanks #2-#8 System"). Leaving only the conditioning and test bed operational period for inclusion in this estimate. Each power station will require ~1.5 MWe for max. power conditioning, therefore:

1.5 MWe x 12 stations x 72 hours = 1,296 MWehr

Operating the HEBT power station at representative levels until required for HEBT commissioning equates to 8760 hours of operation into the dummy load or:

8760 hrs X [1.5 MWe] = 13,140 MWehr

The electric rate used in cost calculations was 0.1 ICF/kWehr.

WORKSHEET
WBS 4.3.2.7 Full Power Acceptance Test (125 mA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	4,074	1,429	762	2,193	8,458

Units: Kilo ICF

B. Description:

This estimate covers the resources necessary to operate the accelerator system, at varying power levels, until stable operation at full power and current is achieved. This estimate details the labor and electricity required to reach full power operation. The schedule for the entire procedure, from initial low current operation, through full current deuterium operation is scheduled to extend over six months. This period of time will allow ample time to address any difficulties encountered during the commissioning process.

C. Detailed WBS Listing:

No lower definition exists

D. Costing Rationale:

The size and composition of the team required to install and commission the diagnostic dump systems is based upon Northrop Grumman experience in commissioning similar devices.

Type of Estimate: Scaling from experience
Allowance for Indeterminates: 35% based on technical risk

E. Detailed Costing:

The costs for this activity are broken into two parts: electrical usage and support labor.

Electricity: [a rate of 0.1 kICF/kWehr was used in the cost calculation]
This activity is scheduled to cover 6 months and ramp from full current 2.5% duty cycle H2+ operation to CW deuterium operation. The estimate includes 50 % operations (@2.5% duty) the first month, full operation for the second through forth month (@2.5% duty), transitioning to CW operation for the last two months. All of this will be done on a 5-day, 40 hr work week. This yields:

1st month:	19.30 MW X 0.025X 20 hrs/week X 4 weeks =	39 MWehrs
2nd month:	19.30 MW X 0.025X 40 hrs/week X 4 weeks =	77 MWehrs
3rd month:	19.30 MW X 0.025X 40 hrs/week X 4 weeks =	77 MWehrs
	First Quarter Total:	193 MWehrs
4th month:	19.30 MW X 0.025X 40 hrs/week X 4 weeks =	77 MWehrs
5th month:	19.30 MW X 40 hrs/week X 4 weeks =	3088 MWehrs
6th month:	19.30 MW X 40 hrs/week X 4 weeks =	3088 MWehrs
	Second Quarter Total:	6253 MWehrs
	TOTAL FOR EFFORT:	6446 MWehrs

Assuming the baseline electric rate is 0.1 ICF/kWehr yields a cost for this of:
(6446e3 kWehr x 0.1 ICF/kWehr)/1e3 ICF/kilo ICF = 645 kilo ICF

Associated Labor:

Projections of the staff required to support commissioning operations were obtained from Northrop Grumman experience commissioning other beam lines. Some of these projects are:

The size and composition of the team required to support the activities were broken into three major categories: institutional engineering, industrial engineering, and technician. After examining the major tasks required the respective full time equivalent personnel in these categories were calculated to be 8 institutional engineers, 15 industrial engineers, and 45 technicians.

WORKSHEET
WBS 4.3.2.8 Accelerator System Control

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
--	--	--	--	--	761.8	--	--	266.2	1,028

Units: Kilo ICF

B. Task Description:

Like the estimate for the installation of the first set of control equipment, the on-site materials/labor encompasses that effort needed for installation, integration and testing of computer, data transfer and instrumentation signal processing equipment. Hardware installation for the accelerator station, three substations and a diagnostic station includes: computer processors, displays, data storage and interface equipment; signal query and processing racks; network bus, router and interfaces; instrumentation cabling, trays and other furniture. Software installation includes station operating system, base applications, network protocols, developed control logic (EPICS routines) and sensor calibration databases.

By far the largest expenditure of effort will be signal calibration of the individual sensor outputs and the establishment of a real-time database for such. Integration and testing of sensor signals for computer monitoring and evaluation, feedback control logic and signal processing, safety interlock parameters and logic will also be a significant on-site effort.

C. Detailed WBS and Cost Listing (without AFI included):

Subsystem		**Cost (kICF)**
Accelerator Control Station		28.9
Injector/LEBT Substation		91.6
RFQ/DTL Substation		366.5
HEBT Substation		274.9
	Total:	761.8

D. Costing Rationale:

The estimate is comprised of two major portions labor and material. Northrop Grumman's past experience delivering control systems on other complex physics programs was used to extrapolate the labor estimates. Examples of these programs are:

- *Continuous Wave Deuterium Demonstrator - CWDD:* a cryogenic accelerator where Northrop Grumman was the accelerator prime manufacturer responsible for delivering the entire accelerator system.

- *Ground Test Accelerator - GTA:* a ground based high power accelerator program used as a test bed for space based strategic defense initiative concepts where Northrop Grumman was selected as the accelerator industrial support contractor.
- *Relativistic Heavy Ion Collider - RHIC*: a collider program where Northrop Grumman was selected as the manufacturer of the long superconducting main dipole magnets.
- *Compact Infra Red Free Electron Laser - CIRFEL*: a program where Northrop Grumman has developed a compact FEL for industrial and university use.

To understand the material costs, suppliers in the various areas were contacted and subsequently provided rough order of magnitude quotes.

Allowance for Indeterminates: 35% based on technical risk

ENGINEERING VALIDATION PHASE
Accelerator

Total - $25M ICF

An Engineering Validation Phase is proposed for 1997-1999. A budget of ~25M ICF is presently allocated for the IFMIF accelerator system, on the basis of a pro-rated 10% of the project cost. The accelerator system is the largest cost system, but also the highest technology system. Based on our assessment of the IFMIF task and knowledge of comparable projects, 25M ICF is quite marginal, but a great deal could be accomplished in these three years with this amount.

Task One - RF System Development and Test - 15M ICF

Development and testing of a 1 MW tetrode-based RF system is identified as the highest impact development item. Existing tetrode operating experience is with pulses of a few seconds to order a minute of CW operation, at frequencies generally lower (easier) than the IFMIF frequency. No test stand capable of 1 MW CW tests to 100-1000 hours is available in the world, with the possible exception of Russia. Detailed costs to design, construct, and test the first RF station are available in the extensive costing information developed for the Tokai meeting, so a reliable estimate of ~15M ICF for this task is in hand. As the EVP proceeds, efforts would be made to economize on this number, including exploration of existing equipment and facilities as well as the possibilities in Russia.

The RF amplifier power level baseline of 1 MW and the defined EVP program have important advantages. The 1 MW power level insures that a competitive bid could be obtained from two manufacturers. Accomplishing a full-scale test of the first system would allow the remaining large procurement to be on a fixed-price basis. The involvement of two manufacturers would help insure a tube supply over the facility lifetime.

Task Two - Injector System Development and Test - 5M ICF

The injector system has the second highest impact in terms of reaching the required performance and RAM goals for IFMIF. Two technical approaches (the ECR and volume type ion sources) are to be developed to the full test stage. The primary effort will be located at EC facilities with strong support from Japanese and US teams. A budget of ~5M ICF is presently assigned to this task. It is anticipated that source test stands can be brought to fully operational level at the end of 1998 within this budget. Operational testing to demonstrate an initial goal of 100-hour lifetime would be conducted in 1999; further budget discussion will probably be required to complete these tests.

Task Three - Design For Acceptable Beam Loss, Minimal Activation And Machine Maintainability - 5M ICF

Minimization of beam loss and activation such that remote handling will not be necessary, is a critical activity that is both more promising and more difficult than for the FMIT design. More promising because of progress in understanding beam dynamics. More difficult due to more stringent radiation requirements worldwide. The remaining ~5M ICF is allotted to this area. The tasks involve detailed design of the baseline and superconducting option for the accelerator beam transport from ion source to target, fundamental investigations to gain understanding of the loss mechanisms, coordination with neutronics calculations and shielding design, coordination with engineering aspects of the accelerator design, and so on. The allocation for this area is insufficient to fully prepare for the construction phase; however much can be accomplished.

Cost Estimating Worksheets

for

WBS 5.0

Conventional Facilities

WORKSHEET
WBS 5. 1. 0 Conventional Facilities Management

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
				2500	0	0	0	0	0

Currency Units: kilo ICF

B. Description:

The governmental management activities required to directly support and complete the Conventional Facilities are included in this element. The larger task of construction management is covered in the overall project management element, WBS 1.0 with an estimate of 24,000 kICF. These include:

- Project Management and Administration: basic institutional management costs such as administration, cost control and scheduling, and documentation to initate and oversee the placement of the CM contract.

- Systems Engineering: costs for Systems Engineering after the IFMIF is approved as an official project will be estimated based upon anticipated activities needed to support the initiation of the conventional facitities work:

    - Preparation of Specifications
    - Preparation of Preliminary Design
    - Fabrication Oversight
    - Verification Testing Oversight
    - Installation Planning and Coordination
    - Installation Oversight
    - Startup Oversight

- Environmental, Health and Safety Documentation: support for personnel responsible for establishing the EH & S procedures to be applied during construction.

- Quality Assurance: support for personnel responsible for establishing and maintaining quality assurance procedures in accordance with the regulations of the country responsible for the Facility.

C. Detailed WBS Listing:

1. 0. 0. 0. 0. Conventional Facilities Management
1. 0. 0. 0. Project Management and Administration
1. 0. 0. Administration
2. 0. 0. Cost Control
3. 0. 0. Schedule
4. 0. 0. Documentation
2. 0. 0. 0. Systems Engineering
1. 0. 0. Design Integration
2. 0. 0. Systems Analysis
3. 0. 0. Requirements/Specs
4. 0. 0. RAM Analysis
3. 0. 0. 0. Environmental, Safety & Health Documentation
4. 0. 0. 0. Quality Assurance

D. Costing Rationale:

The cost of management is based on a factor of approximately 3% of the Conventional Facilities TEC.

E. Detailed Costing:

Not Applicable

WORKSHEET
WBS 5.2.1.1 Accelerator Hall

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'al			Constr Contr		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	nc	5460	328	55	876	6719

Currency Units: kilo$

B. Description:

The accelerator hall includes the two accelerator tunnels and routing space for the RF power and other services between the accelerators. Clearance is provided on the other side for horizontal removal of accelerator modules. The hall structure is reinforced concrete. The roof is 2.5 m thick to shield the RF power bay above. The floor is a 1 m thick slab to provide stability. The walls are 1 m thick below grade or 2.5 m thick above grade. The accelerator horizontal spacing of 11 m and vertical spacing of 5 m are based on the beam optics design. The internal dimensions of each tunnel are 7.5 m wide by 58.53 m long and 6 m high. The overall structure external dimensions are approximately 22 m wide by 15 m high by 60 m long. A 2.5 ton crane is provided in each tunnel.

C. Detailed WBS Listing:

5.2.1.1 Accelerator Hall

D. Costing Rationale:

The building quantities were estimated from the conceptual design drawings, and costs scaled using the ITER unit cost codes.

- Type of Estimate: Scaling
- Allowance for Indeterminates: 15% AFI is applied to account for uncertainty in the building requirements.

E. Detailed Costing:

A spreadsheet showing the cost calculation by the ITER codes is attached. The ITER JCT has developed labor codes and unit hourly costs and commodity codes to support consistent costing of facilities. Associated with each commodity code is a unit labor code and content, unit material content and cost, and unit support content and cost. The current values are maintained on a cost data file and are those used for the ITER May 1995 interim cost estimate. The IFMIF spreadsheet is organized by the commodity code. It combines the associated labor code, unit hourly content of the commodity unit, and unit hourly cost as a unit labor cost based on the commodity units. The support cost is assumed to be equal to the labor cost, consistent with the current ITER estimates.

5.2.1.1 Accelerator Hall Costing Sheet
Based on ITER data for similar facilities

Account Description	Quantity	Unit	Material	Labor	Support	Total	Code	Unit Matl Cost	Unit Lab Cost	Unit Sup Cost	Unit Lab Hours	Craft Hours
Excavation	16,938	m3	$ -	$ 118,566	$ 118,566	$ 237,132	G1002	-	7.0	7.0	0.3	4,743
Backfill	3,008	m3	$ -	$ 20,334	$ 20,334	$ 40,668	G1007	-	6.8	6.8	0.3	812
Concrete	6,395	m3	$ 703,450	$ 470,800	$ 470,800	$ 1,645,050	C1007	110.0	73.6	73.6	3.0	19,185
Rebar	499	ton	$ 374,250	$ 391,855	$ 391,855	$ 1,157,959	C1004	750.0	785.3	785.3	32.0	15,968
Formwork	5,281	m2	$ 63,372	$ 518,383	$ 518,383	$ 1,100,138	C1005	12.0	98.2	98.2	4.0	21,124
Embedded steel	50	ton	$ 113,000	$ 161,964	$ 161,964	$ 436,928	C1006	2,260.0	3,239.3	3,239.3	132.0	6,600
Waterproofing	1,404	m2	$ 15,444	$ 15,500	$ 15,500	$ 46,444	C1008	11.0	11.0	11.0	0.5	632
Misc. structural steel	20	mt	$ 116,000	$ 44,370	$ 44,370	$ 204,740	S1002	5,800.0	2,218.5	2,218.5	85.0	1,700
Arch. finish & features	1,024	m2	$ 128,000	$ 20,326	$ 20,326	$ 168,653	A1001	125.0	19.9	19.9	0.9	922
Electr. grounding grid	1,304	m2	$ 2,608	$ 6,533	$ 6,533	$ 15,674	E1003	2.0	5.0	5.0	0.2	261
Plumbing & drainage	1,024	m2	$ 10,342	$ 8,663	$ 8,663	$ 27,668	P1001	10.1	8.5	8.5	0.3	307
Fire protection system	1,024	m2	$ 92,160	$ 28,877	$ 28,877	$ 149,914	P1006	90.0	28.2	28.2	1.0	1,024
Lighting & small power	1,024	m2	$ 12,800	$ 11,878	$ 11,878	$ 36,557	E1001	12.5	11.6	11.6	0.4	440
Special eqt - cranes	2	ea	$ 150,000	$ 22,500	$ 22,500	$ 195,000		75,000	11,250	11,250		
Totals			$ 1,781,426	$ 1,840,550	$ 1,840,550	$ 5,462,525						73,718

Each Tunnel 7.5 m w by 6 m h
Grade at top of upper tunnel

WORKSHEET
WBS 5.2.1.2 Beam Turning Building

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'al			Constr Contr		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	nc	7680	460	77	1232	9449

Currency Units: kilo$

B. Description:

The beam turning building internal dimensions are approximately 25 m wide by 64 m long and 11 m high. The building is divided by shielding walls into a steering vault 14.4 m long, a turning vault 42 m long, and maintenance area 5 m long. Clearance and a 10 ton crane are provided to allow replacement of transport elements. Hatches are provided to lift removed components into the hot cell area above. The structure is reinforced concrete, 2.5 m thick for shielding above grade and 1 m thick below grade.

C. Detailed WBS Listing:

5.2.1.2 Beam Turning Building

D. Costing Rationale:

The building quantities were estimated from the conceptual design drawings, and costs scaled using the ITER unit cost codes.

- Type of Estimate: Scaling
- Allowance for Indeterminates: 15% AFI is applied to account for uncertainty in the building requirements.

E. Detailed Costing:

A spreadsheet showing the cost calculation by the ITER codes is attached.

5.2.1.2 IFMIF Beam Turning Building
Factors Based on ITER Data for Similar Construction

Account Description	Quant.	Unit	Material	Labor	Support	Total	Code	Unit Matl Cost	Unit Lab Cost	Unit Sup Cost	Unit Lab Hours	Craft Hours
Excavation	32,339	m3	-	226,373	226,373	452,746	G1002	-	7.0	7.0	0.3	9,055
Backfill	7,084	m3	-	47,888	47,888	95,776	G1007	-	6.8	6.8	0.3	1,913
Concrete	8,497	m3	934,670	625,549	625,549	2,185,768	C1007	110.0	73.6	73.6	3.0	25,491
Rebar	663	ton	497,250	520,641	520,641	1,538,531	C1004	750.0	785.3	785.3	32.0	21,216
Formwork	7,460	m2	89,520	732,274	732,274	1,554,067	C1005	12.0	98.2	98.2	4.0	29,840
Embedded steel	85	ton	192,100	275,339	275,339	742,778	C1006	2,260.0	3,239.3	3,239.3	132.0	11,220
Waterproofing	2,000	m2	22,000	22,080	22,080	66,160	C1008	11.0	11.0	11.0	0.5	900
Misc. structural steel	30	mt	174,000	66,555	66,555	307,110	S1002	5,800.0	2,218.5	2,218.5	85.0	2,550
Arch. finish & features	1,529	m2	191,125	30,351	30,351	251,826	A1001	125.0	19.9	19.9	0.9	1,376
Electr. grounding grid	1,745	m2	3,490	8,742	8,742	20,975	E1003	2.0	5.0	5.0	0.2	349
Plumbing & drainage	1,529	m2	15,443	12,935	12,935	41,314	P1001	10.1	8.5	8.5	0.3	459
Fire protection system	1,529	m2	137,610	43,118	43,118	223,846	P1006	90.0	28.2	28.2	1.0	1,529
Lighting & small power	1,529	m2	19,113	17,736	17,736	54,585	E1001	12.5	11.6	11.6	0.4	657
Special eqt - cranes	1	ea	100,000	21,000	21,000	142,000		100,000	21,000	21,000		
Total			2,376,320	2,650,581	2,650,581	7,677,482						106,555

WORKSHEET
WBS 5.2.1.3 RF Power Bay

A. Summary Cost Estimate:

Off-IFMIF Site						On-Site at IFMIF				
Industry		Instit'al				Constr Contr		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total		Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	nc		4858	291		772	5921

Currency Units: kilo$

B. Description:

The RF power supplies for the two accelerators are located above the accelerator hall in a steel framed structure with insulated metal siding and roof. The building is approximately 44 m wide by 51 m long by 12 m high. A partial basement, 18 m wide by 49 m long by 4 m high, is provided for support systems. A 25 ton crane is provided.

C. Detailed WBS Listing:

5.2.1.3 RF Power Bay

D. Costing Rationale:

The building size was estimated from the conceptual design, and costs scaled with volume from similar ITER buildings.

- Type of Estimate: Scaling
- Allowance for Indeterminates: 15% AFI is applied to account for uncertainty in the building requirements.

E. Detailed Costing:

A task to perform the structural design and costing of the ITER conventional steel-framed buildings was recently completed. The average building cost was $160/m3 with a range of $125/m3 to $200/m3. The average cost was used for the RF power bay.

WORKSHEET
WBS 5.2.1.4 Accelerator Assembly/Maintenance Bay

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'al			Constr Contr		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	nc	2961	178	0	470	3609

Currency Units: kilo$

B. Description:

The accelerator assembly and maintenance bay is a steel-framed structure located at the injector end of the accelerator hall. It is approximately 43 m wide by 23 m long by 12 m high, and includes a basement for access to the tunnels.

C. Detailed WBS Listing:

5.2.1.4 Accelerator Assembly/Maintenance Bay

D. Costing Rationale:

The building sizes were estimated and costs scaled with volume from similar ITER buildings.

- Type of Estimate: Scaling
- Allowance for Indeterminates: 15% AFI is applied to account for uncertainty in the building requirements.

E. Detailed Costing:

A task to perform the structural design and costing of the ITER conventional steel-framed buildings was recently completed. The average building cost was $160/m3 with a range of $125/m3 to $200/m3. The average cost was used for the accelerator maintenance bay.

WORKSHEET
WBS 5.2.2 Target Complex

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF			
Industry Mat'l/Lab	Engin'g	Instit'al Engin'g	AFI	Total	Const. Contractor Mat'l/Lab	Engin'g	AFI	Total
					5210,0	579,0	1157,9	**6946,9**

Units: kECU

B. Description:

The Target Complex consists of 8 cells designed to host the Lithium loop, the Chemistry Purification Loop, the Impurity Monitoring Loop, the Li-transfer System and all loop components. The cells are located below the Test Cell. The floors and the walls, up to an height of 2 metres, are lined with a stainless steel plate 1 cm thick. The overall structure external dimensions are approximately 29 m wide by 30 m high by 27.5 m long.

C. Detailed WBS Listing:

0. 0. Target Complex
1. 0. Lithium Processing Cells
   1. Liners

D. Costing Rationale:

The Complex size has been estimated and the cost scaled with volume from the total cost of IFMIF Main Building. This last has been estimated by a bottom-up procedure based on prices quoted in the manuals "Prezzi informativi delle OPERE EDILI in Milano" August 1995 and "Prezzi informativi dell'Edilizia (ediz. 1994)" published by DEI-Tipografia of Genio Civile, updated according to the official inflation rate. The reinforced concrete costs have been worked out using the ENEA PEC Nuclear Installation construction experience.
Two main sections, on the cost estimate point of view, were singled out; the former is the so called **Bunker**, that is the part of the building realised mainly below the ground level, and consisting mainly of shielded areas and cells, the latter is the so called **Industrial Building** including the above ground level construction plus the Radwaste Treatment and Shipping bays (located below ground level).

Type of Estimate: Mixed Bottom-up + Factoring
Allowance for Indeterminates: 20% based mainly on the uncertainties on design specifications

E. Detailed Costing:

	Mat'l/Lab	Engin'g	AFI	Total
Target Complex	**5210,0**	**579,0**	**1157,9**	**6946,9**
Lithium Processing Cells	4630,5	521,0	1042,0	6193,5
Liners	579,5	58,0	115,9	753,4

WORKSHEET
WBS 5.2.3.0 Test and Examination Complex

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF			
Industry Mat'l/Lab	Engin'g	Instit'al Engin'g	AFI	Total	Const. Contractor Mat'l/Lab	Engin'g	AFI	Total
					2946,9	294,7	589,4	**3830,9**

Units: kECU

B. Description:

The Test and Examination Complex consists of a number of Cells, Hot Cells and Operative Areas, designed to host the Test Module during irradiation and to transport safely the material samples to the Post Irradiation Examination Laboratory.

C. Detailed WBS Listing:

0. 0. Test and Examination Complex
1. 0. Test Cells
2. 0. Beam Calibration Station Cell
3. 0. Test Cell Technology Rooms
4. 0. Access Cell
4. 1. Shielding Doors
5. 0. Service Cell
5. 1. Shielding Doors
6. 0. Test Module Handling Cell
6. 1. Shielding Door
7. 0. Control Room
8. 0. Data Acquisition Room
9. 0. PIE Laboratory Area
10. 0. Tritium Laboratory Area
11. 0. Hot Cell Utilitiy Area
12. 0. Corridors

D. Costing Rationale:

The Complex size has been estimated and the cost scaled with volume from the total cost of IFMIF Main Building. This last has been estimated by a bottom-up procedure based on prices quoted in the manual "Prezzi informativi delle OPERE EDILI in Milano" August 1995 and "Prezzi informativi dell'Edilizia (ediz. 1994)" published by DEI-Tipografia of Genio Civile, updated according to the official inflation rate. The reinforced concrete costs have been worked out using the ENEA PEC Nuclear Installation construction experience.

Two main sections, on the cost estimate point of view, were singled out; the former is the so called **Bunker**, that is the part of the building realised mainly below the ground level, and consisting mainly of shielded areas and cells, the latter is the so called **Industrial Building** including the above ground level construction plus the Radwaste Treatment and Shipping bays (located below ground level).

Type of Estimate: Mixed Bottom-up + Factoring

Allowance for Indeterminates: 20% based mainly on the uncertainties on design specifications

E. Detailed Costing:

	Mat'l/Lab	Engin'g	AFI	Total
Test and Examination Complex	**2946,9**	**294,7**	**589,4**	**3830,9**
Test Cells	44,1	4,4	8,8	57,3
Beam Calibration Station Cell	22,0	2,2	4,4	28,6
Test Cell Technology Rooms	117,5	11,8	23,5	152,8
Access Cell	626,7	62,7	125,3	814,7
Shielding Doors	52,7	5,3	10,5	68,5
VTA & Target Service Cell	325,2	32,5	65,0	422,8
Shielding Doors	52,7	5,3	10,5	68,5
Module Handling Cell	156,1	15,6	31,2	202,9
Shielding Door	31,1	3,1	6,2	40,4
Control Room	34,7	3,5	6,9	45,1
Data Acquisition Room	37,8	3,8	7,6	49,2
PIE Laboratory Area	170,3	17,0	34,1	221,4
Tritium PIE Laboratory Area	252,4	25,2	50,5	328,1
Hot Cell Utilitiy Cell	422,7	42,3	84,5	549,5
Corridors	135,1	13,5	27,0	175,7
Cell liners	465,6	46,6	93,1	605,3

WORKSHEET
WBS 5.2.4 Building High Bay

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF			
Industry Mat'l/Lab	Engin'g	Instit'al Engin'g	AFI	Total	Const. Contractor Mat'l/Lab	Engin'g	AFI	Total
					3047,6	304,8	609,5	**3961,9**

Units: kECU

B. Description:

The Building High Bay consists of a series of halls designed to host plant general facilities. It is characterised by a Bridge Crane running in a High Bay and serving almost all the halls including the Test Complex and Examination Complex.

C. Detailed WBS Listing:

0. 0. Building High Bay
1. 0. High Bay
1. 1. Bridge Crane (30 t capacity load)
2. 0. Hot Shop
3. 0. Uncontaminated Shop
4. 0. Manipulator Repair Room
5. 0. Shipping Bay
6. 0. Rad Waste Processing Bay
7. 0. Rad Waste Shipping Bay
8. 0. Health Physics Station
9. 0. Corridors

D. Costing Rationale:

The Complex size has been estimated and the cost scaled with volume from the total cost of IFMIF Main Building. This last has been estimated by a bottom-up procedure based on prices quoted in the manual "Prezzi informativi delle OPERE EDILI in Milano" August 1995 and "Prezzi informativi dell'Edilizia (ediz. 1994)" published by DEI-Tipografia of Genio Civile, updated according to the official inflation rate. The reinforced concrete costs have been worked out using the ENEA PEC Nuclear Installation construction experience.
Two main sections, on the cost estimate point of view, were singled out; the former is the so called **Bunker**, that is the part of the building realised mainly below the ground level, and consisting mainly of shielded areas and cells, the latter is the so called **Industrial Building** including the above ground level construction plus the Radwaste Treatment and Shipping bays (located below ground level).

Type of Estimate: Mixed Bottom-up + Factoring
Allowance for Indeterminates: 20% based mainly on the uncertainties on design specifications

E. Detailed Costing:

	Mat'l/Lab	*Engin'g*	*AFI*	*Total*
Building High Bay	**3047,6**	**304,8**	**609,5**	**3961,9**
High Bay	1670,6	167,1	334,1	2171,7
Bridge Crane	364,4	36,4	72,9	473,7
Hot Shop	66,7	6,7	13,3	86,7
Uncontaminated Shop	48,8	4,9	9,8	63,4
Manipulator Repair	27,6	2,8	5,5	35,9
Shipping Bay	292,6	29,3	58,5	380,4
Rad Waste Processing	215,0	21,5	43,0	279,5
Rad Waste Shipping	178,1	17,8	35,6	231,5
Health Phisycs Station	48,8	4,9	9,8	63,4
Corridors	135,1	13,5	27,0	175,7

WORKSHEET
WBS 5.2.5.0 Support Facility Buildings

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'al			Constr Contr		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	nc	1058	42	0	165	1265

Currency Units: kilo$

B. Description:

An office area of 4000 m3 is provided for local administrative services at the IFMIF facility which is located within an existing nuclear research site. It provides space for 80 people, meeting rooms, and a reception area for controlled access to the main building. A local shop area of 2700 m3 is also provided for conventional plant services, parts storage and ordinary repair and calibration. The process maintenance shops and activities are located in the main building areas they serve. The host site is assumed to provide visitor control, shipping and receiving control, and conventional infrastructure services.

C. Detailed WBS Listing:

5.2.5 Support Facility Buildings
5.2.5.1 Plant Service Halls
5.2.5.2 Office Complex

D. Costing Rationale:

The building sizes were estimated and costs scaled with volume from similar ITER buildings.

- Type of Estimate: Scaling
- Allowance for Indeterminates: 15% AFI is applied to account for uncertainty in the building requirements.

E. Detailed Costing:

A task to perform the structural design and costing of the ITER conventional steel-framed buildings was recently completed. The average building cost was 160 $/m3 with a range of 125 to 200 $/m3. The office building, with its special furnishings is assumed to be 180 $/m3, while the simple shop area is taken as 125 $/m3.

WORKSHEET
WBS 5.3.1.0 Heating, Ventilation and Air Conditioning (HVAC)

A. Summary Cost Estimate:

Off-IFMIF Site					*On-Site At IFMIF*			
Industry *Mat'l/Lab*	*Engin'g*	*Instit'al* *Engin'g*	*AFI*	*Total*	*Const. Contractor* *Mat'l/Lab*	*Engin'g*	*AFI*	*Total*
7.207	1.153		1.25 4	**9.615**	7.207	0.288	1.124	**8.620**

Units: M$

B. Description:

The Heating and Ventilation Air Conditioning system provides sufficient air throughput to ensure acceptable air quality for continuous access of the operating staff. Air is drawn from the external, filtered, conditioned and distributed to the IFMIF plant operating areas.
HVAC includes an Industrial HVAC and a Nuclear HVAC plus the Active Ventilation System.
The Industrial HVAC simply provides air conditioning and distribution to areas where the risk of radiological contamination is excluded. The Nuclear HVAC serves potentially contaminated rooms, as the maintenance bay, the lithium cells, the accelerator hall, the RF power bay and the beam turning areas. These rooms are continuously monitored for gamma and/or tritium and are kept at a lower pressure than the external, to prevent uncontrolled releases of radioactivity. Air effluents from Nuclear HVAC are filtered by means of prefilters and HEPA filters and discharged through a stack of adequate characteristics. Effluents are monitored for radioactivity.
Part of the area supplied from the Nuclear HVAC is subtracted from the operating areas and used for the ventilation of some secondary containment enclosures (Service Cell, Access Cell, Test Module Handling Cell). Effluents from these enclosures are collected by a dedicated piping system, (active ventilation) provided of independent exhaust blowers and HEPA filters. The pressure at the pipe headers is negative in the range of 1 - 2 kPa.

C. Detailed WBS Listing:

1. 0. Heating, Ventilation and Air Conditioning (HVAC)
1. 1. Nuclear HVAC
1. 2. Industrial HVAC
1. 3. Active Ventilation

D. Costing Rationale:

The cost of the Industrial HVAC was obtained by an analogous estimate done for the Italian TERA Project (a facility for the Oncological Hadronoterapy) scaling up the cost according to the share with respect to the building cost. A value of 48 US$/m^3 was considered.
The cost for the Nuclear HVAC was worked out using as a reference the unitary cost reported in "ITER Outline Design Cost Estimate" Doc. ITER TAC-4-14, January 1994. A value of 211 US$/m^3 was considered. Costs of the Active Ventilation System (including the exhaust ducts, air filtering and expulsion) were evaluated, on the basis of a cost breakdown, about 0.6 M$ for a 91000 m^3/h system. These were added to the Industrial and Nuclear HVAC costs.
An equal share between on-site (50%) and off-site (50%) for the Material and Labor Cost was assumed, while the share for Engineering Costs was assumed 80% off-site and 20% on-site.

Type of Estimate: Factoring

Allowance for Indeterminates: 15% based mainly on the uncertainties on design specifications.

E. Detailed Costing:

			Mat'l/Lab	*Engin'g*	*AFI*	*Total*
1.	0	Heating, Ventilation and Air Conditioning	**14.415**	**1.441**	**2.378**	**18.235**
1.	1.	Industrial HVAC	4.581	0.458	0.756	5.794
1.	2.	Nuclear HVAC	9.354	0.935	1.543	11.832
1.	3.	Active Ventilation	0.481	0.048	0.079	0.608

WORKSHEET
WBS 5.3.2.0 Power System

A. Summary Cost Estimate with 380KV GRID

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'al			Const. Contractor		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
1300		28	266	1594	310		29	67	406

Units: kilo ECU.

B. Description:

The Power System serves to receive electrical power from the 60 MW which includes 9 MW for possible power increase. In order to carry out this mission it consists of the components listed in the following poin C and in the annex

The present valutations are based on the following assumptions:

-The level of the grid voltage is 380KV 50Hz with a short circuit power of 10GVA and with no feedthrough line. The advantages of this solution are: the problems of reactive power compensation and filtering of the generated harmonics are very small, high reliability of the grid,power availability for future plant's increases.

- Excluded reactive power compensation and the filtering of the generated harmonics, as included in the tetrode HV supply unit.
- The power sizes of the generating set and UPS are arbitrary.
- Voltage levels according to the European Standard (380KV or 132KV - 20KV-380V).
- Not included autotransformers to adapt the imput voltage of the RF feeders
- Not included civil works.

C. Detailed WBS Listing:

5. 3. 2. 0. 0. Power System
1. 0. Substation
1. Main transformer with general breaker and switches
2. Circuit breakers (20 KV), auxiliary power transformer
3. Generating set and UPS

D. Costing Rationale:

The costs were drawn by scaling from the projects ITER and IGNITOR, these datas are given by primary European firms.

Allowance for Indeterminates: 20% based mainly on the uncertainties on design specifications

E. Detailed Costing:

A detailed list of the equipments used to develop summary costs and a general scheme of the power substation are attached

WORKSHEET
WBS 5.3.3.0 Heat Rejection System

A. Summary Cost Estimate:

Off-IFMIF Site					*On-Site At IFMIF*			
Industry Mat'l/Lab	*Engin'g*	*Instit'al Engin'g*	*AFI*	*Total*	*Const. Contractor Mat'l/Lab*	*Engin'g*	*AFI*	*Total*
					3104,3	310,4	620,9	**4035,6**

Units: kECU

B. Description:

The Heat Rejection System is required to reject process heat. A circulating water system with cooling towers will serve all of the water-cooled equipment where risk of contamination cannot be excluded like accelerator and beam transport elements. Approximately 14000 l/min of deionized water for each accelerator and 3000 l/min for the beam transport elements are envisaged. The total required heat rejection capacity through water circulation is approximately 10 MW. The heat rejection system (10 MW) for the target is accounted for in cost estimate of the Target Complex. Another 20 MW of heat power are rejected through the plant ventilation system (it is not accounted for).

C. Detailed WBS Listing:

0. 0. Heat Rejection System

D. Costing Rationale:

The cost of the Heat Rejection System has been worked out using as a reference the cost reported by an analogous estimate done for the Italian TERA Project (a facility for the Oncological Hadronoterapy). The heat rejected in the TERA by the demineralised water cooling is 0.6 MW, so the cost has been scaled up using a correlation with the cost proportional to the power removed with exponent 0.60. The cost estimate has been also checked against one worked out applying the same correlation in scaling down the cost estimation done for the ITER Project heat rejection system, (reference "ITER Outline Design Cost Estimate" Doc. ITER TAC-4-14, January 1994).

Type of Estimate: Factoring
Allowance for Indeterminates: 20% based mainly on the uncertainties on design specifications

E. Detailed Costing: na

WORKSHEET
WBS 5.3.3.0 Heat Rejection System

A. Summary Cost Estimate:

Off-IFMIF Site					*On-Site At IFMIF*			
Industry Mat'l/Lab	*Engin'g*	*Instit'al Engin'g*	*AFI*	*Total*	*Const. Contractor Mat'l/Lab*	*Engin'g*	*AFI*	*Total*
					3104,3	310,4	620,9	**4035,6**

Units: kECU

B. Description:

The Heat Rejection System is required to reject process heat. A circulating water system with cooling towers will serve all of the water-cooled equipment where risk of contamination cannot be excluded like accelerator and beam transport elements. Approximately 14000 l/min of deionized water for each accelerator and 3000 l/min for the beam transport elements are envisaged. The total required heat rejection capacity through water circulation is approximately 10 MW. The heat rejection system (10 MW) for the target is accounted for in cost estimate of the Target Complex. Another 20 MW of heat power are rejected through the plant ventilation system (it is not accounted for).

C. Detailed WBS Listing:

0. 0. Heat Rejection System

D. Costing Rationale:

The cost of the Heat Rejection System has been worked out using as a reference the cost reported by an analogous estimate done for the Italian TERA Project (a facility for the Oncological Hadronoterapy). The heat rejected in the TERA by the demineralised water cooling is 0.6 MW, so the cost has been scaled up using a correlation with the cost proportional to the power removed with exponent 0.60. The cost estimate has been also checked against one worked out applying the same correlation in scaling down the cost estimation done for the ITER Project heat rejection system, (reference "ITER Outline Design Cost Estimate" Doc. ITER TAC-4-14, January 1994).

Type of Estimate: Factoring
Allowance for Indeterminates: 20% based mainly on the uncertainties on design specifications

E. Detailed Costing: na

WORKSHEET
WBS 5.3.4.0 Service Water System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'al			Constr Contr		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	nc	500	25	0	79	604

Currency Units: kilo$

B. Description:

The plant service water system provides piping for potable water, fire water, and sanitary sewage between the IFMIF buildings and the site services.

C. Detailed WBS Listing:

5.3.4.0 Service Water Systems

D. Costing Rationale:

The system costs are scaled from estimates for similar facilities.

- Type of Estimate: Scaling
- Allowance for Indeterminates: 15% AFI is applied to account for uncertainty in the system requirements.

E. Detailed Costing:

Service water system costs are scaled based on estimated length of pipe and ITER unit costs per length.

WORKSHEET
WBS 5.3.5.0 Radioactive Waste Treatment Systems

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
2859	2114	787	2468	8228		2493	2493	2138	7124

Currency Units: kilo ICF

B. Description:

The Waste Treatment Systems will manage the gaseous, liquid and solid wastes generated from IFMIF components. They consist of Exhaust Gas Detritiation System, Temporary Exhaust Detritiation System, Liquid Waste Treatment System and Solid Waste Treatment System. Exhaust gas that contains tritium is cleaned in the processing systems described here and sent to the Nuclear HVAC for disposal from stack. Solid and Liquid wastes are processed and packaged for shipment to the final processing / disposal facility of the hosting site.

C. Detailed WDS Listing

5.3.5.1 Exhaust Gas Detritiation System
5.3.5.2 Temporary Exhaust Gas Detritiation System
5.3.5.3 Liquid Waste Treatment System
5.3.5.4 Solid Waste Treatment System

D. Costing Rationale:

Most of the cost estimated are obtained by scaling and factoring from the experience of the existing facilities that handles irradiated and/or contaminated materials. Equipments to be installed in the system are assumed to be purchased from the industry including design, assembly and testing. Industry and institutional engineering costs are estimated for the total of the each subsystems. AFIs are estimated to be 30%, because of the uncertainty of the detailed requirements and source terms, while major part of the system can be assembled with existing technology. Personnel costs are estimated as follows;

Industry: 10 % manager, 50% experts and 40% labor, averaged to be 19Myen/year. Institutional : 15M yen/year.

WBS 5.3.5.1 Exhaust Detritiation System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
899	453	215	671	2238		950	950	814	2714

Currency Units: kilo ICF

B. Description:

Exhaust Gas Detrtiation System is operated for management of the exhaust gas from vacuum systems, the tritium cell, GB exhaust system and some other process effluent. The exhaust gas from the vacuum system is assumend to consist of about 1m3/h of Ar with 1x105Bq/cc tritium gas and about 19m3/h of air with 0-5Bq/cc liquid tritiated water equivalent vapor. The amount of the exhaust gas from other sources such as tritium cell and GB exhausting system is considered to be total of 200m3/h with a small amount of tritiated water. Process is based on permeation membrane technology and no materials are consumed by the operation.

C. WBS Listing:

5.3.5.1 Exhaust Detritiation System

D. Costing Rationale:

Cost estimate on this system is based on the industrial dry air production equipment, and a detritiation system being developed in Japanese facility.

WBS 5.3.5.2 Temporary Exhaust Detritiation System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
335	302	143	334	1114		470	470	403	1343

Currency Units: kilo ICF

B. Description:

Temporary Exhaust Gas Detritiation System is operated for management of the gas, mostly anticipated to be air with low level tritiated water vapor which is exhausted in operation for maintenance. The amount of temporary exhaust gas is considered to be 100m3/h with a small amount of tritiated water, fed through the flexible ventilation ducts from various areas of the facility where the maintenance operation with radioactive contamination is anticipated.

C. WBS Listing:

5.3.5.2 Temporary Exhaust Detritiation System

D. Costing Rationale:

Cost is estimate from a dry air production unit based on hollow fiber permeation membrane comercially available in Japan.

WBS 5.3.5.3 Liquid Waste Treatment System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
414	453	143	433	1443		640	640	549	1829

Currency Units: kilo ICF

B. Description:

Liquid Waste Treatment System is operated for management of liquid wastes. Liquid wastes are considered to be generated mainly from cooling system of accelerator facility and decontamination facility for the components removed for maintenance purpose. Backwall and target assemble from the target system, and irradiated VTA and sample capsule parts are anticipated to be the major source of the solid waste to be cleaned. The amount of the liquid wastes is considered to be about 10m3/year of alkaline water with lithium hydroxide and about 5m3/year of neutral water. A small amount of tritiated water and radioactive metals generated by collosion are considered to be included in the liquid wastes.

Waste water is recycled after the treatment by neutralization, evaporation and ion exchange for purification. Concentrated liquid waste is solidified for disposal. Tritium removal is not attempted.

C. WBS Listing:

5.3.5.3 Liquid Waste Treatment System

D. Costing Rationale:

Cost is based on a small liquid waste handling equipment recently installed in a irradiation facility in Japan.

WBS 5.3.5.4 Solid Waste Treatment System

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
1211	906	286	1030	3433		433	433	372	1238

Currency Units: kilo ICF

B. Description:

Solid Waste Treatment System is operated for management of solid wastes. The main solid wastes are considered to be irradiated articles of consumption from the target room. About 30kg/year of solid wastes are considered to be generated from the target room in normal operation, and about 200kg/batch of solid wastes are also considered to be generated irregularly at maximum. The amount of other solid wastes such as irradiated specimens and holders, etc., is considered to be about 10 containers/year.

The system is installed in the tritiu hot cell in the Post Irradiation Examination facility that has a capability to handle activated and tritium-contaminated materials.

C. WBS Listing:

5.3.5.3 Solid Waste Treatment System

D. Costing Rationale:

Cost is based on a small solid waste handling equipment recently installed in a irradiation facility in Japan.

WORKSHEET
WBS 5.4.0.0 Site Improvements

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site at IFMIF				
Industry		Instit'al			Constr Contr		Instit'al		
Mat'l/Lab	Engin'g	Engin'g	AFI	Total	Mat'l/Lab	Engin'g	Engin'g	AFI	Total
nc	nc	nc	nc	nc	1005	20	0	100	1125

Currency Units: kilo$

B. Description:

The IFMIF site includes a land area of 10 ha, of which 2 ha are developed. The land is provided within an existing nuclear research facility with central infrastructure support. The site improvements cost includes road transportation, land clearing and landscaping, and storm drainage for the area dedicated to IFMIF.

C. Detailed WBS Listing:

5.4.0 Site Improvements
5.4.1 Roads and Parking
5.4.2 Grading and Landscaping
5.4.3 Storm Drainage

D. Costing Rationale:

The required quantities were estimated using an assumed site layout, and costs were estimated using the ITER cost data base.

- Type of Estimate: Scaling
- Allowance for Indeterminates: 10% AFI is applied to account for unusual site conditions.

E. Detailed Costing:

A spreadsheet showing the cost elements and ITER unit costs is attached.

IFMIF Site Improvements Costing Sheet
Costs Factoring Based on ITER Data for Similar Facilities

Account Description	Quant.	Unit	Mat'l	Labor	Support	Total	Code	Unit Matl Cost	Unit Lab Cost	Unit Sup Cost	Unit Lab Hrs	Craft Hrs
Roadway	700	m	105,000	122,696	122,696	350,392	G1010	150	175	175	7	4,900
Parking	2,000	m2	8,000	6,000	6,000	20,000	G1012	4	3	3	0	240
Lighting	25	ea	6,250	6,743	6,743	19,735	E1002	250	270	270	10	250
Clearing and grading	100,000	m2	-	88,000	88,000	176,000	G1001	-	1	1	0	4,000
Landscaping	10,000	m2	10,000	150,200	150,200	310,400	G1006	1	15	15	1	6,000
Fencing	1,200	m	38,400	30,048	30,048	98,496	G1008	32	25	25	1	1,200
Storm drainage	20,000	m2	20,000	5,000	5,000	30,000	G1005	1	0	0	0	200
Total			187,650	408,687	408,687	1,005,023						16,790

WORKSHEET
WBS 5.1.0 Conventional Facilities ; Management (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	1,043,418	nc	nc	208,844	1,252,262

Currency Units: **kilo Yen**

B. Description:

The total price is consist of management (1.5%) and tax (5%).

C. Costing Rational:

Type of Estimate : factor

D. Detailed Costing: **(Unit : k-yen)**

	Mat'l/Lab	AFI
	16,052,576	3,212,972
5.2 Buildings	8,818,762	1,763,752
5.3 Utilities	4,122,308	824,462
5.4 Electric Utilities	3,100,760	620,152
5.5 Radioactive Waste Treatment Systems	10,746	4,606

Item		Cost	(k-ICF)
Management (1.5%)		**288,984**	**2,753**
Mat'l/Lab	16,052,576 x 1.5%	**240,789**	**2,294**
AFI	3,212,972 x 1.5%	**48,195**	**459**
Tax (5%)		**963,278**	**9,174**
Mat'l/Lab	16,052,576 x 5%	**802,629**	**7,644**
AFI	3,212,972 x 5%	**160,649**	**1,530**
Mat'l/Lab :	240,789+802,629	**1,043,418**	**9,938**
AFI :	48,195+160,649	**208,844**	**1,989**
	Total	**1,252,262**	**11,927**

WORKSHEET
WBS 5.2.0 Conventional Facilities ; Buildings (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	8,818,762	nc	nc	1,763,752	10,582,514

Currency Units: **kilo Yen**

B. Description:

The conventional facilities buildings for IFMIF consists of accelerator complex, target complex, neutron imaging, building high bay, support facilities and plant gaseous effluent system. This cost is not included the expense of a geological survey and hedging and ditching works. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

1. 0. 0. 0. Buildings
- 1. 0. 0. Construction
  - 1. 0. RF Power Bay
  - 2. 0. Target Cell and etc.
  - 3. 0. Lab. rooms and etc.
  - 4. 0. Administration Building
  - 5. 0. Machine rooms and etc.
  - 6. 0. Caisson/Post
  - 7. 0. Water proof on Mat
  - 8. 0. Water proof at Basement
  - 9. 0. Improvement of Ground
- 2. 0. 0. Special Equipment
  - 1. 0. Shielding Door
  - 2. 0. Crane
  - 3. 0. Shielding Plug
  - 4. 0. Lift
  - 5. 0. Free Access Flower at Control Room
  - 6. 0. Epoxy Lining
  - 7. 0. SUS Lining
  - 8. 0. Hatch at ceiling and etc.

D. Costing Rational:

Type of Estimate : nearly bottom-up and scaling
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

Item	Cost	(k-ICF)
Buildings	5,856,337	55,775
Special Equipment	2,962,425	28,214

WORKSHEET
WBS 5.2.1.1 Construction (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	5,856,337	nc	nc	1,171,267	7,056,385

Currency Units: **kilo Yen**

B. Description:

This cost is not included the expense of a geological survey and hedging and ditching works. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

1. 0. 0. Construction
1. 0. RF Power Bay
2. 0. Target Cell and etc.
3. 0. Lab. rooms and etc.
4. 0. Administration Building
5. 0. Machine rooms and etc.
6. 0. Caisson/Post
7. 0. Water proof on Mat
8. 0. Water proof at Basement
9. 0. Improvement of Ground

D. Costing Rational:

Type of Estimate :	nearly bottom-up and scaling
Allowance for Indeterminates :	20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

		Cost
1.1 RF Power Bay	3,360 m^2 x 12 mH	799,108
1.2 Target Cell, etc.	13,000 m^2 x 6 mH	3,113,110
1.3 Lab. rooms, etc.	1,365 m^2 x 5 mH	222,870
1.4 Administration Building	1,650 m^2 x 5 mH	269,404
1.5 Machine rooms, etc.	900 m^2 x 6 mH	153,945
1.6 Caisson/Post		371,800
1.7 Water proof on Mat		132,000
1.8 Water proof at Basement		102,000
1.9 Improvement of Ground		692,100
	Total	**5,856,337**

WORKSHEET
WBS 5.2.1.2 Special Equipment (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	2,962,425	nc	nc	592,485	3,554,910

Currency Units: **kilo Yen**

B. Description:

This cost is not included the expense of a geological survey and hedging and ditching works. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

2. 0. 0. Special Equipment
1. 0. Shielding Door
2. 0. Crane
3. 0. Shielding Plug
4. 0. Lift
5. 0. Free Access Flower at Control Room
6. 0. Epoxy Lining
7. 0. SUS Lining
8. 0. Stach
8. 0. Hatch at ceiling and etc.

D. Costing Rational:

Type of Estimate : nearly bottom-up and scaling
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

Item	Specification	Cost
2.1 Shielding Door	5m W x 8m H x 2.5m T x 2	190,000
	1m W x 2m H x 1m T	10,000
2.2 Crane	30/5-ton, 24m-span x 34m L x 25m H	76,000
	25/5-ton, 40m-span x 70m L x 20m H	132,000
	10-ton, 24m-span x 41m L x 10m H	39,000
	5-ton, 7.5m-span x 50m L x 10m H x 2	38,800
2.3 Shielding Plug	2.5m x 5.2m x 1.8 mT x 2	90,000
2.4 Lift	1-ton x 2	100,000
2.5 Free Access Flower at Control Room	175 m^2	9,625
2.6 Epoxy Lining	14,900 m^2	132,000
2.7 SS Lining	5,000 m^2	2,000,000
2.8 Stach	30 mH	48,000
2.9 Hatch at ceiling, etc.		692,100
	Total	**2,962,425**

WORKSHEET
WBS 5.3 Conventional Facilities ; Utilities/Ventilation etc. (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	4,122,308	nc	nc	824,462	4,946,770

Currency Units: **kilo Yen**

B. Description:

The utilities for IFMIF consists of ventilation, water cooling system, service water system, cooling water utilities and special equipment. This utility is not included electric utilities. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

3. 0. 0. 0. Utilities
1. 0. 0. Ventilation
1. 0. Cold Area
2. 0. Type-1 Controlled Area
3. 0. Type-2 Controlled Area
2. 0. 0. Service Water System
1. 0. Cold Area
2. 0. Type-1 Controlled Area
3. 0. Type-2 Controlled Area
3. 0. 0. Cooling Water Utilities
1. 0. Cooling system for Type-1 Area
2. 0. Cooling system for Type-2 Area
3. 0. Cooling system for Accelerator & Target
4. 0. 0. Special Equipment
1. 0. Filter and etc.
2. 0. Control System

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

Item	Cost	(k-ICF)
Ventilation	1,520,767	14,484
Service Water System	578,162	5,506
Cooling Water Utilities	1,117,500	10,643
Special Equipment	905,879	8,627
Ground Total	**4,122,308**	**39,260**

WORKSHEET
WBS 5.3.1 Ventilation (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	1,520,767	nc	nc	304,153	1,824,920

Currency Units: **kilo Yen**

B. Description:

The total price is not included management (1.5%) and tax (5%).

C. Detailed WBS Listing:

1. 0. 0. Ventilation
1. 0. Cold Area
2. 0. Type-1 Controlled Area
3. 0. Type-2 Controlled Area

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

				Cost
1.1.0 Cold Area :	**11,407 m^2**			**795,888**
1. AAMB	350 m^2	(7 mH) x	57.90 x 1.10 x 1.00	22,292
2. RF Power Bay	3,283 m^2	(12 mH) x	57.90 x 1.40 x 1.00	266,120
3. Staircase Hall	105 m^2	(40 mH) x	57.90 x 4.00 x 1.00	24,318
4. Data Acquisition	232 m^2	(5 mH) x	57.90 x 1.00 x 1.00	13,433
5. HEBT Assembly Maintenance Bay				
	249 m^2	(8 mH) x	57.90 x 1.20 x 1.00	17,301
6. Staircase Hall	82 m^2	(10 mH) x	57.90 x 1.40 x 1.00	6,647
7. Ventilation Room	217 m^2	(5 mH) x	57.90 x 1.00 x 1.00	12,564
8. Auxiliary Equipment Room				
	1,088 m^2	(5 mH) x	57.90 x 1.00 x 1.00	62,995
9. Accelerator Assembly Maintenance				
	350 m^2	(5 mH) x	57.90 x 1.00 x 1.00	20,265
10. Control Room	165 m^2	(7 mH) x	57.90 x 1.10 x 1.00	10,509
11. Shipping Bay	249 m^2	(8 mH) x	57.90 x 1.20 x 1.00	17,301
12. Health Physics Station	70 m^2	(5 mH) x	57.90 x 1.00 x 1.00	4,053
13. Uncontaminated Shop	70 m^2	(5 mH) x	57.90 x 1.00 x 1.00	4,053
14. Storage	318 m^2	(5 mH) x	57.90 x 1.00 x 1.00	18,412

15. Shipping Bay	173 m^2 (10 MH) x	57.90 x 1.40 x 1.00	14,023
16. Passage Hall	113 m^2 (5 mH) x	57.90 x 1.00 x 1.00	6,543
17. Passage Hall	79 m^2 (5 mH) x	57.90 x 1.00 x 1.00	4,574
18. Staircase Hall	50 m^2 (5 mH) x	57.90 x 1.00 x 1.00	2,895
19. Passage Hall	113 m^2 (5 mH) x	57.90 x 1.00 x 1.00	6,543
20. Passage Hall	113 m^2 (5 mH) x	57.90 x 1.00 x 1.00	6,543
21. High Hall	2,288 m^2 (9 mH) x	57.90 x 1.20 x 1.00	158,970
22. Administration Building	1,650 m^2 (5 mH) x	57.90 x 1.00 x 1.00	95,535
1.2.0 Type-1 Controlled Area	<u>**4182 m^2**</u>		<u>**551,555**</u>
1. Li Cooler Room	188 m^2 (6 mH) x	57.90 x 1.10 x 2.00	23,947
2. N/A	211 m^2 (20 mH) x	57.90 x 1.80 x 2.00	43,981
3. Li Purification Room	161 m^2 (6 mH) x	57.90 x 1.10 x 2.00	20,508
4. Li Surge Tank Room	177 m^2 (6 mH) x	57.90 x 1.00 x 2.00	22,546
5. Access Maintenance Room	161 m^2 (14 mH) x	57.90 x 1.40 x 2.00	26,101
6. Target Interface Room	102 m^2 (10 mH) x	57.90 x 1.40 x 2.00	16,536
7. Beam Calibration Station	139 m^2 (7 mH) x	57.90 x 1.20 x 2.00	19,315
8. Test Cell Technology Room	23 m^2 (3 mH) x	57.90 x 1.00 x 2.00	2,663
9. Test Cell	13 m^2 (6 mH) x	57.90 x 1.10 x 2.00	1,656
10. Beam Calibration Station	13 m^2 (4 mH) x	57.90 x 1.10 x 2.00	1,505
11. Test Call	13 m^2 (6 mH) x	57.90 x 1.10 x 2.00	1,656
12. Test Cell Technology Room	23 m^2 (3 mH) x	57.90 x 1.10 x 2.00	2,663
13. Operating Area	560 m^2 (12 mH) x	57.90 x 1.40 x 2.00	90,787
14. Red Waste Processing	150 m^2 (5 mH) x	57.90 x 1.00 x 2.00	17,370
15. Red Waste Shipping	150 m^2 (5 mH) x	57.90 x 1.00 x 2.00	17,370
16. Hot Cell Utility Area	821 m^2 (5 mH) x	57.90 x 1.10 x 2.00	95,072
17. PIE Laboratory Area	605 m^2 (5 mH) x	57.90 x 1.00 x 2.00	70,059
18. Tritium Laboratory	518 m^2 (5 mH) x	57.90 x 1.00 x 2.00	59,984
19. Manipulator Repair	77 m^2 (5 mH) x	57.90 x 1.00 x 2.00	8,917
20. Hot Shop	77 m^2 (5 mH) x	57.90 x 1.00 x 2.00	8,917
1.3.0 Type-2 Controlled Area	<u>**2466 m^2**</u>		<u>**173,324**</u>
1. Li Dump Tank Room	453 m^2 (7 mH) x	57.90 x 1.10 x 1.00	28,852
2. Spare Room	176 m^2 (5 mH) x	57.90 x 1.00 x 1.00	10,190
3. Beam Turning Room	995 m^2 (11 mH) x	57.90 x 1.40 x 1.40	80,655
4. Accelerator Hall	421 m^2 (6 mH) x	57.90 x 1.10 x 1.00	26,813
5. Accelerator Hall	421 m^2 (6 mH) x	57.90 x 1.10 x 1.00	26,813
		Ground Total	**1,520,767**

WORKSHEET
WBS 5.3.2 Service Water System (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	578,162	nc	nc	115,632	693,794

Currency Units: **kilo Yen**

B. Description:

The total price is not included management (1.5%) and tax (5%).

C. Detailed WBS Listing:

2. 0. 0. Service Water System
1. 0. Cold Area
2. 0. Type-1 Controlled Area
3. 0. Type-2 Controlled Area

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

			Cost
1.1.0 Cold Area	**11,407 m^2**		**296,582**
1. AAMB	350 m^2 (7 mH) x	26.00 x 1.00 x 1.00	9,100
2. RF PowerBay	3,283 m^2 (12 mH) x	26.00 x 1.00 x 1.00	85,358
3. Staircase Hall	105 m^2 (40 mH) x	26.00 x 1.00 x 1.00	2,730
4. Data Acquisition	232 m^2 (5 mH) x	26.00 x 1.00 x 1.00	6,032
5. HEBT Assembly Maintenance Bay	249 m^2 (6 mH) x	26.00 x 1.00 x 1.00	6,474
6. Staircase Hall	82 m^2 (10 mH) x	26.00 x 1.00 x 1.00	2,132
7. Ventilation Room	217 m^2 (5 mH) x	26.00 x 1.00 x 1.00	5,642
8. Auxiliary Equipment Room	1,088 m^2 (5 mH) x	26.00 x 1.00 x 1.00	28,288
9. Accelerator Assembly Maintenance	350 m^2 (5 mH) x	26.00 x 1.00 x 1.00	9,100
10. Control Room	165 m^2 (7 mH) x	26.00 x 1.00 x 1.00	4,290
11. Shipping Bay	249 m^2 (6 mH) x	26.00 x 1.00 x 1.00	6,474
12. Health Physics Station	70 m^2 (5 mH) x	26.00 x 1.00 x 1.00	1,820
13. Uncontaminated Shop	70 m^2 (5 mH) x	26.00 x 1.00 x 1.00	1,820
14. Storage	318 m^2 (5 mH) x	26.00 x 1.00 x 1.00	8,268
15. Shipping Bay	173 m^2 (10 mH) x	26.00 x 1.00 x 1.00	4,498

16. Passage Hall	113 m^2	(5 mH) x	26.00 x 1.00 x 1.00	2,938
17. Passage Hall	79 m^2	(5 mH) x	26.00 x 1.00 x 1.00	2,054
18. Staircase Hall	50 m^2	(5 mH) x	26.00 x 1.00 x 1.00	1,300
19. Passage Hall	113 m^2	(5 mH) x	26.00 x 1.00 x 1.00	2,938
20. Passage Hall	113 m^2	(5 mH) x	26.00 x 1.00 x 1.00	2,938
21. High Hall	2,288 m^2	(9 mH) x	26.00 x 1.00 x 1.00	59,488
22. Administration Building	1,650 m^2	(5 mH) x	26.00 x 1.00 x 1.00	42,900

1.2.0 Type-1 Controlled Area	<u>4182 m^2</u>			<u>217,464</u>
1. Li Cooler Room	188 m^2	(6 mH) x	26.00 x 1.00 x 2.00	9,776
2. N/Aq	211 m^2	(20 MH) x	26.00 x 1.00 x 2.00	10,972
3. Li Purification Room	161 m^2	(6 mH) x	26.00 x 1.00 x 2.00	8,372
4. Li Surge Tank Room	177 m^2	(6 mH) x	26.00 x 1.00 x 2.00	9,204
5. Access Maintenance Room	161 m^2	(14 mH) x	26.00 x 1.00 x 2.00	8,372
6. Target Interface Room	102 m^2	(10 mH) x	26.00 x 1.00 x 2.00	5,304
7. Beam Calibration Station	139 m^2	(9 mH) x	26.00 x 1.00 x 2.00	7,228
8. Test Cell Technology Room	23 m^2	(3 mH) x	26.00 x 1.00 x 2.00	1,196
9. Test Cell	13 m^2	(6 mH) x	26.00 x 1.00 x 2.00	676
10. Beam Calibration Station	13 m^2	(4 mH) x	26.00 x 1.00 x 2.00	676
11. Test Call	13 m^2	(6 mH) x	26.00 x 1.00 x 2.00	676
12. Test Cell Technology Room	23 m^2	(3 mH) x	26.00 x 1.00 x 2.00	1,196
13. Operating Area	560 m^2	(12 mH) x	26.00 x 1.00 x 2.00	29,120
14. Red Waste Processing	150 m^2	(5 mH) x	26.00 x 1.00 x 2.00	7,800
15. Red Waste Shipping	150 m^2	(5 mH) x	26.00 x 1.00 x 2.00	7,800
16. Hot Cell Utility Area	821 m^2	(5 mH) x	26.00 x 1.00 x 2.00	42,692
17. PIE Laboratory Area	605 m^2	(5 mH) x	26.00 x 1.00 x 2.00	31,460
18. Tritium Laboratory	518 m^2	(5 mH) x	26.00 x 1.00 x 2.00	26,936
19. Manipulator Repair	77 m^2	(5 mH) x	26.00 x 1.00 x 2.00	4,004
20. Hot Shop	77 m^2	(5 mH) x	26.00 x 1.00 x 2.00	4,004

1.3.0 Type-2 Controlled Area	<u>2466 m^2</u>			<u>64,116</u>
1. Li Dump Tank Room	453 m^2	(7 mH) x	26.00 x 1.00 x 1.00	11,778
2. Spare Room	176 m^2	(5 mH) x	26.00 x 1.00 x 1.00	4,576
3. Beam Turning Room	995 m^2	(11 mH) x	26.00 x 1.00 x 1.00	25,870
4. Accelerator Hall	421 m^2	(6 mH) x	26.00 x 1.00 x 1.00	10,946
5. Accelerator Hall	421 m^2	(6 mH) x	26.00 x 1.00 x 1.00	10,946

Ground Total **578,162**

WORKSHEET
WBS 5.3.3 Cooling Water Utilities (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	1,117,500	nc	nc	223,500	1,341,000

Currency Units: **kilo Yen**

B. Description:

The Cooling Water Utilities consist of cooling system for type-1 area, type-2 &cold area and accelerator & target. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

3. 0. 0. Cooling Water Utilities
1. 0. Cooling system for Type-1 Area
2. 0. Cooling system for Type-2 Area & Cold Area
3. 0. Cooling system for Accelerator & Target

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: **(Unit : k-yen)**

		cost
3.1 Type-1 Area	1,380-ton x @150	207,000
3.2 Type-2 & Cold Area	850-ton x @150	127,500
3.3 Accelerator & Target	40 MW (Open type)	783,000
	Total	**1,117,500**

WORKSHEET
WBS 5.3.4 Special Equipment (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	905,879	nc	nc	181,176	1,087,055

Currency Units: **kilo Yen**

B. Description:

The total price is not included management (1.5%) and tax (5%).

C. Detailed WBS Listing:

4. 0. 0. Special Equipment
1. 0. Filter and etc.
2. 0. Control System

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

			cost
4.1 Filter, etc.	1,380-ton x @150		**614,891**
1. Ventilation Filter		@26,600 x 5	133,000
2. Automatic valve	(1000A)	@ 9,883 x 10	98,830
	(500A)	@ 4,612 x 16	73,792
3. High density Dumper	(1200A)	@ 3,878 x 4	15,512
	(600A)	@ 2,560 x 12	30,720
4. Monitor tube	4,182 m^3 x	@ 5.3	22,165
5. Root Blower			16,570
6. Pressure Control System		@ 2,610 x 6	15,660
7. Flow Meter		@ 2,830 x 6	16,980
8. Central Control Plate	16,405 m^2 x	@ 8.3	136,162
9. Factory Waste Pool	20 m^3 x	@16,730 x 2	33,460
10. Factory Waste Path	1 set		2,300
11. Factory Waste Meter		@ 3,590 x 2	7,180
12. Drain Pump		@ 3,140 x 4	12,560
4.2 Control System	850-ton x	@ 150	**290,988**
		Ground Total	**905,879**

WORKSHEET
WBS 5.4 Conventional Facilities ; Electric Utilities (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	3,100,760	nc	nc	620,152	3,720,912

Currency Units: **kilo Yen**

B. Description:

The electric service for IFMIF consists of electric service, electric system, special equipment and outside electric utilities. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

4. 0. 0. 0. Electric Utilities
1. 0. 0. Electric Service
1. 0. Cold Area
2. 0. Type-1 Controlled Area
3. 0. Type-2 Controlled Area
2. 0. 0. Electric System
1. 0. System for Utilities
2. 0. System for Accelerator & Target
3. 0. On/Off Station
4. 0. Transformer
5. 0. UPS
6. 0. Emergency Power Supply
3. 0. 0. Electric Special Equipment
1. 0. Power System
2. 0. Ground System
4. 0. 0. Outside Electric Utilities

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

Item		Cost	(k-ICF)
Electric Service		548,144	5,221
Electric System		2,433,640	23,178
Special Equipment		100,760	959
Outside Electric Utilities		18,216	173
	Total	**3,100,760**	29,531

WORKSHEET
WBS 5.4.1 Electric Service (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	548,144	nc	nc	109,629	657,773

Currency Units: **kilo Yen**

B. Description:

The total price is not included management (1.5%) and tax (5%).

C. Detailed WBS Listing:

1. 0. 0. Electric Service
1. 0. Cold Area
2. 0. Type-1 Controlled Area
3. 0. Type-2 Controlled Area

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

			Cost
1.1.0 Cold Area	**11,407 m²**		**351,918**
1. AAMB	350 m² (7 mH) x	25.30 x 1.10 x 1.00	9,740
2. RF PowerBay	3,283 m² (12 mH) x	25.30 x 1.40 x 1.00	116,283
3. Staircase Hall	105 m² (40 mH) x	25.30 x 4.00 x 1.00	10,626
4. Data Acquisition	232 m² (5 mH) x	25.30 x 1.00 x 1.00	5,869
5. HEBT Assembly Maintenance Bay	249 m² (8 mH) x	25.30 x 1.20 x 1.00	7,559
6. Staircase Hall	82 m² (10 mH) x	25.30 x 1.40 x 1.00	2,904
7. Ventilation Room	217 m² (5 mH) x	25.30 x 1.00 x 1.00	5,490
8. Auxiliary Equipment Room	1088 m² (5 mH) x	25.30 x 1.00 x 1.00	27,526
9. Accelerator Assembly Maintenance	350 m² (5 mH) x	25.30 x 1.00 x 1.00	8,855
10. Control Room	165 m² (7 mH) x	25.30 x 1.10 x 1.00	8,748
11. Shipping Bay	249 m² (8 mH) x	25.30 x 1.20 x 1.00	7,559
12. Health Physics Station	70 m² (5 mH) x	25.30 x 1.00 x 1.00	1,771
13. Uncontaminated Shop	70 m² (5 mH) x	25.30 x 1.00 x 1.00	1,771
14. Storage	318 m² (5 mH) x	25.30 x 1.00 x 1.00	8,045
15. Shipping Bay	173 m² (10 mH) x	25.30 x 1.40 x 1.00	6,127

16. Passage Hall	113 m^2 (5 mH) x	25.30 x 1.00 x 1.00	2,858
17. Passage Hall	79 m^2 (5 mH) x	25.30 x 1.00 x 1.00	1,998
18. Staircase Hall	50 m^2 (5 mH) x	25.30 x 1.00 x 1.00	1,265
19. Passage Hall	113 m^2 (5 mH) x	25.30 x 1.00 x 1.00	2,858
20. Passage Hall	113 m^2 (5 mH) x	25.30 x 1.00 x 1.00	2,858
21. High Hall	2,288 m^2 (9 mH) x	25.30 x 1.20 x 1.00	69,463
22. Administration Building	1,650 m^2 (5 mH) x	25.30 x 1.00 x 1.00	41,745
1.2.0 Type-1 Controlled Area	<u>4182 m^2</u>		<u>120,494</u>
1. Li Cooler Room	188 m^2 (6 mH) x	25.30 x 1.10 x 2.00	5,232
2. N/A	211 m^2 (20 mH) x	25.30 x 1.80 x 2.00	9,608
3. Li Purification Room	161 m^2 (6 mH) x	25.30 x 1.10 x 2.00	4,480
4. Li Surge Tank Room	177 m^2 (6 mH) x	25.30 x 1.00 x 2.00	4,925
5. Access Maintenance Room	161 m^2 (14 mH) x	25.30 x 1.40 x 2.00	5,702
6. Target Interface Room	102 m^2 (10 mH) x	25.30 x 1.40 x 2.00	3,612
7. Beam Calibration Station	139 m^2 (9 mH) x	25.30 x 1.20 x 2.00	4,220
8. Test Cell Technology Room	23 m^2 (3 mH) x	25.30 x 1.00 x 2.00	581
9. Test Cell	13 m^2 (6 mH) x	25.30 x 1.10 x 2.00	361
10. Beam Calibration Station	13 m^2 (4 mH) x	25.30 x 1.10 x 2.00	328
11. Test Call	13 m^2 (6 mH) x	25.30 x 1.10 x 2.00	361
12. Test Cell Technology Room	23 m^2 (3 mH) x	25.30 x 1.10 x 2.00	581
13. Operating Area	560 m^2 (12 mH) x	25.30 x 1.40 x 2.00	19,835
14. Red Waste Processing	150 m^2 (5 mH) x	25.30 x 1.00 x 2.00	3,795
15. Red Waste Shipping	150 m^2 (5 mH) x	25.30 x 1.00 x 2.00	3,795
16. Hot Cell Utility Area	821 m^2 (5 mH) x	25.30 x 1.10 x 2.00	20,771
17. PIE Laboratory Area	605 m^2 (5 mH) x	25.30 x 1.00 x 2.00	15,306
18. Tritium Laboratory	518 m^2 (5 mH) x	25.30 x 1.00 x 2.00	13,105
19. Manipulator Repair	77 m^2 (5 mH) x	25.30 x 1.00 x 2.00	1,948
20. Hot Shop	77 m^2 (5 mH) x	25.30 x 1.00 x 2.00	1,948
1.3.0 Type-2 Controlled Area	<u>2466 m^2</u>		<u>75,732</u>
1. Li Dump Tank Room	453 m^2 (7 mH) x	25.30 x 1.10 x 1.00	12,606
2. Spare Room	176 m^2 (5 mH) x	25.30 x 1.00 x 1.00	4,452
3. Beam Turning Room	995 m^2 (11 MH) x	25.30 x 1.40 x 1.40	35,242
4. Accelerator Hall	421 m^2 (6 mH) x	25.30 x 1.10 x 1.00	11,716
5. Accelerator Hall	421 m^2 (6 mH) x	25.30 x 1.10 x 1.00	11,716
		Ground Total	**548,144**

WORKSHEET
WBS 5.4.2 Electric System (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	2,433,640	nc	nc	486,728	2,920,368

Currency Units: **kilo Yen**

B. Description:

The total price is not included management (1.5%) and tax (5%).

C. Detailed WBS Listing:

2. 0. 0. Electric System
1. 0. System for Utilities
2. 0. System for Accelerator & Target
3. 0. On/Off Station
4. 0. Transformer
5. 0. UPS
6. 0. Emergency Power Supply

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

			Cost	
2.1.0 System for Utilities			**427,150**	
1. 22 kV System		1 set	25,000	
2. Master Line Board		2 sets x @ 5,500	11,000	
3. Primary Board		6 sets x @10,000	60,000	
4. Transformer 1000 kAV 22 kV/420V		@ 15,000 x 7	105,000	
5. High Voltage Swiching board 6 kV VCB		2 sets x @14,000	28,000	
6. Low Voltage Swiching board		20 sets x @ 7,500	150,000	
7. System watching Board		1 set	17,500	
8. Power Supply 250 AH		1 set	29,551	
9. Ground E1, ES3, E2		1 set		1,099
2.2.0 Accelerator & Target			**500,000**	
2.3.0 On/Off Station			**700,000**	
2.4.0 Transformer	60 MVA		**620,000**	
2.5.0 UPS	100 kVA		**80,000**	
2.6.0 Emergency Power Supply	200 kVA		**106,490**	
		Total	**2,433,640**	

WORKSHEET
WBS 5.4.3 Electric Special Equipment (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	100,760	nc	nc	20,152	120,912

Currency Units: **kilo Yen**

B. Description:

The Cooling Water Utilities consist of cooling system for type-1 area, type-2 & cold area and accelerator & target. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

3. 0. 0. Special Equipment
1. 0. Power System
2. 0. Ground System

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

		cost
3.1 Power System		97,600
3.2 Ground System	10 sets x @316	3,160
	Total	**100,760**

WORKSHEET
WBS 5.4.4 Outside Electric Utilities (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	18,216	nc	nc	3,644	21,860

Currency Units: **kilo Yen**

B. Description:

The distance from substation to this building is 100 m. **The total price is not included management (1.5%) and tax (5%).**

C. Detailed WBS Listing:

4. 0. 0. Outside Electric Utilities

D. Costing Rational:

Type of Estimate : bottom-up
Allowance for Indeterminates : 20% based on technical risk

E. Detailed Costing: (Unit : k-yen)

		cost
1. 22 kV CVT 150	100 m x @ 60.00	6,000
2. CVVS 2-10C	100 m x @ 1.70	170
3. CPEVS 0.9 x 30P	100 m x @ 2.00	200
4. Outside Path GL-1200, 150x2	100 m x @ 37	3,700
5. Outside Path GL-600, 100x3	100 m x @ 34	3,400
6. Manhole for 22 kV	3 sets x @ 844	2,532
7. Manhole	3 sets x @ 738	2,214
	Total	**18,216**

WORKSHEET
WBS 5.5.0 Radioactive Waste Treatment Systems (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
2,859	2,114	787	2,468	8,228	nc	2,493	2,493	2,138	7,124

Currency Units: **kilo ICF**

B. Description:

The Waste Treatment Systems will manage the gaseous, liquid and solid wastes generated from IFMIF components. They consist of Exhaust Gas Detritiation System, Temporary Exhaust Detritiation System, Liquid Waste Treatment System and Solid Waste Treatment System. Exhaust gas that contains tritium is cleaned in the processing systems described here and sent to the Nuclear HVAC for disposal from stack. Solid and Liquid wastes are processed and packaged for shipment to the final processing / disposal facility of the hosting site.

C. Detailed WBS Listing

5.5.1 Exhaust Gas Detritiation System
5.5.2 Temporary Exhaust Gas Detritiation System
5.5.3 Liquid Waste Treatment System
5.5.4 Solid Waste Treatment System

D. Costing Rational:

Most of the cost estimated are obtained by scaling and factoring from the experience of the existing facilities that handles irradiated and/or contaminated materials. Equipment to be installed in the system are assumed to be purchased from the industry including design, assembly and testing. Industry and institutional engineering costs are estimated for the total of the each subsystems. AFIs are estimated to be 30%, because of the uncertainty of the detailed requirements and source terms, while major part of the system can be assembled with existing technology. Personnel costs are estimated as follows;

Industry: 10 % manager, 50% experts and 40% labor, averaged to be 19 Myen/year. Institutional : 15M yen/year.

WORKSHEET
WBS 5.5.1 Exhaust Detritiation System (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
899	453	215	671	2,238	nc	950	950	814	2,714

Currency Units: **kilo ICF**

B. Description:

Exhaust Gas Detritiation System is operated for management of the exhaust gas from vacuum systems, the tritium cell, GB exhaust system and some other process effluent. The exhaust gas from the vacuum system is assumed to consist of about $1m^3/h$ of Ar with 1×10^5 Bq/cc tritium gas and about $19m^3/h$ of air with 0-5 Bq/cc liquid tritiated water equivalent vapor. The amount of the exhaust gas from other sources such as tritium cell and GB exhausting system is considered to be total of $200m^3/h$ with a small amount of tritiated water. Process is based on permeation membrane technology and no materials are consumed by the operation.

C. WBS Listing:

5.5.1 Exhaust Detritiation System

D. Costing Rational:

Cost estimate on this system is based on the industrial dry air production equipment, and a detritiation system being developed in Japanese facility.

WORKSHEET
WBS 5.5.2 Temporary Exhaust Detritiation System (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
335	302	143	334	1,114	nc	470	470	403	1,343

Currency Units: **kilo ICF**

B. Description:

Temporary Exhaust Gas Detritiation System is operated for management of the gas, mostly anticipated to be air with low level tritiated water vapor which is exhausted in operation for maintenance. The amount of temporary exhaust gas is considered to be $100m^3/h$ with a small amount of tritiated water, fed through the flexible ventilation ducts from various areas of the facility where the maintenance operation with radioactive contamination is anticipated.

C. WBS Listing:

5.5.2 Temporary Exhaust Detritiation System

D. Costing Rational:

Cost is estimate from a dry air production unit based on hollow fiber permeation membrane commercially available in Japan.

WORKSHEET
WBS 5.5.3 Liquid Waste Treatment System (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
414	453	143	433	1,443	nc	640	640	549	1,829

Currency Units: **kilo ICF**

B. Description:

Liquid Waste Treatment System is operated for management of liquid wastes. Liquid wastes are considered to be generated mainly from cooling system of accelerator facility and decontamination facility for the components removed for maintenance purpose. Backwall and target assemble from the target system, and irradiated VTA and sample capsule parts are anticipated to be the major source of the solid waste to be cleaned. The amount of the liquid wastes is considered to be about $10m^3$/year of alkaline water with lithium hydroxide and about $5m^3$/year of neutral water. A small amount of tritiated water and radioactive metals generated by collision are considered to be included in the liquid wastes.

Waste water is recycled after the treatment by neutralization, evaporation and ion exchange for purification. Concentrated liquid waste is solidified for disposal. Tritium removal is not attempted.

C. WBS Listing:

5.5.3 Liquid Waste Treatment System

D. Costing Rational:

Cost is based on a small liquid waste handling equipment recently installed in a irradiation facility in Japan.

WORKSHEET
WBS 5.5.4 Solid Waste Treatment System (JA)

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
1,211	906	286	1,030	3,433	nc	433	433	372	1,238

Currency Units: **kilo ICF**

B. Description:

Solid Waste Treatment System is operated for management of solid wastes. The main solid wastes are considered to be irradiated articles of consumption from the target room. About 30 kg/year of solid wastes are considered to be generated from the target room in normal operation, and about 200 kg/batch of solid wastes are also considered to be generated irregularly at maximum. The amount of other solid wastes such as irradiated specimens and holders, etc., is considered to be about 10 containers/year.

The system is installed in the tritium hot cell in the Post Irradiation Examination facility that has a capability to handle activated and tritium-contaminated materials.

C. WBS Listing:

5.5.4 Solid Waste Treatment System

D. Costing Rational:

Cost is based on a small solid waste handling equipment recently installed in a irradiation facility in Japan.

Cost Estimating Worksheets

for

WBS 6.0

Central Instrumentation and Control Systems

WORKSHEET
WBS 6.0 Common Instrumentation and Central Control Systems
WBS 6.1 System Management
WBS 6.1.1 Project Management and Administration

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
		38	2	40	0	0	76	4	80

Currency Units: kilo ICF

B. Description:

This project management and administration are included in works : a) Outline system design, b) Time schedule management, c) Process management, d) Cost management, e) Regulation with the Accelerator, Test Cell Facilities, Target System, Conventional Facility, etc., f) Documentation.

C. Detailed WBS Listing:

1. 0. 0. 0. Project Management and Administration
   1. 0. 0. Administration
   3. 0. 0. Schedule
   4. 0. 0. Documentation

D. Costing Rationale:

(1) Cost of Labor : 6 My
Type of Estimate: Bottoms-up

E. Detailed Costing:

(1) 114,000 ICF (2 My for off-site + 4 My for on-site)
(2) AFI : about 5% 6,000 ICF

WORKSHEET
WBS 6.2.1 Beam Instrumentation

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
92,000	nc	nc	27,600	119,600	0	18,000	nc	5,400	23,400

Currency Units: kilo Yen

B. Description:

Two types of on-target beam profile monitors are considered here. One is a set of IR thermal image camera, telescope lens, mirror and sapphire window. The other is a set of collimators and small neutron detectors.

C. Detailed WBS Listing:

1. 0. 0. 0. Beam Instrumentation
1. 0. 0. On-Target Profile Monitor
1. 0. Optical/IR Viewing
2. 0. Neutron Imaging

D. Costing Rationale:

The cost estimation is based on the information of IR thermal image camera makers micro-channel plate/image intensifier maker and JAERI's experience.
Type of Estimate : nearly bottom-up and scaling
Allowance for Indeterminates : 30% based on technical risk

E. Detailed Costing:

6.2.1.1.1 Optical IR Viewing
(1) Research and Development Cost : 40,000k-yen for two years
(2) Manufacturing 32,000k-yen for two sets
(3) Installation and test 6,000k-yen

6.2.1.1.2 Neutron Imaging
(1) Research and Development Cost : 80,000k-yen for three years
(2) Manufacturing 60,000k-yen for two sets
(3) Installation and test 12,000k-yen

WORKSHEET
WBS 6.2.2 Radiation Monitoring

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/Lab	Engin	Engin	AFI	Total	Mat'l/Lab	Engin	Engin	AFI	Total
274,630	7,200	nc	5,466	287,296	14,700	44,340	nc	614	59,654

Currency Units: kilo Yen

B. Description:

The radiation monitoring system for IFMIF consists of existing ordinary equipment, devices, detectors and electronic modules. They are summarized in attached table. No R&D is needed.

C. Detailed WBS Listing:

2. 0. 0. 0. Radiation Monitoring
1. 0. 0. Radiation Monitor
2. 0. 0. Device Controller

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates : usually low
Additional two gamma and one neutron monitors are assumed as AFI.

E. Detailed Costing: (Unit : k-yen)

1. Radiation Monitor

Item	Price	Number	Cost	Remarks
Hand & Foot Monitor	8,500,	3	25,500,	MBR-49
GM Survey Meter	390,	6	2,340,	TGS-133
Dose Meter (g & b)	350,	6	2,100,	ICS-311
Neutron REM Counter	1,200,	3	3,600,	TPS-451BS
Surface Tritium Survey Meter	1,200,	3	3,600,	TPS-303
Potable Tritium/Gas Monitor	5,500,	2	11,000,	MGR-121
Pocket Dosimeter	50,	25	1,250,	ADM-102
Liquid Scintillation Counter		1	16,800,	LSC-LB III

Item	Price	Number	Cost	Remarks
Personnel Glass Dosimeter		Subtotal	11,900,	
Glass Dosimeters with holder	9,	100	900,	GD-402
Continuous Reader		1	11,000,	FGD-603
Stack Gas Monitor		Subtotal	12,000,	
Detector Module		1	9,000,	RIC-512BU
Measuring Modules		1	3,000,	AM-23MR74, etc.
Stack Dust Monitor		Subtotal	6,910,	
Detector Module		1	4,350,	DSH-451R,
Measuring Modules		1	2,560,	
Integral Tritium Monitor				
Tritium Catcher		1	1,700,	S-1878TND
Liquid Scintillation Counter		See Above		
Room Gas Monitor		Subtotal	34,000,	
Detector Module	9,000,	3	27,000,	RIC-512BU
Detector Modules		1	7,000,	MGR-R74, etc.
Neutron Area Monitor		Subtotal	15,400,	
Detector Module	1,440,	5	7,200,	NDB-52152,
Measuring Modules		1	8,200,	
Gamma-Ray Area Monitor		Subtotal	59,640,	
Detector Module	870,	25	21,750,	
Measuring Modules		1	37,890,	
Outdoor Monitoring Post		Subtotal	30,000,	
Monitoring Post	9,000,	2	18,000,	DPM-201
Measuring Modules			12,000,	
Leak Detector for Organic Loop		Subtotal	2,360,	
Detector Module		1	870,	
Measuring Modules		1	1,490,	
Indication Panel		Subtotal	21,750,	
Air Sampling System			5,400,	
Installation (on-site)			14,100,	
Total System Design			6,000,	
Total Test and Adjustment			6,800,	
Test at Factory		1,200,		

Item	Price	Number	Cost	Remarks
Transportation/Shipping			600,	
Inspection/Test (0n-site)			9,200,	
Documents			4,800,	
Total Charge			28,340,	
AFI for Materials			5,466,	
AFI for Construction			614,	

Total of Radiation Monitor 344,370, k-Yen

2. Device Controller

Item	Price	Number	Cost	Remarks
CPU		1	700,	DVE-AT486, 32MB
ADC	300,	3	900,	MVNE-512, 16ch
Data Input	160,	2	320,	DVE-528, 49ch
Data Output		1	160,	DVE-529, 16ch
Chassis		1	400,	
Software (OS)		1	100,	Windows-NT

Total of Device Controller 2,580, k-Yen

IFMIF Site and Building Health Physics Monitors

Type	Location	Number	Distance*	Remarks
Hand & Foot Monitor	Entrance of Controlled Area	2	15 m	
	Rad Waste Processing	1	30 m	
GM Survey Meter	Entrance of Controlled Area	6		
Dose Meter (g & b)	Entrance of Controlled Area	6		
Neutron REM Counter	Entrance of Controlled Area	3		
Surface Tritium Survey Meter	Entrance of Controlled Area	3		
Potable Tritium/Gas Monitor	Entrance of Controlled Area	2		
Pocket Dosimeter	Entrance of Controlled Area	25		with alarm
Personnel Glass Dosimeter	Entrance of Controlled Area	100		g , X, n_{th}
Reader for Glass Dosimeter	Entrance of Controlled Area	1		> 100
Liquid Scintillation Counter	Entrance of Controlled Area	1		Ultra-Low Level
Stack Gas Monitor	Ventilation Stack	1	30** + 40 m	
Stack Dust Monitor	Ventilation Stack	1	30** + 40 m	
Integral Tritium Monitor	Ventilation Stack	1		L.S.C. is needed.
Room Gas Monitor	PIE Laboratory Areas	2	60** + 40 m	
	Li Process Area	1	30** + 40 m	
	Target Access Rooms	2	30** + 40 m	
Neutron Area Monitor	Control Room	1	20 m	
	Beam Turning Areas	2	60 m	
	Test Cell Technology Rooms	2	30 m	
Gamma Area Monitor	Accelerator Rooms	4	120 m	
	Beam Turning Area	2	60 m	
	RF Power Bay	4	120 m	
	Test Cell Technology Rooms	2	30 m	
	Control Room	2	20 m	
	PIE Laboratory Areas	4	40 m	
	Hot Shop	2	80 m	
	Manipulator Repair	1	80 m	
	Rad Waste Processing	2	50 m	
	Rad Waste Shipping	2	60 m	
Monitoring Post (n & g)	Outside	2	150 m	for Skyshine
Leak Detector (g & b)	Organic Loop	1	30 m	

* Distance between detector head and controller/recorder
** Distance between sampler head and detector, and between detector and controller/recorder

WORKSHEET
WBS 6.2.3 Video Monitoring

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
78,154	24,000	0	11,415	113,569	21,000	0	0	0	21,000

Currency Units: kilo Yen

B. Description:

Video monitoring system considered here are used for visually monitoring all over the IFMIF facility. This system includes 24 zoom cameras with panheads, 6 video displays and 1 local area network. Because this system send both image data and camera control signals through its own local area network, it is very easy to expand.

C. Detailed WBS Listing:

3. 0. 0. 0. Video Monitoring
1. 0. 0. ITV Camera
2. 0. 0. Display
3. 0. 0. Device Controller

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
5WBS 6.2.4 Access Control

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
28,855	24,000	0	6,486	59,341	14,000	0	0	0	14,000

Currency Units: kilo Yen

B. Description:

Access control system is provided for the protection of personal from the hazards of radiation generated by the machine. This system limits personal access by door limit switches and keybank combination, and notify the operation mode by warning lights. This system also includes emergency stop switches.

C. Detailed WBS Listing:

4. 0. 0. 0. Access Control
1. 0. 0. Door Limit Switch
2. 0. 0. Keybank
3. 0. 0. Warning Light
4. 0. 0. Emergency Stop Switch

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.2.5 Annunciator

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
22,500	24,000	0	5,850	52,350	8,400	0	0	0	8,400

Currency Units: kilo Yen

B. Description:

Annunciator system is used for alerting and notifying about system condition. This system is also usable as paging and broadcasting system over this facility.

C. Detailed WBS Listing:

5. 0. 0. 0. Annunciator
1. 0. 0. Speaker
2. 0. 0. Device Controller

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.2.6 Information Display Stations

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
55,617	24,000	0	9,162	88,779	16,800	0	0	0	16,800

Currency Units: kilo Yen

B. Description:

Information display stations considered here is used for broadcasting system condition, operation schedules, shift tables, and so on. On each terminal, any information is available by selecting channel on this CCTV network.

C. Detailed WBS Listing:

6. 0. 0. 0. Information Display Stations
1. 0. 0. CCTV Network
2. 0. 0. Controller
3. 0. 0. Display Terminals

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.2.7 Safety and Emergency Equipment

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
9,730	nc	nc	nc	9,730	0	500	nc	nc	500

Currency Units: kilo Yen

B. Description:

Equipment considered here are used for fire, oxygen deficit, Li leak, radioactive gas leak accidents and so on. All of them are commercially available.

C. Detailed WBS Listing:

7. 0. 0. 0. Safety and Emergency Equipment
1. 0. 0. Oxygen Deficit
2. 0. 0. Fire
3. 0. 0. Radio Active Gas Leak

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates : low

E. Detailed Costing: (Unit : k-yen)

Item	Price	Number	Cost	Remarks
Oxygen Monitor		Subtotal	2,760,	Riken-Kagaku
Sensor	80,	8	640,	OH-D4
Indicator/Controller	920,	1	920,	KU-7/G
Recorder	350,	2	700,	mR1800
Installation/Test	500,	1	500,	
Fire-proof Protective Clothing	289,	10	2,890,	FC-30PM
Self-Contained Breathing Apparatus		Subtotal	3,670,	
Mask with cylinder	282	10	2,820,	L30-815FG
Storage Case	170,	5	850,	
Escape Mask for Oxygen Deficit	25,	10	250,	Life Rescue mini-2
Oxygen Rescue	330	2	660,	
	Total		**10,230, k-Yen**	

Safety and Emergency Equipment at IFMIF Site and Building

Type	Location	Number	Distance*	Remarks
Oxygen Monitor	Accelerator Rooms	4	120 m	
	Li Process Area	2	40 m	
	Target Access Rooms	2	40 m	
Fire-proof Protective Clothing	Entrance of Controlled Area	10		fire accident
Self-Contained Breathing Apparatus	Entrance of Controlled Area	10		radioactive gas Li accident
Escape Mask for Oxygen Deficit	Each Room to be expected	10		for evacuation
Oxygen Rescue	Entrance of Controlled Area	2		oxygen accident

WORKSHEET
WBS 6.3.1 Central Control

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
88,830	192,000	0	37,683	318,513	7,000	0	0	0	7,000

Currency Units: kilo Yen

B. Description:

Central Control (CC) concerned here supervisory controls operations, manages data and fault, and monitors conditions of all facilities. The main computer that works as a data server provides acquisition, formatting, storage, and concurrent archiving of time-tagged diagnostics data, status data, and values of plant performance parameters. This control system also has two equivalent workstations named as support computer provide all supervisory functions that the main computer does not provide, operation and configuration control, acquiring, processing and displaying of IFMIF system status, data analysis, software development, and so on. This computer system should have redundancy. The main computer has 4 CPU's and has auto-disconnection function of troubled CPU's. The two workstations share their functions, and one of them execute important functions (such as operation control, system monitoring, etc.) when the other workstation can not works well. The 8 X-window terminals with touch panels are provided as operator interfaces. Operator interfaces are connected to computers via the HUB for CC terminals.

C. Detailed WBS Listing:

1. 0. 0. 0. Central Control
1. 0. 0. Computer System
2. 0. 0. Computer Racks, Furniture
3. 0. 0. Data Storage
4. 0. 0. Uninterruptable Power Supply
5. 0. 0. Operator Interface

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.3.2 Local Area Network

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
51,072	24,000	0	8,707	83,779	16,800	0	0	0	16,800

Currency Units: kilo Yen

B. Description:

Through the Local Area Network the central control controls all substations, sends information and gathering data and status of all systems. This LAN is a star-like connection of a FDDI switch and connects the central control to X-terminals, network printers, 4 substations of other subfacilities and so on.

C. Detailed WBS Listing:

2. 0. 0. 0. Local Area Network
1. 0. 0. Network
2. 0. 0. Substation Interface
3. 0. 0. Network Printer

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.3.3 Interlock Logic

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
43,055	96,000	0	18,706	157,761	21,000	0	0	0	21,000

Currency Units: kilo Yen

B. Description:

Interlock Logic is composed from programmable logic units and provide equipment safety, plant safety and personnel access interlock according to interlock signals sent from all other systems. Status of interlock are monitored by the central control and displayed on a logic status display panel.

C. Detailed WBS Listing:

3. 0. 0. 0. Interlock Logic
1. 0. 0. Hardwired Logic
2. 0. 0. Logic and Status Display
3. 0. 0. Interface for Computer Control

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.3.4 Central Display Panel

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
166,676	12,000	0	18,468	197,144	14,000	0	0	0	14,000

Currency Units: kilo Yen

B. Description:

There are two 150" screen color display are used as the Central Display Panels. One of these panels displays subsystem status and the other displays radiation monitoring and area access status.

C. Detailed WBS Listing:

4. 0. 0. 0. Central Display Panel
1. 0. 0. Subsystem Status
2. 0. 0. Radiation and Area Access Status

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.3.5 Sequence Synchronizer

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
124,628	24,000	0	16,063	164,691	14,000	0	0	0	14,000

Currency Units: kilo Yen

B. Description:

Sequence Synchronizer generates timing pulses and event triggered pulses for synchronous operation of IFMIF facility. Modes and patterns of pulses are controlled by the central computer.

C. Detailed WBS Listing:

5. 0. 0. 0. Sequence Synchronizer
1. 0. 0. Timing Data Generator
2. 0. 0. Interface for Computer Control

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.3.6 Dummy Substation

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
34,779	96,000	0	17,878	148,657	7,000	0	0	0	7,000

Currency Units: kilo Yen

B. Description:

Dummy Substation simulates the responses of substations. By using this substation, we can test performance of control system without the other substations and develop software with no interrupt to other substations.

C. Detailed WBS Listing:

6. 0. 0. 0. Dummy Substation
1. 0. 0. Computer
2. 0. 0. Operator Interface
3. 0. 0. Interface for Computer Control

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 10% AFI is applied to account for change in material and laboring cost, and 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.3.7 Operation and Configuration Control

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	240,000	0	36,000	276,000	0	0	0	0	0

Currency Units: kilo Yen

B. Description:

Operation and Configuration Software provides functions to control operations, manage data and fault, and monitor conditions of all facilities. We assigned 10 man-year to basic and detailed designing and coding of these software.

C. Detailed WBS Listing:

7. 0. 0. 0. Operation and Configuration Control
1. 0. 0. Operation and Configuration Software

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.
Type of Estimate : bottom-up
Allowance for Indeterminates: 15% AFI is applied to account for ambiguity of development of application software in engineering cost.

E. Detailed Costing: See detailed estimate

WORKSHEET
WBS 6.4.1 Installation and Test

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	12,000	0	0	12,000	0	36,000	0	0	36,000

Currency Units: kilo Yen

B. Description:

Installation and test mentioned here is for operating system, applications and device driver software. The costs for installation of hardware are included in costing in each elements. We assigned 2 man-year totally to engineering cost of factory off- and on-IFMIF site. This cost also includes AFI.

C. Detailed WBS Listing:

1. 0. 0. 0. Installation and Test

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.

E. Detailed Costing:

1.	Planning	0.5 man-year	12,000 k Yen
2.	Installation and Testing	1.0 man-year	24,000 k Yen
3.	Documentation	0.5 Man-year	12,000 k Yen

WORKSHEET
WBS 6.4.2 System Verification Testing

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
0	12,000	0	0	12,000	0	36,000	0	0	36,000

Currency Units: kilo Yen

B. Description:

System Verification Testing is verification of overall CC and CI systems. We assigned 2 Man-year totally to engineering cost of factory off- and on-IFMIF site. This cost also includes AFI.

C. Detailed WBS Listing:

1. 0. 0. 0. System Verification Testing

D. Costing Rationale:

The cost estimation is based on manufacturer quotes.

E. Detailed Costing:

1.	Planning	0.5 Man-year	12,000 k Yen
2.	System Verification	1.0 Man-year	24,000 k Yen
3.	Documentation	0.5 Man-year	12,000 k Yen

Cost Estimating Worksheets

for

WBS 7.0

Startup and Commissioning

WORKSHEET
WBS 7.1 Startup & Commissioning Personnel

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	0	0	32918	3292	36210

Currency Units: kilo ICF

B. Description:

This element includes the technical support staff on-site to operate the Facilities during startup and commissioning, and the operations personnel hired during the Startup and Commissioning phase of the construction project to be trained by the technical support staff.

This element covers activites in calendar years 2005 and 2006 per the current IFMIF construction schedule.

Not included are costs associated with the installation and check-out of equipment prior to the Facility startup. Those costs are included in the individual Facility construction costs.

C. Detailed WBS Listing:

See listing in Table 7.1.2 below.

D. Costing Rationale:

The personnel costs were determined in a two step process; first, the unit cost for each type of personnel (i.e. technicians, managers, engineers and shop labor) including all burdens and overhead in each of the prospective countries was determined. The summary of the rates is included in attached Table 7.1.1. The US figures are based on rates at Oak Ridge National Laboratory and those used by Northrop Grumman in similar estimates The EU rates were provided by Frascati and FZK, and the Japanese rate by JAERI. Since the rates for all the countries are comparable within the accuracy of the overall estimate a single average rate was agreed on as shown in the Table.

In the second step of the estimating process, the number of personnel required to operate the facilities during startup of both the total IFMIF facility and the individual technical facilities was estimated by the appropriate groups. In addition, the core of the operations staff expected to be hired during the startup and commissioning period was determined. This group will include key supervisory and technical leaders who will ultimately train the operators. An annual summary for the two years (calendar years 2005 and 2006) of the startup is attached as Table 7.1.2.

The Allowance For Indeterminates is established at 10% to account for probable but unpredictable difficulties which will result in overtime and extended operating times.

A detailed explanation of the subelements in this WBS is as follows:

7.1.1 Administration

The plant management team will begin to assemble in second year and increase each year throughout the startup phase

7.1.2 Operations

The operations staff is built for each Facility group in accordance with the construction schedule.

7.1.3 Maintenance

This staff is generally hired late in the startup phase to avoid conflict with the on-site construction crews which are responsible for the maintenance and tuning of the uncommissioned systems.

7.1.4 Experimental Operations

This staff will be start being assembled in the final year of the startup phase.

7.1.5 Startup Staffs

The technical teams brought on-site to perform the startup operations. The teams will be supplemented by installation and construction personnel costed to the individual facilities. The startup staff will be responsible for training the permanent operations team.

ESTIMATE TYPE: BOTTOMS UP; each element and unit cost was determined individually based on a detailed analysis of the requirements of IFMIF.

E. Detailed Costing:

Table 7.1.1. Average Annual Personnel Costs (CY-96 ICF)

		Rate (kICF/yr)						
		US	*Japan*	Japan	*Italy*	Italy	Ger.	**Average**
Administration			*MY/yr*		*Lira/hr*			
	Plant Manager	195	*24.52*	234	*116.7*	198	152	**195**
	Office Support	50	*15.14*	144	*53.9*	91	88	**93**
Engineers								
	Engineers	173	*15.14*	165	*90.85*	154	152	**161**
	Technicians	150	*15.14*	145	*90.85*	154	121	**143**
Operations								
	Shift Superintendent	149	*19.66*	187	*90.85*	154	152	**161**
	Central Control Operators	94	*15.14*	144	*90.85*	154	121	**128**
	Plant Operators	94	*12.47*	119	*53.9*	91	121	**106**
	Plant Protection	94	*12.47*	119	*53.9*	91	121	**106**
	Safety Officer	164	*15.14*	144	*90.85*	154	152	**153**
	HP Technicians	156	*12.47*	119	*90.85*	154	121	**137**
Maintenance								
	Maintenance Manager	111	*18.69*	178	*90.85*	154	152	**149**
	Shop Labor	92	*12.47*	119	*53.9*	91	88	**98**
Experimental Operations								
	Hot Cell Operators	94	*12.47*	119	*53.9*	91	88	**98**
	Data Acquisition	111	*15.14*	144	*90.85*	154	88	**124**

Table 7.1.2. IFMIF Startup Personnel Costs

	Year 2005		Year 2006		Total
	Total	Cost kICF/yr	Total	Cost kICF/yr	Cost
Administration	**3**	**381**	**4**	**475**	**856**
Plant Manager	1	195	1	195	389
Office Support	1	93	2	187	280
Visitor Control	1	93	1	93	187
Plant Operations	**15**	**1696**	**26**	**3184**	**4880**
Shift Superintendent	1	161	4	642	803
Plant Operators	4	425	7	744	1170
Plant Protection	9	957	9	957	1914
Safety Officer	1	153	1	153	307
HP Technicians	0	0	5	687	687
Test Operations	**0**	**0**	**2**	**309**	**309**
Experiment Control	0	0	1	161	161
Operations Labor	0	0	1	149	149
Target Operations	**1**	**161**	**4**	**642**	**803**
Supervision	1	161	4	642	803
Accelerator Operations	**91**	**11974**	**93**	**11744**	**23718**
Supervision	10	1605	15	2408	4013
Operations Labor	13	1382	22	2339	3722
Engineering &Tech Support	46	6840	30	4461	11301
Accellerator Shop Labor	22	2146	26	2536	4683
Maintenance	**1**	**149**	**10**	**1180**	**1329**
Maintenance Manager	1	149	4	595	744
Shop Labor	0	0	6	585	585
Central Control	**1**	**128**	**7**	**894**	**1023**
Central Control Operators	1	128	6	770	898
Data Acquisition	0	0	1	124	124
Startup Staff	**112**	**14489**	**146**	**18429**	**32918**

Notes:

1. Pers'l costs include all benefits and overhead

WORKSHEET
WBS 7.2 Startup & Commissioning-Electric Power

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	22,509	0	0	2251	24,759

Given the substantial differences between the different potential sites the range of power costs is:

Maximum: 37,000
Minimum: 14,000

Currency Units: kilo ICF

B. Description:

Electric power required during the Startup and Commissioning phase of the project will be used primarily for two purposes; the accelerator and a wide range of smaller users grouped under the heading of "Balance of Plant".

Note: All power used during the Startup and Commissioning phase, calendar years 2005 and 2006, of the project will be charged to this WBS since it will not be possible to segregate costs to individual Facilities.

C. Detailed WBS Listing:

See Section E for listing.

D. Costing Rationale:

Because the cost of electricity varies substantially between potential site countries both an average cost and site specific costs are computed. The estimated power costs computed for a 40 MW facility are shown in Table 7.2.1:

Table 7.2.1. Average power costs for potential site countries

Costs (40 MW cap'ty)	Capacity kICF/yr	Use Rate ICF/kWhr
Italy		0.131
Germany		0.0934
Japan	5,146	0.12
United States		0.066
Average	1,286	0.103

Table 7.2.2 shows the power requirements estimated for IFMIF during the startup and commissioning process. The accelerator requirements are assumed to be roughly half of the maximum operating capacity or; 25% of capacity in 2005 and 50% of capacity in 2006. The balance of plant requirements were estimated based on the startup dates for the remaining facilities.

The Allowance For Indeterminates is established at 25% to account for probable but unpredictable difficulties which will result in extended operating times.

ESTIMATE TYPE: BOTTOMS UP; each element and unit cost was determined individually based on an analysis of the requirements of IFMIF operations.

E. Detailed Costing:

Table 7.2.2. Electric Power

Hours/Year 8766	Full Power Usage Mw	Full Power On-time %	Half Power On-time %	Power Off Time %	Annual Power Usage Mwhr	Power Rate Rate ICF/kWhr	Total kICF
Year 2005					**6.99E+07**	**0.103**	**7,174**
1. 0. "Castor" Accel & HEBT	19.2	20%	30%	50%	5.90E+07		
2. 0. "Pollux" Accel & HEBT	19.2	0%	0%	100%	0.00E+00		
3. 0. Balance of Plant	5.0	0%	50%	50%	1.10E+07		
1. Test Facilities							
2. Target Facilities							
3. Accelerator Facility							
4. Conventional Fac's							
5. Central Control							
Year 2006					**1.49E+08**	**0.103**	**15,334**
1. 0. "Castor" Accel & HEBT	19.2	33%	18%	49%	7.08E+07		
2. 0. "Pollux" Accel & HEBT	19.2	20%	30%	50%	5.90E+07		
3. 0. Balance of Plant	5.0	40%	10%	50%	1.97E+07		
1. Test Facilities							
2. Target Facilities							
3. Accelerator Facility							
4. Conventional Fac's							
5. Central Control							
Total	-	-	-	-	**2.19E+08**	**0.103**	**22,509**

WORKSHEET
WBS 7.3 Startup & Commissioning-Utilities

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	578	0	0	58	636

Currency Units: kilo ICF

B. Description:

Conventional Utilities will be purchased from commercial vendors and public utilities to support IFMIF operations. These include, sanitary water, sewer, natural gas for heating and inert gases.

The inert gases are assumed to be provided in over-the-road tank trucks or in bottles delivered by a commercial vendor. The gases will be transferred to on-site storage facilities. The quality of the gases required are important in the cost determination; for this estimate the gases are assumed to be pure at the 10^{-4} level.

It is assumed that there will be a water dionization unit on-site at IFMIF, thus all provided water is potable quality. The water and sewer charges vary by a factor of about eight between the three potential sites; however, an average number is applied because the impact on the total cost is relatively small.

It is assumed that all water effluent will not be contaminated with chemicals or radionuclides.

C. Detailed WBS Listing:

See detailed listing in Table 7.3.1

D. Costing Rationale:

Table 7.3.1 shows the utility requirements estimated for IFMIF during the startup and commissioning process. The estimated usages were provided by each Facility group. Note that the sewer charge assumes that all water is cycled to the sewer system.

The Allowance For Indeterminates is established at 10% to account for probable but unpredictable difficulties which will result in extended operating times and increased utility usage.

ESTIMATE TYPE: BOTTOMS UP (Estimate) each utility requirement is estimated; unit costs were determined individually.

E. Detailed Costing:

Table 7.3.1 IFMIF Startup Costs-Utilities

	Year 2005			Year 2006			Total
	Usage m^3	Cost ICF/m^3	Total kICF	Usage m^3	Cost ICF/m^3	kICF	Total kICF
Utilities			**86**			**492**	**578**
1. 0. 0. Inert Gas (m^3 @ STP)		**0**				**25**	
1. 0. Argon	0	14.61	0	1700	14.61	25	
1. Test Facilities	0			200			
2. Target Facilities	0			1500			
3. Accelerator Facility	0			0			
4. Conventional Facilities	0			0			
2. 0. Liquid Nitrogen	0	9.1	0	20	9.1	0	
1. Test Facilities	0			20			
2. Target Facilities	0			0			
3. Accelerator Facility	0			0			
4. Conventional Facilities	0			0			
2. 0. Helium	0	16.91	0	10	16.91	0	
1. Test Facilities	0			10			
2. Target Facilities	0			0			
3. Accelerator Facility	0			0			
2. 0. 0. Water	**51000**	**0.091**	**4.641**	**276200**	**0.091**	**25**	
1. 0. Test Facilities	0			50000			
2. 0. Target Facilities	0			50000			
3. 0. Accelerator Facility	1000			1000			
4. 0. Conventional Facilities	50000			175200			
3. 0. 0. Sewer	**51000**	**1.6**	**81.6**	**276200**	**1.6**	**442**	

WORKSHEET
WBS 7.4 Startup & Commissioning-Maintenance

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	1000	0	0	100	1100

Currency Units: kilo $

B. Description:

Maintenance operations during the Startup and Commissioning Phase will be negligible since the Facility construction groups will be responsible for the upkeep and condition of the buildings and equipment. Consequently most maintenance costs are assumed to be included in the Facility estimates. An arbitrary cost of 1000 kICF with an AFI of 10% has been estimated to account for miscellaneous maintenance items not covered by the construction contracts.

C. Detailed WBS Listing:

7.4. 0. 0. Maintenance

D. Costing Rationale:

Engineering Judgement

E. Detailed Costing:

None

WORKSHEET
WBS 7.5 Startup & Commissioning-Waste Disposal

A. Summary Cost Estimate:

Off-IFMIF Site					On-Site At IFMIF				
Industry		Instit'			Const. Contractor		Instit'al		
Mat'l/ Lab	Engin	Engin	AFI	Total	Mat'l/ Lab	Engin	Engin	AFI	Total
nc	nc	nc	nc	nc	298	0	0	30	327

Currency Units: kilo $

B. Description:

Waste Disposal Services will be purchased from commercial vendors or public services to support IFMIF operations. Uncontaminated waste will be handled and removed via conventional transport. Low level contaminated waste will be handled in accordance with local requirements. High level waste is not included in this estimate; the volume will be relatively small and it is considered the responsibility of the Host country.

Note; it is exteremly difficult to estimate both the type and quantity of waste generated by IFMIF. It is also difficult to obtain costs for disposal at most facilities. As a result approximate numbers based on engineering judgement are used in this preliminary estimate.

All waste generated on the IFMIF site during the Startup and Commissioning period, calendar years 2005 and 2006 is included in this element.

It is important to note that waste resulting from construction activities concurrent with the startup and commissioning work will be costed in the Facility estimates.

C. Detailed WBS Listing:

7.5. 0. 0. Waste Disposal
1. 0. Uncontaminated
2. 0. Low Level Contaminated

D. Costing Rationale:

The estimated costs for waste disposal costs in the US are based on costs at ORNL; costs for Europe and Japan are guesses.

Table 7.5.1 shows the disposal requirements estimated for IFMIF during the startup and commissioning process. The estimated rates were estimated by consensus of the IFMIF design integration group based on engineering judgment.

The Allowance For Indeterminates is established at 10% to account for probable but unpredictable difficulties which will result in extended operations and additional waste.

E. Detailed Costing:

Table 7.5.1. IFMIF Startup Costs-Waste Disposal

	Annual		
	Usage m^3	Rate ICF/m^3	Total kICF
Year 2005			**38**
1. Uncontaminated	500	75	38
2. Contaminated	0	7400	0
Year 2006			**260**
1. Uncontaminated	1000	75	75
2. Contaminated	25	7400	185
Waste Disposal			**298**